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REVIEW ARTICLE

Hartmann's Procedure for Complicated Diverticulitis: A Critical Reappraisal

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Abstract:

Background:

Complicated diverticulitis in advanced stages (Hinchey III, IV) is an important surgical emergency for which Hartmann's Procedure (HP) has traditionally represented the gold standard treatment. HP, however, has high mortality and morbidity and a low percentage of reanastomosis rate. Increasing efforts have therefore been made in recent years to propose alternatives.

Objective:

To critically review studies on the outcome of HP *vs.* alternative procedures for complicated diverticulitis Resection-Anastomosis without [RA] or with [RAS] protective stomia, Laparoscopic Lavage [LL].

Methods:

Literature search in PubMed for original and review papers in the past 20 years (up to July 2019) with keywords: Hartmann's procedure, complicated diverticulitis.

Results:

Comparative studies on HP *vs*. RA/RAS overall reveal better outcomes of RA/RAS, *i.e*., reduced mortality, morbidity and healthcare costs. However, most studies have limitations due to lack of randomization, limited number of patients and significant impact of surgeons' specialization and hospital setting/organization in the decision of the type of surgery to perform. These factors might induce preferential allocation of the most critical patients (advanced age, hemodynamic instability, numerous comorbidities) to HP rather than RA/RAS. LL shows promising results but has been tested in a too small number of trials *vs*. HP to draw definite conclusions.

Conclusion:

Though valid alternatives to HP are being increasingly employed, consensus on the best approach to complicated diverticulitis has not yet been reached. HP is still far from representing an obsolete intervention, rather it appears to be the preferred choice in the most critical patients.

Keywords: Complicated diverticulitis, Hinchey III, Hinchey IV, Hartmann's procedure, Resection-anastomosis, Laparoscopic lavage.

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1. INTRODUCTION

Diverticulosis of the colon, *i.e.*, the out-pouching of the mucosa and submucosa through the muscle layer of the organ wall, is a common condition, especially in developed countries. Diverticulosis incidence is the same in the two sexes and increases with age, the condition affecting around 40% of the population over 60 years of age and 50-70% of the population over 80 years [1, 2]. In 80% of the cases it affects people aged over 50 years, but the incidence rate is increasing also in the young population (10% below 40 years). The pathogenesis of diverticulosis is multifactorial, the main determinants being represented by genetic predisposition, environmental factors, and colonic dysmotility [2]. In 20-25% of the patients with diverticulosis, the condition can become symptomatic, producing recurrent abdominal pain (Diverticular Disease DD), and in around 5% of these, inflammation of the diverticula may lead to acute diverticulitis [2 - 4]. Medical therapies can increase the risk of developing DD. For instance, use of oral corticosteroids, opiate analgesics, and particularly Non-Steroidal Anti-Inflammatory Drugs (NSAIDs, these induce mucosal damage *via* reduction of prostaglandin synthesis) has

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been associated with complicated diverticulitis [5 - 10], an important factor considering the wide use of these drugs in the general population to treat different forms of pain, particularly musculoskeletal pain in the elderly [11, 12]. Diverticulitis can be uncomplicated when the colon inflammation is confined to the wall of the bowel and mesocolon, or complicated in the case of pericolic, distant intraabdominal abscesses or diffuse peritonitis. Hinchey classification is classically adopted to establish the degree of diverticulitis, *i.e*., Stage I locally complicated, with confined pericolic phlegmon or abscess, Stage II diverticulitis with abscess distant from the primary site of inflammation (intra-abdominal or pelvic), Stage III generalized purulent peritonitis and Stage IV fecal peritonitis [13]. Diverticulitis of Stages I and II is normally handled with medical therapy, involving antibiotics and eventually analgesics for pain symptoms and percutaneous drainage. Stages III and IV require, instead, surgical therapy. Acute diverticulitis needs emergency surgery in around 25% of the cases [14 - 16].

The surgical strategy to adopt in complicated diverticulitis depends on many variables, among which the most important are: stage of peritonitis, duration of the sepsis, age and comorbidities of the patient (the incidence of perforation is maximal in the elderly with multiple comorbidities) [17 - 22], surgeon expertise and hospital environmental conditions [23]. The severity of the clinical presentation determines the degree of the disease stage and Hinchey's classification provides sufficient means to establish the degree of severity. Patients undergoing urgent surgery have an advanced degree of severity corresponding to Hinchey stage III and IV, of purulent diffuse peritonitis and fecal peritonitis, respectively, as reported above. In spite of the importance of the condition, unanimous agreement on the best surgical approach to the treatment of complicated diverticulitis still does not exist internationally. Hartmann's Procedure (HP), involving resection of the affected segment of the colon, with exteriorization of the bowel during the first intervention, eventually followed by a later second intervention of reversal, has traditionally been the operation of choice in these cases, based on the assumption that it is preferable to save the patient's life in two stages rather than risk a direct anastomosis in a sepsis context. However, in recent decades, this approach has been challenged in favour of other types of surgical intervention which would be associated with a lesser degree of complications. After a brief introduction on the historical background of Hartmann's procedure, this narrative review is intended to examine the most relevant papers published in the past 20 years in the field, to critically evaluate the results of HP *vs.* other approaches in the treatment of complicated diverticulitis.

2. HISTORICAL BACKGROUND

Henri Albert Hartmann, born in Paris on June 16, 1860, obtained his medical degree from Paris University in 1887. He started his surgical training at the Bichat Hospital under the guidance of his master Felix Terrier and there he spent his entire university career, becoming a full professor and director of the Surgery Unit in 1909. In 1914, he became director of the Surgery Unit of the Hotel de Dieu Hospital where he remained till retirement in 1930. Henry Hartmann first described the intervention that bears his name in 1921, at the 30th congress of the French Surgery Society. This consisted of resection of the lowest sigmoid and rectum in 2 patients with obstructive carcinoma of the sigma as an alternative to the Miles abdomino-perineal amputation, whose mortality rate at the time was 38%. Since then, this intervention has been widely applied.

Hartmann then described the operation in detail in the book entitled "Surgery of the Rectum" published in 1931. He resected and removed the sigmoid-rectum making the section well above the tumour and distally below the elevator muscle of the anus, after ligaturing the median hemorroidarian arteries, at the level of the seminal vesicles in men and at an equivalent level in women. He used to section the rectum as low as possible, at least 3 cm below the tumour. Concluding the intervention with a suture of the rectal stump and making a terminal colostomy, Hartmann performed this surgery on a total of 34 patients, reporting an operative mortality rate of only 8.8%. Originally, he conceived the intervention as definitive, never trying to restore bowel continuity, considering reversal too risky [24].

Boyden in 1950 and Neilson in 1960 refined the procedure, in patients with complicated diverticulitis, restricting the resection to only the perforated segment of the sigmoid, with the closure of the stump at recto-sigmoid level [25]. These changes led to a significant reduction in the duration of the intervention, with consequently decreased mortality in elderly patients [23]. Over time, there was then a progressive increase in the indications of Hartmann's procedure for numerous pathologic conditions of the colon, among which the most important are: Perforated and obstructive tumoral lesions of the sigmoid, volvolus of the sigmoid, ischemic colitis, traumatic colon perforations, actinic lesions of the colon, anastomotic dehiscences, pseudomembranous colitis, jatrogenic perforations and chronic inflammatory intestinal diseases [26]. At present, Hartmann's procedure is most frequently performed to treat diverticulitis with peritonitis complication, replacing, since the last seventies, the so-called three-stage procedure developed by Mayo, Rankin and Brown, which reached a mortality rate of 44% *vs.* a rate of 14% with Hartmann's procedure [25, 27, 28].

3. HARTMANN'S PROCEDURE FOR COMPLICATED DIVERTICULITIS: STILL THE BEST OPTION?

3.1. Evaluation of the Patient with Suspected Complicated Diverticulitis

The clinical evaluation of the patient with suspected acute diverticulitis is the first fundamental step to assess indication for surgery. This starts with the collection of the clinical history and careful physical examination. The past clinical history may reveal previous episodes of recurrent abdominal pain, which need to be evaluated in relation to their specific site, intensity and modality of occurrence for differential diagnosis with visceral pain conditions other than diverticulitis [29 - 46]. The recent clinical history may be that of pain in the left lower abdominal quadrant, although the intensity of the symptom may vary among individuals, being not correlated with the severity of the internal damage, especially in the elderly who may present mild symptoms even in severe cases [47, 48]. Fever is also usually present and physical examination

reveals tenderness to palpation in the painful abdominal areas. Urgent hematochemical analyses need to be performed including complete blood count, electrolytes, renal function and liver function enzymes and coagulation parameters (prothrombin time and partial thromboplastin time). The analyses can reveal leukocytosis. Left lower quadrant pain, leukocytosis, and fever are, indeed, the three most common findings in decreasing order [23].

In severe cases, patients can also have hemodynamic instability, with tachycardia and hypotension because of intravascular volume depletion and sepsis, which requires immediate administration of Intravenous (IV) fluids and broad-spectrum antibiotics. A 12-lead electrocardiogram should be performed, especially for patients with cardiovascular risk factors [20]. Plain abdominal radiography, carried out in the acute situation, can reveal pneumoperitoneum or colonic obstruction in a patient requiring an imminent laparotomy. Computed Tomography (CT) scan of the abdomen and pelvis with contrast is, however, the gold standard diagnostic tool, having very high sensitivity and specificity, and a low false-positive rate. It allows evaluation of the severity of the condition, providing precise indications to the surgeon [23].

3.2. Hartmann's Procedure

The American Surgical Society of the Colon-Rectum, in 2006, recommended Hartmann's procedure as the "gold standard" in the urgent surgical treatment of diverticulitis complicated with peritonitis [4]. Since then, this recommendation has been subjected to critical revision and re-evaluation, in the absence of a high level of evidence to support the procedure as the best surgical approach for patients with peritonitis complication. Therefore, the ideal surgical treatment in these cases still remains debated.

The results of a number of studies and revisions of the literature on HP have, indeed, shown significant complications with this intervention: Wound infection (>29.1%), stomia complications (7-12%), anastomotic dehiscence after reversal (30%), and a 15-30% mortality, which further increases in octogenarians *vs.* patients younger than 80 years, even after controlling for baseline comorbidities [23, 27, 49 - 53].

The intervention of reanastomosis is furthermore associated with postoperative morbidity higher than 30% and mortality around 14%. A further negative aspect is that thirty-fifty percent of the patients will never undergo reanastomosis [23, 53]. In a retrospective study on 228 patients undergoing HP between 2008 and 2014, of whom 44% had complicated diverticular disease, for instance, Hallam *et al*. (2017) [54] showed a reversal rate of 47%, concluding that HP is reversed less frequently than thought and originally planned.

Most authors have pointed out that the critical figures about HP outcomes are at least in part due to the fact that this type of intervention is preferentially performed in patients with the worst clinical conditions in terms of the degree of peritonitis, hemodynamic status and comorbidities [23, 55, 56]. Nevertheless, attempts to provide alternatives to HP, even in critical cases, have been increasingly more numerous in the past two decades, to treat the patient in one stage, rather than in two separate successive interventions, in the hope of reducing the mortality and morbidity rates.

Primary resection and anastomosis without [RA] or with [RAS] proximal diversion, and Laparoscopic Lavage (LL) are increasingly being considered as alternatives to HP with a potential for improving the outcome in adequately selected patients, as summarized below.

3.3. Hartmann's Procedure *vs.* Primary Resection and Anastomosis

Published papers report numerous casuistries of patients with diverticulitis with peritonitis complication treated with primary resection and anastomosis, with or without protective stomia, with results defined as encouraging by many. In principle, the prompt restoration of the intestinal continuity avoids the technical difficulties and risk of the second intervention of reanastomosis, reducing the economic costs and hospitalization days [51, 57].

The European Association of Surgical Endoscopy supports this intervention as an alternative to HP in the perforation with diffuse purulent peritonitis (Hinchey III) when performed with protection stomia [52]. Comparative revisions of the literature are, indeed, in favour of RAS *vs.* HP in the advanced stage of complicated diverticulitis. These evaluations need, however, to be interpreted with caution due to the lack of rigorous inclusion criteria for patients in the revised studies, such as the variability in the judgement of the severity of disease presentation and the absence of prospective studies with sufficiently numerous sample sizes.

In the revision by Salem *et al*. in 2004 [53] of 98 studies (1957-2003) on cases of diverticulitis complicated with peritonitis (Hinchey III and IV), the operative mortality rate in 1,051 patients undergoing HP (data from 54 studies) was 18.8% *vs.* an aggregated mortality rate of 9.9% in 569 patients undergoing primary anastomosis (data from 50 studies). Wound infection was 24.2% for HP *vs*. 9.6% for primary anastomosis. Abbas in 2007 [49] reports similar results after revision in 18 studies between 1966 and December 2003 on 84 patients with complicated diverticulitis, with a mortality rate of 9% in primary anastomosis *vs*. 19% in HP, and a wound infection rate of 14% in RA/RAS *vs*. 22.6% in HP. The authors conclude that since mortality and morbidity are not higher in RA/RAS *vs*. HP, RA/RAS represents a safe alternative in the treatment of some patients with peritonitic diverticulitis. In the revised studies by both reviews, however, a real statistical comparison between the two procedures is not possible due to the variability of the assessment criteria of the severity of diverticulitis, the lack of randomization of the patients to the arms of treatment and the potential higher frequency of assignment to the HP arm of the most critical, and in an advanced stage, cases of complicated diverticulitis.

Another revision of the literature by Constantinides *et al*. in 2006 [27] of 15 comparative studies published between 1984 and 2004, and including 963 patients (57% primary anastomosis and 43% HP) shows a significant reduction of postoperative mortality with primary anastomosis *vs.* HP (4.9% *vs.* 15.1%, odds ratio 0.41). In the subgroup of patients undergoing the intervention in emergency conditions, mortality was lower among those treated with primary anastomosis with

respect to those undergoing HP (7.4% *vs*. 15.6%, odds ratio 0.44). However, when comparing patients undergoing an emergency intervention who all had a comparable degree of peritonitis (Hinchey >II), the differences in mortality between primary anastomosis and HP were no longer present (14.1% *vs*. 14.4%, odds ratio 0.85). The authors conclude that primary anastomosis has lower mortality than HP in emergency surgical treatment, and equal mortality in advanced complicated diverticulitis (Hinchey>II). However, prudence is advisable in extrapolating the results clinically because of the scarce selection of the patients in the reviewed studies and a lack of prospective, randomized trials on a large scale.

Another paper was published by the same authors in the subsequent year [51], aimed at determining the best surgery strategy in the treatment of a hypothetical 65-year old patient affected with peritonitic perforated diverticulitis at Hinchey stage III and IV, using a model of decisional analysis to compare the different strategies of treatment among RA and RAS with respect to HP. The probability estimation of the results in terms of morbidity was obtained from a database of 6,879 patients (relative to the period 1980-2005) affected with complicated diverticulitis at Hinchey stage III and IV, who underwent RA (n. 135), RAS (n. 125), and HP with or without reanastomosis (n. 6,619). From the analysis performed in this study, RA proved the surgical approach with the highest probability of complications (55%), followed by RAS (40%) and HP (35%). A shift from the optimal surgical strategy from HP to RAS was due to the increased risk of a permanent stomia after HP (27.4%) with respect to RAS (8%), as well as to the increased risk of complications of the reanastomosis after HP (9.3%) compared to reanastomosis after RAS (5.2%). According to the authors, RAS should thus be the intervention of choice if the risk of postoperative complications is below 44%. When the frequency of complications is estimated to be above this value, the short-term benefit of HP can be of more importance compared to the risk of RAS, provided the risk of a complicated reanastomosis after HP or a permanent stomia is not too high [49]. This study presents, however, several limitations, such as the high variability of the parameters employed to estimate the probability of the postoperative results, and the reduced number of patients in the RA and RAS groups. As commented by Bauer (2009) [23], due to a lack of randomized prospective multicenter studies with sufficiently large samples, the surgical choice towards RA, RAS and HP still remains subjective, based on the surgeon's judgement of the operative risk, the development of a validated model to estimate the risk of the colorectal surgery still being underway [23].

Since then, numerous other studies have attempted to compare primary anastomosis and HP with variable results and different conclusions. In 2011, Trenti *et al.* [58] reported their experience with 87 patients with purulent or diffuse fecal peritonitis of whom 69% had received HP and 31% primary anastomosis from January 1995 to December 2008. Postoperative complications were significantly less numerous in primary anastomosis than HP (p<0.05). An anastomotic leakage developed in 11.1% of the primary anastomosis patients (n. 3), which required reoperation. The authors conclude that primary anastomosis is a valid procedure for diffuse diverticular peritonitis and that HP should be performed only in hemodynamically unstable or high-risk patients.

Herzog *et al*. in 2011 [59] published the results of 40 patients undergoing emergency surgery over a period of 18 months. In 21 patients receiving primary anastomosis *vs*. 19 receiving HP: major complications were significantly less numerous (2 *vs*. 12 patients, p<0.04) and mean hospital stay was significantly shorter (13 *vs.* 38 days, p<0.01). These results made the authors state that in emergency surgery for complicated diverticulitis primary anastomosis is advantageous for both patients and hospitals.

Here again, we believe that the results of both the above-reported studies should be interpreted with caution, given the fact that there is apparently no precise information about the initial conditions of patients of the two groups, which might have been worse for HP, impacting onto the different outcome of the intervention.

The ongoing debate about primary anastomosis *vs.* HP in perforated diverticulitis is also reported by Kreis *et al*. in 2012 [60]. They noted that both options had advantages and disadvantages. HP is undoubtedly the best choice in complicated cases, *i.e*., patients in severe conditions and extensive peritonitis, since it is an "extremely safe" operation. The problem with HP is linked to the high risk of nonreversal of the stoma or, in the case this is performed, high levels of morbidity and mortality linked to the second operation.

Primary anastomosis involves a slightly longer operating time than HP but has the advantage that there is no necessity for the operation of stoma reversal. The crucial point remains the criteria of choice of one or the other option. The authors underline that in spite of the various case series published on primary anastomosis, showing the validity of this intervention, no Randomized Controlled Trials (RCTs) are available to the date of their published paper. The problem with the non-randomized case series is the bias, since obviously the most critical patients were subjected to HP while primary anastomosis was classically reserved to patients in better conditions. The conclusion of the authors is that HP should be preferably chosen in critical patients (*i.e*., patients with hemodynamic instability and with comorbidities, while the extent of peritonitis would be less important in their view) and primary anastomosis in patients with better general health conditions. This view is also taken by other groups, who published papers on the topic in the subsequent years. Toro *et al*. [61], who published in 2012 a review of the literature of the previous 20 years on primary anastomosis *vs.* HP, state that the former should be the treatment of choice in acute complicated diverticulitis since it showed lower morbidity and mortality than HP, while HP should be performed only in very selected cases. Occhionorelli *et al.* in 2016 [62], based on the results of a retrospective study in their department (June 2010-March 2015) to assess the best treatment strategies for diverticulitis needing surgical approach, also concluded that primary anastomosis is a good option in Hinchey III and IV selected patients, while HP remains the gold standard in patients with higher ASA scores, although the reduced rate of stoma reversal remains a problematic issue.

The advantages of primary anastomosis *vs.* HP are

underlined by Bridoux *et al*. in 2017 [16], who reported on a prospective multicenter randomized trial (DIVERTI, -Primary *vs*. Secondary Anastomosis for Hinchey Stage III-IV Diverticulitis) comparing HP with primary anastomosis with a diverting stoma, for generalized peritonitis from perforated diverticulitis. This multicenter randomized controlled trial, one of the very few RCTs in the field, was conducted between June 2008 and May 2012 in France, with an 18-month follow-up period on a random sample of 102 eligible patients (all of comparable age, sex, Hinchey stage III *vs*. IV and Mannheim Peritonitis Index) presenting with purulent or fecal peritonitis from diverticulitis referred from tertiary care centers and associated centers. Patients were randomized to the RAS or HP arm of the study. The analysis was conducted on an intention-to-treat basis. The mortality rate at 18 months represented the primary endpoint, while postoperative complications, operation time, length of hospital stay, rate of definitive stoma and morbidity represented secondary outcomes. No significant difference was found in overall mortality and morbidity for both resection and stoma reversal between the two arms. However, the rate of stoma reversal was significantly higher in the RAS than HP arm at 18 months (96% *vs*. 65%, $p<0.0002$), a result which makes the authors conclude that primary anastomosis with diverting ileostomy has advantage with respect to HP in patients presenting with peritonitis from diverticulitis.

A systematic review and meta-analysis of RCTs performed up to March 2018 was published by Cirocchi *et al.* in 2018 [63], for the comparison of primary anastomosis and HP for perforated sigmoid diverticulitis and generalised peritonitis (Hinchey III or IV) in adults. Three RCTs were included, on a total of 254 patients, 116 primary anastomosis and 138 HP. Most evaluated parameters (mortality, overall morbidity, permanent stoma rate, anastomotic leaks) did not differ between the 2 interventions, with only the risk of a postoperative intra-abdominal abscess being significantly lower after primary anastomosis than HP ($p<0.05$). In spite of the limitations of the analyzed RCTs (small size, lack of blinding and possible selection bias) the authors conclude from their analysis that the 2 procedures provide substantially equivalent outcomes.

Another systematic review and meta-analysis was published in the same year by Gachabayov *et al.* (2018) [64], aimed at assessing mortality and morbidity rates in an emergency setting. They included seventeen studies (3 RCTs), involving 1,016 patients (392 primary anastomosis *vs.* 624 HP). In primary anastomosis *vs.* HP, overall mortality ($p<0.0001$) was significantly lower, but in RCTs it did not differ between the two groups. Globally, in primary anastomosis organ/Space Surgical Infection (SSI) ($p<0.004$), reoperation ($p<0.03$) and ostomy nonreversal rates ($p<0.03$) were significantly decreased while the mean operating time was significantly longer ($p<0.003$). The authors concluded that primary anastomosis involved decreased organ/space SSI rates and ostomy nonreversal rates at the cost of prolonging the operating time.

A further systematic review and meta-analysis of studies comparing Hartmann's procedure with primary anastomosis in perforated left sided colonic diverticulitis was published by Shaban *et al*. in 2018 [65]. Fourteen studies were included (2 RCTs, 4 prospective non-randomised and 8 retrospective non-randomised) with a total of 765 patients. Primary anastomosis (n. 283) *vs.* HP (n. 482) produced significantly lower mortality (10.6% *vs.* 20.7%, $p < 0.0004$) and morbidity (41.8% *vs.* 51.2%, $p < 0.05$). The average anastomotic leak rate was 5.9%. In the authors' opinion, resection with primary anastomosis can represent a valid alternative to HP in selected patients, though there is a need for further research in the field to confirm the results.

Also Roig *et al*. in 2018 [66], in discussing HP *vs.* primary anastomosis, suggest that the latter should be increasingly employed in complicated diverticulitis, considering the high rate of mortality and complications linked to HP.

The still ongoing debate and controversy about the best operating choice in complicated diverticulitis is also underlined in the recent paper by Galentin *et al*. in 2018 [67], where a systematic review and comparison of national and international guidelines on diverticular disease is reported. The authors identified eleven guidelines on diverticular disease published over the previous 10 years. While concordance was found among guidelines for most items regarding uncomplicated diverticulitis, main differences were indeed found about the mode of surgery for diverticular perforation. Controversies thus still remain for central aspects of the management of diverticular disease.

In the current year, numerous studies have appeared about HP *vs*. primary anastomosis, testifying that this debate is still a "hot topic". A very recent study by Ahmadi *et al.,* published in July 2019 [68], analyzed if there had been an increase, in recent decades, in the frequency of primary anastomosis (*vs*. HP), based on the mounting evidence that this is a valid alternative to HP for acute diverticulitis. An observational study was conducted on 118 patients operated on for acute diverticulitis from January 2001 to December 2015 at a tertiary teaching hospital. Primary anastomosis *vs.* HP showed no difference in complications, both medical and surgical, readmission rate and mortality; it was a more likely option to be chosen when a colorectal surgeon was operating compared with a colorectal surgery fellow or general surgeon (36% *vs*. 19% *vs*. 10%, $p<0.04$). An increased primary anastomosis rate was observed within the study period, 21%, 43%, 63% to 57% from the first to the fourth quartile of patients ($p< 0.04$). The authors conclude that there has been a steady trend towards increasing application of primary anastomosis in complicated diverticulitis, especially when the operating surgeon is a colorectal specialist, however the two procedures produce similar morbidity and mortality.

Another study was published by Lambrichts *et al*. (2019) [69] to evaluate HP *versus* primary anastomosis with or without defunctioning ileostomy in 133 patients (aged 18-85 years) with perforated diverticulitis with purulent or faecal peritonitis. This was a multicentre, parallel-group, randomised, open-label, superiority trial carried out in 34 teaching hospitals in Belgium, the Netherlands and Italy in the years 2010-2016. The authors aimed at evaluating if the primary anastomosis is superior to HP and if the probability of stoma reversal after

primary anastomosis with ileostomy is higher than after HP, with reversal associated with lower morbidity and mortality. Patients with purulent or faecal peritonitis (Hinchey III or IV disease) were allocated 1:1 to Hartmann's procedure or sigmoidectomy with primary anastomosis, with or without defunctioning ileostomy. Randomisation was stratified by age (<60 and ≥60 years). The primary endpoint was 12-month stoma-free survival. The final analysis considered 66 HP patients (n. 46 Hinchey III, n. 20 Hinchey IV) and 64 patients with primary anastomosis (n. 46 Hinchey III, 18 Hinchey IV). Seventeen out of 64 primary anastomosis patients (27%) received no stoma. The 12-month stoma-free survival was significantly better for primary anastomosis than HP patients (94.6% *vs.* 71.7%, $p<0.0001$), though the two groups did not differ significantly for short-term morbidity and mortality (morbidity: 44% in HP *vs.* 39% in primary anastomosis; mortality: 3% *vs.* 6%). The authors' interpretation of the results is that in patients younger than 85 years primary anastomosis has to be preferred to HP for perforated diverticulitis provided the patients are hemodynamically stable and immunocompetent.

Again in 2019, Lee *et al*. [70] published a paper on HP *vs.* RAS for acute diverticulitis, performing a nationwide analysis of 2,729 emergency surgery patients (median age 64 yrs, 48.5% male). Using the American College of Surgeons NSQIP Colectomy Procedure Targeted Database from 2012 to 2016, they assessed the 30-day mortality, overall morbidity, and individual postoperative complications (*e.g*., surgical site infection, bleeding, sepsis) of the 2 procedures, controlling for all preoperative variables (*e.g*., demographics, comorbidities, laboratory values, illness severity), as well as intraoperative and procedure-specific variables (*e.g*., wound classification). Out of 2,729 patients, the majority underwent HP and only 208 (7.6%) underwent RAS. HP patients had more comorbidities, were more functionally dependent and sicker (*e.g*., septic shock) compared with RAS patients. In multivariate analyses, compared with HP, RAS did not result in increased rates of mortality or morbidity. The odds of most major postoperative complications were also similar for HP and RAS overall. Thus the authors conclude that although surgeons perform HP much more frequently than RAS, the latter is indeed a safe alternative to HP in selected patients.

In the very recent review paper by Halim *et al*. (2019) [14], conclusions have been drawn which can be regarded as a summary of the debate on the opportunity of Hartmann's procedure for complicated diverticulitis, *versus* primary anastomosis, with or without fecal diversion. The authors conducted a meta-analysis of the published papers on the topic, including 25 studies (22 observational studies and 3 RCTs) for a total of 3,546 patients. In observational studies, the overall mortality was 10.8%, being 40% lower in primary anastomosis than HP ($p<0.04$), in RCTs it was 9.4%, being still lower in primary anastomosis than HP but with a non significant difference from a statistical point of view. The two groups did not differ significantly for wound infection rates. Although data from observational studies may indicate a better outcome of primary anastomosis than HP, according to the authors the overall data from all studies performed so far are not sufficient to indicate the superiority of one approach on the other, thus " both surgical strategies appear to be acceptable". The authors, in fact, argue that in spite of several papers reporting in the past 20 years that both mortality and morbidity are lower in patients subjected to primary anastomosis [16, 71, 72] the results cannot be interpreted uniquely and caution is mandatory. Patients in stages III and IV of the Hinchey classification are, in fact, the most critical as regards the general conditions, due to dehydration, sepsis, generalized inflammatory response. It is, thus, possible that factors linked to case selection or selection bias have profoundly impacted on the results. Probably patients selected for primary anastomosis were in better general conditions and had lesser comorbidities while those selected for HP were the most critical. It appears that the decision to perform primary anastomosis or HP in perforated diverticulitis is largely dependent on the severity of the condition, in terms of the degree of inflammation and intraoperative findings but also on the surgeon's expertise and preference in facing one intervention or the other in relation to the involved risk. Complicated patients, who are hemodynamically unstable and have sepsis and comorbidities, particularly if elderly and frail, are believed to be more safely handled with HP. In this view, it is not surprising that HP is often reported to involve more frequent postoperative infections and higher rates of mortality [73], many of them not being subsequently subjected to stoma reversal [74].

3.4. Hartmann's Procedure *vs.* Laparoscopic Lavage

An increasingly higher number of studies report favourable results with the use of the laparoscopic lavage in the urgent treatment of the diverticulitis complicated into peritonitis. Angenete *et al.* in 2016 [75] published the first results from the randomized controlled trial DILALA [DIverticulitis - LAparoscopic LAvage *vs.* resection (Hartmann's proce- dure) for acute diverticulitis with peritonitis] conducted in Denmark and Sweden in the years 2010-2014, showing that laparoscopic lavage is an effective and safe option for the treatment of perforated diverticulitis with purulent peritonitis (Hinchey III), traditionally treated with HP, which is associated with a high level of morbidity and mortality. Laparoscopic lavage (n. 39 patients) was compared with HP (n. 36 patients) in a randomized controlled multicenter study, where initial diagnostic laparoscopy showing Hinchey III was followed by randomization, collecting data up to 12 weeks post-intervention. Morbidity and mortality did not differ between the two groups, but laparoscopic lavage was associated with shorter: operating time, time spent in the recovery unit and hospitalization time. A health economic analysis conducted by Gehrman *et al*. on the patients of the DILALA trial, published in 2016 [76], also showed a significant cost reduction with laparoscopic lavage *vs.* Hartmann's procedure in complicated diverticulitis with purulent peritonitis.

The two-year results of the DILALA study were then published in 2018 by Kohl *et al.* [77]. Patients diagnosed with Hinchey III perforated diverticulitis at diagnostic laparoscopy were randomized during surgery (43 to laparoscopic lavage and 40 to HP). In the lavage group *vs.* the HP group, patients had a 45% reduced risk of undergoing one or more operations within 24 months ($p<0.02$) and had fewer operations ($p<0.03$). The two groups did not differ, instead, regarding the mean number

of readmissions or mortality. Three patients undergoing lavage and nine patients subjected to HP had a colostomy at 24 months. The authors concluded that laparoscopic lavage is preferable to HP for perforated diverticulitis with purulent peritonitis.

In spite of the reported favourable results, the data in the field are still limited to draw definite conclusions about the possible superiority of the methodology with respect to HP. At the present time, we feel that the considerations expressed by Bauer in 2009 [23] are still valid, *i.e*., this treatment can be indicated in patients in relatively good physical conditions and in clinical stability. Laparoscopic lavage could be a useful means to substage the severity of the disease or serve as a bridge towards another treatment, but further studies are necessary to ascertain the real cost-benefit ratio of the technique in the different clinical conditions [23].

3.5. Laparoscopic *vs.* Open Hartmann's Procedure

One of the developments in the last few years in the field of HP has been the attempt to perform the procedure with laparoscopic rather than the open approach in order to reduce mortality and morbidity. A study published by Turley *et al*. in 2013 [78] evaluated laparoscopic *vs.* open HP for diverticulitis in an emergency setting. In this comparative effectiveness study, data from the American College of Surgeons National Surgical Quality Improvement Program Participant User Files from 2005 through 2009 were used. A total of 1,186 patients were included who had been subjected to emergency partial colectomy with end colostomy for diverticulitis. Patients undergoing the procedure laparoscopically had a significantly reduced number of overall complications (p<0.009, 26% *vs.* 41.7%) and shorter duration of hospitalization (p<0.0009, 8.9 *vs.* 11.6 days). When controlling for potential confounders, however, laparoscopy was not associated with decreased morbidity or mortality. The authors' conclusion is that the laparoscopic approach to HP in complicated diverticulitis has no specific advantage in terms of mortality and morbidity with respect to the open technique.

A subsequent study published in 2017 by Cassini *et al*. [79] evaluated emergency Hartmann's procedure and its reversal for the treatment of Hinchey III and IV diverticulitis, considering the possible advantages of a laparoscopic approach. In their retrospective review of charts, they analyzed 60 patients with diverticular diffuse peritonitis subjected to urgent HP followed by a reversal, divided into two groups according to laparoscopic (LP, 36 patients) or open (OP, 24 patients) Hartmann's procedure. No significant differences were found between the two groups regarding operating time, blood loss and duration of stay in the intensive care unit. In the LP *vs.* the OP group, overall morbidity and incidence of medical and surgical complications were significantly lower (33.33% *vs.* 66.7%, p<0.02 for morbidity; 22.2% *vs.* 41.7%, p<0.05, for surgical complications; 24.3% *vs.* 45.8%, p<0.03 for medical complications). Mortality, however, was the same in each group (16.6%). LP patients also showed a more rapid return to bowel movements and a shorter hospital stay than OP patients. The secondary intestinal reversal was carried out in 92% of the patients, successfully completed with a laparoscopic approach in 91.3% of the cases, with no patients needing conversion to the open approach. The authors conclude with positive considerations about laparoscopic approaches to the treatment of diverticular diffuse peritonitis.

Other groups have subsequently published on the topic of the laparoscopic approach to the intervention for complicated diverticulitis. In 2018 Cirocchi *et al*. [80] published a systematic review of RCTs that compared the effectiveness and safety of laparoscopic *vs.* open sigmoidectomy in an acute setting for generalized purulent or fecal peritonitis due to perforated sigmoid diverticulitis. They identified 4 RCTs involving 436 patients subjected to LP (n. 181) or open sigmoid resection (n. 255). LP slightly improved the rates of overall postoperative complications and postoperative hospital stay, but not the other clinical outcomes, *i.e*., the rate of Hartmann's *vs.* anastomosis, operating time, reoperation rate and postoperative 30-day mortality. In the analyzed studies, however, there was a lack of hemodynamic data and reasons for operative approach, probably patients subjected to open surgery were sicker than those for whom a laparoscopic approach was chosen, thus rendering it difficult to correctly interpret the results.

In synthesis, studies evaluating LP *vs.* open surgery in the field still appear too limited in number and with some limitations in the design, to draw definite conclusions, and more research is needed in the future with this approach, which appears indeed promising in an era where minimally invasive surgery is gaining progressively more space and importance in all surgery fields [34, 35, 81].

3.6. Hartmann's Procedure Over Time and the "Surgeon" Factor

There have been several attempts to evaluate any change in the outcomes of Hartmann's procedure for complicated diverticulitis in the course of the years.

Ince *et al*. in 2012 [82] published an analysis of their surgical database for mortality and morbidity of HP performed for perforated diverticulitis from 1992 and 2010, with a total of 199 patients, divided into four groups based on the year of surgery. Mortality was 15% and did not change significantly over time. Independent predictors for mortality were American Society of Anesthesiologist Physical Status Score (ASA PS) > 3, altered creatinine, steroid employment, Hinchey IV, low albumin and low body mass index ($0.002<p<0.04$). Overall morbidity was 52%, with a significant increase over time at univariate analysis (p<0.008) but not at multivariate analysis. Independent predictors of morbidity were Hinchey IV and hypoproteinaemia ($0.001<p<0.002$). The authors concluded that over the preceding 18 years there had been no decrease in mortality with HP for perforated diverticulitis, instead, morbidity had increased, although this finding may be linked to increased disease severity and comorbidity.

Jafferji *et al*. in 2014 [83] published an interesting study in which they stressed the concept that the surgeon, not the disease severity, often determines the choice of the operation for acute complicated diverticulitis. They reviewed consecutive patients operated on for acute complicated diverticulitis from 1997 to 2012 at an academic medical center to assess if the surgeon or patient-specific factors direct the choice of the type

of procedure that is applied. Out of 136 patients, 82 (65.1%) underwent resections by noncolorectal surgeons and 44 (34.9%) by colorectal surgeons. HP was performed significantly more by noncolorectal surgeons ($p<0.02$, 68.3% *vs.* 40.9%) in spite of comparable ASA classification, Hinchey stage and demographics. In the group operated on by colorectal surgeons, length of stay, time to stoma reversal, Intensive Care Units (ICU) days, and postoperative complications were all significantly lower ($p<0.03$). The authors conclude that the "surgeon" factor is crucial as a predictor of the type of intervention performed in an emergency setting for complicated diverticulitis.

Another study published by Sartelli *et al*. in 2017 [84] draws attention to the "surgeon" factor in the operating approach to complicated diverticulitis. The IPOD study (Italian Prospective Observational Diverticulitis study) about emergency treatment of acute left colon diverticulitis in Italian centers was a prospective observational study performed over 6 months (April -September 2015) involving 89 Italian surgical departments, including all consecutive patients with a suspected clinical diagnosis of the condition confirmed by imaging and seen by a surgeon. Eleven hundred and twenty-five patients with a median age of 62 years were assessed. Surgical approaches appeared to vary considerably, indicating, according to the authors, that the choice of the type of intervention is frequently determined by the personal preference of the surgeon rather than by the scientific evidence.

In June 2017, Hess *et al*. [85] reported on a retrospective study on 67 patients (median age 76 yrs) subjected to HP for complicated diverticulitis at a tertiary referral hospital in the period May 2005- December 2010. The aim was to assess the frequency of reversal and the impact of patient-related factors on the surgeon's decision to carry out reversal. The authors started from the principle that although HP is very commonly employed for complicated diverticulitis and is intended to restore intestinal continuity through the subsequent reversal intervention, reversal is in reality not carried out in all patients. After 48 weeks the cumulative incidence of reversal was 48%, the intervention being significantly less likely in the elderly with cardiac comorbidities (cardiac insufficiency, coronary heart disease) and preoperative immunosuppression or chemotherapy at the time of the first operation, although these conditions had no apparent influence on mortality. These data indicate that age and these specific comorbidities have an important impact on the decision by the surgeon to carry out the reversal, which is, indeed, performed in around half of the patients initially submitted to HP. The surgeon ultimately appears as the crucial determinant of the decision of the type of intervention to be performed.

CONCLUSION

The treatment of complicated diverticulitis is at present still the subject of active debate. Especially in the past 20 years, there have been increasing efforts to replace Hartmann's procedure, the classic gold standard operation in this context, with alternative interventions able to reduce the high mortality and morbidity of HP and bypass the problems related to the reanastomosis, requiring a second intervention in HP, which is typically carried out in only about a half of the patients. Primary anastomosis has been evaluated in numerous studies *vs.* HP, overall showing better results in terms of reduced mortality, morbidity and healthcare costs, although preferably in observational studies than in the few RCTs performed. Most studies in the field, have indeed limitations due to lack of randomization, in addition to an often limited number of patients allocated in the two arms and a significant impact of surgeons' specialization and environmental hospital context on the decision of the type of surgery to perform. As underlined by many authors, in this general context these results are to be interpreted with caution, due to the high probability of preferential allocation of the most critical patients (advanced age, hemodynamic instability, numerous comorbidities) to HP rather than primary anastomosis. Laparoscopic lavage has also shown promising results but it has been tested in a relatively small number of trials *vs.* HP to draw definite conclusions. Undoubtedly the development of the new mini-invasive and laparoscopic procedures will lead to evolution and a change in the standards of the surgical practice in the years to come; at present, however, HP is still far from representing an obsolete intervention. In the choice of the most appropriate procedure for each patient, multiple factors are indeed to be considered, which include: the judgement by the surgeon of the severity of the clinical presentation of the diverticulitis, the age of the patients and the careful preoperative consideration of the concurrent pathologies, a realistic evaluation of the hospital environmental conditions and the individual technical skills of the surgeon himself. Based on the data from the literature, Hartmann's procedure still maintains a prominent role in the surgical treatment of patients with an advanced degree of complicated diverticulitis, and by some International Associations, it is still regarded as the "gold standard" in Hinchey stages III and IV. HP remains a realistic and reliable approach in difficult situations since a direct resection-anastomosis in an advanced sepsis stage and in difficult –often extreme – clinical conditions remains a difficult choice to make, for fear of dehiscence. HP is an option to be preferred, for example, in an elderly patient with diverticulitis complicated by peritonitis, serious hemodynamic instability, a history of coronary heart disease or corticosteroid therapy. Seemingly, HP can be the best treatment in a patient in relatively good physical conditions, who, however, needs an emergency intervention for complicated diverticulitis when the environmental setting is non optimal, for instance in the middle of the night, in a minor hospital with limited health care personnel, where surgeons expert in colo-rectal or laparoscopic procedures are not always present or available. From the data of the literature, it is evident that the percentages of mortality and morbidity of the patients subjected to Hartmann's procedure unfortunately still remain too high, even considering the characteristics of the higher risk of the population that preferentially undergoes this intervention. Furthermore, it should not be forgotten that the HP has a weak point in the difficulty and risks of reanastomosis, which increases these percentages. As already reported above, alternative surgical procedures, such as the resection-anastomosis in one stage with or without protection stomia or laparoscopic lavage, are obtaining encouraging results in terms of reduction of mortality and morbidity. If these data are confirmed in larger-scale studies these procedures can possibly play a major role in the standard treatment of complicated diverticulitis disease in the future.

LIST OF ABBREVIATIONS

ASA PS = American Society of Anesthesiologist Physical Status Score

CT = Computed Tomography

DD = Diverticular Disease

HP = Hartmann's Procedure

ICU = Intensive Care Units

IV = Intravenous

LL = Laparoscopic Lavage

NSAIDs = Non-Steroidal Anti-Inflammatory Drugs

RA = Resection-Anastomosis Without Stomia

RAS = Resection-Anastomosis with Stomia

RCTs = Randomized Controlled Trials

SSI = Space Surgical Infection

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CONFLICT OF INTEREST

The author declares no conflict of interest in relation to the present paper.

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