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Diagnostic utility of ultrasonography in the management of postoperative fluid collections and abdominal indwelling catheters following pancreaticoduodenectomy: retrospective cohort study

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Abstract

Introduction The management of postoperative fluid collections, which refers to the accumulation of fluid in the peritoneal cavity following pancreaticoduodenectomy, presents significant challenges. However, ultrasonography has emerged as a promising tool for diagnosing and guiding interventions for this condition. Ultrasonography offers several advantages, including accessibility, cost-effectiveness, and real-time imaging capabilities. It plays a crucial role in identifying ascitic fluid collections, characterizing their contents, and evaluating the severity of fluid collections. Moreover, ultrasound guidance enhances the safety and effectiveness of placing abdominal catheters. The aim of this study is to assess the diagnostic utility of ultrasonography in postoperative fluid collections following pancreaticoduodenectomy and evaluate the clinical efficacy of ultrasound-guided abdominal catheter placement.

Methods A total of 309 hospitalized patients underwent postoperative pancreaticoduodenectomy, with 171 patients undergoing laparoscopic pancreaticoduodenectomy (LPD) and 138 patients undergoing open pancreaticoduodenectomy (OPD), as assessed by ultrasonography. We examined the abdominal cavity for the presence of postoperative fluid collections and evaluated the site of postoperative fluid collections and the necessity for tube drainage. In cases where an abdominal indwelling catheter was required, we observed the location of postoperative fluid collections, performed echocardiography, and analyzed the characteristics of drainage fluid. We conducted a comparative analysis of short-term postoperative outcomes between LPD and OPD, encompassing hospitalization duration, fever duration, presence or localization of postoperative fluid collections, number of abdominal indwelling catheters used, location of abdominal drainage fluid collection, and time until postoperative catheter removal.

Results The LPD group demonstrated a significantly lower incidence of postoperative fluid collections compared to the OPD group, as determined by ultrasonography (39.2% vs. 59.3%, $p = 0.001$). Additionally, the LPD group had shorter hospital stays (16 [13, 21] vs. 21 [17, 28] days; $p < 0.001$), reduced duration of fever (1 [0, 3] vs. 3 [1, 5] days;

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$p < 0.001$), faster time to postoperative catheterization (7 [5, 10] vs. 8 [6, 13] days; $p < 0.001$), fewer required tubes (0 [0, 1] vs. 1 [0, 1]; $p < 0.001$), and shorter extubation time (7 [5, 9] vs. 9 [5, 12] h; $p < 0.001$) compared to the OPD group. There were correlations observed between the two groups regarding postoperative fluid collections, ultrasound sound transmission, separation of postoperative fluid collections, and traits of drainage fluid. However, there were no significant differences between the two groups in terms of postoperative fluid collections location (dissociative or restrictive), ultrasound sound transmission (excellent or poor), and separation of postoperative fluid collections (no separation, less separation, and more separation).

Conclusions Postoperative fluid collections is a commonly encountered concurrent condition following pancreatic oduodenectomy. Ultrasonography allows for the observation of diverse characteristics related to postoperative fluid collections, including its precise localization, sound transmission properties, and the presence of internal separations. Moreover, it enables timely guidance for precise placement of drainage tubes.

Keywords Periampullary neoplasms, Laparoscopic, Pancreaticoduodenectomy, Comparative study, Ultrasonography

Introduction

Pancreaticoduodenectomy (PD) is a classic treatment for the treatment of benign and malignant tumors in the pancreatic and periampullary regions [1–3]. Laparoscopic pancreaticoduodenectomy (LPD) and open pancreaticoduodenectomy (OPD) are two methods of performing PD, with LPD experiencing rapid development in recent years due to advancements in abdominal techniques, accumulated surgical experience, and the evolution of minimally invasive approaches. Studies have suggested that LPD offers more advantages over OPD; for example, LPD reduces intraoperative bleeding and faster postoperative recovery [4, 5]. Despite several studies confirming the superiority of LPD over OPD, there is currently a lack of comparative ultrasound investigations between LPD and OPD for postoperative outcomes. Postoperative fluid collections are common complications following PD, and the presence of significant intra-abdominal fluid results in an increase in intra-abdominal pressure, inhibition of intestinal function, and exacerbation of systemic inflammatory response, which makes postoperative fluid collections an essential factor to consider for prognosis [6]. Effective control of postoperative fluid collections can alleviate patient suffering and improve their quality of life. Therefore, early implementation of appropriate minimally invasive treatment strategies for postoperative patients can enhance patient satisfaction. Ultrasound demonstrates nearly 100% sensitivity in detecting postoperative fluid collections. In this study, we used ultrasound to observe postoperative fluid collections in PD patients and investigated the therapeutic value of ultrasound-guided catheter placement and drainage for such cases.

Methods

Patients

We conducted a retrospective analysis of clinical data from 171 patients (71 males, 100 females) who underwent laparoscopic pancreaticoduodenectomy (LPD) and 138 patients (83 males, 55 females) who underwent open pancreaticoduodenectomy (OPD) at our institution between January 2018 and March 2020. The mean age in the LPD group was 61.69 ± 11.13 years, while in the OPD group, it was 62.73 ± 10.31 years. There were no statistically significant differences in age and gender distribution between the two groups.

Indications for the placement of drainage tubes

Indications for the placement of drainage tubes include several clinical indications as well as ultrasonographic imaging features. The clinical indications for tube drainage included poor conditions, abdominal pain, abdominal distension, elevated white blood cell counting, elevated CRP levels, fever above 38.5 °C or lasting and uncontrollable low-level fever, etc. The ultrasonographic imaging features for tube drainage include poor sonolucency of, membrane appearance or floating dots inside the collected fluid or fluid collections, which probably indicated infectious fluid collections or abscess, bile leakage, chyle leakage, hemorrhagic exudate fluid, etc. If needed, a multidisciplinary consultation will be held to determine what kind of procedure be performed for the treatment. If possible, a more minimally invasive syringe aspiration of the fluid will be performed to check the nature of the fluid before the tubes were inserted under local anesthesia.

Ultrasound examination and interventional treatment method

We utilized the ultrasound of HI VISION ASCENDUS (Hitachi, Japan) with an abdominal convex transducer (frequency 3–5 MHz), and when necessary, we would use a higher frequency linear probe. The patients were positioned in a supine position with the abdomen fully exposed. The critical areas examined included the surgical incision site, hepatorenal recess, splenorenal recess, and lower abdomen. In cases requiring catheter placement and drainage, we used ultrasound or precisely localizing the puncture site, followed by a standard disinfection protocol, and then applied a sterile surgical drape. After local anesthesia with 2% lidocaine at the puncture site, a disposable pigtail catheter was inserted into the abdominal cavity and securely fixed. We connected the distal end of the catheter to a sterile disposable drainage bag for continuous drainage of the abdominal fluid. If necessary, we would perform irrigation until the drainage fluid decreased and became clear, and then we removed the catheter.

Statistical analysis

Using SPSS 24 software (IBM Corp, Armonk, NY, USA), we conducted Kolmogorov–Smirnov test and Shapiro–Wilk test to assess the normal distribution of the continuous variables. Then, we used categorical variables to represent the frequencies (%) and used Chi-square test to for analysis. As for non-normally distributed data, we used medians with interquartile range (IQR) to report and used Mann–Whitney U test to compare the result. Finally, we used Spearman's correlation analysis to examine the correlation. For significance level of $p < 0.05$, the result is regarded as statistically significant.

Results

Ultrasound examination revealed that both the LPD and OPD groups tended to develop varying degrees of postoperative intra-abdominal fluid accumulation, including free peritoneal effusion and localized peritoneal effusion. Based on the patients' clinical presentation and the fluid accumulation's ultrasound imaging characteristics, we performed ultrasound-guided catheter placement and drainage for selected cases of postoperative intra-abdominal fluid.

The common site of postoperative fluid collections

The incidence of postoperative intra-abdominal fluid accumulation requiring intervention differed between the LPD and OPD groups, with rates 39.2% and 59.3%, respectively. In the LPD group, the postoperative intra-abdominal fluid was predominantly located in the perihepatic region (57.9% vs. 82.8%), lesser sac (79.4% vs. 92%), subdiaphragmatic space (55% vs. 81.8%), and pelvic cavity (20% vs 50%) (n% indicates the ratio of fluid accumulation requiring catheterization treatment within the respective locations; for example, in 50 cases of fluid accumulation in the lesser sac, 25 subjects underwent catheter placement, resulting in a ratio of 50%) (Fig. 1). Although both groups exhibited a higher rate of fluid accumulation requiring catheter drainage

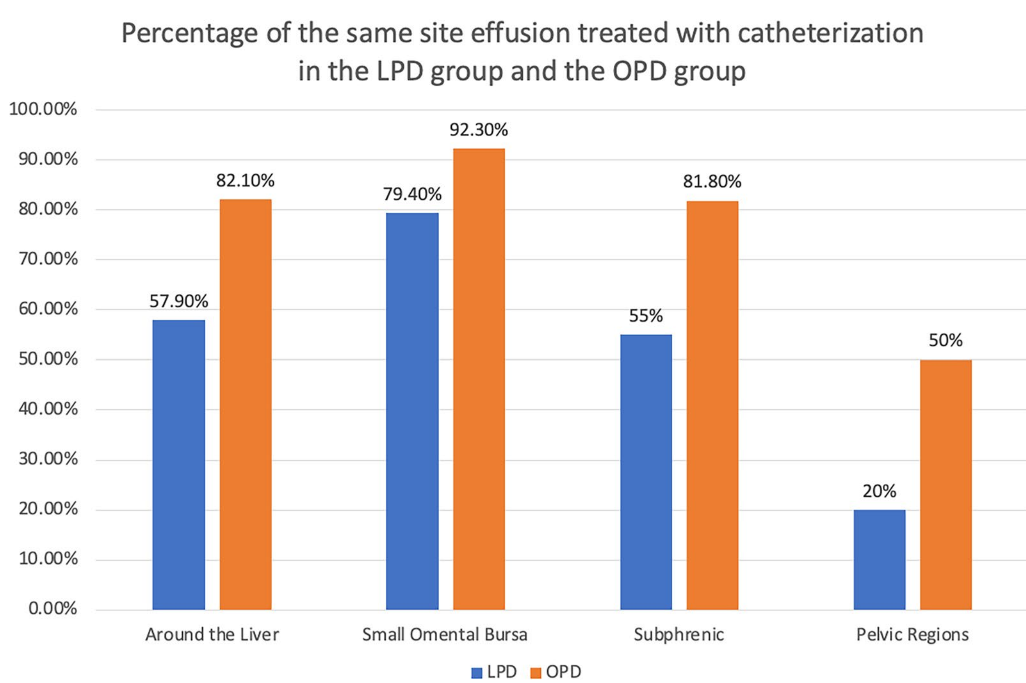

Fig. 1 Percentage of the same site effusion treated with catheterization in the LPD group and the OPD group

Table 1 Comparison of basic information between LPD group and OPD group

	LPD ($n=171$)	OPD ($n=138$)	p-value
Age [y, M (P25, P75)]	64 (56, 70)	64 (57, 70)	0.07
Hospital stays [d, M (P25, P75)]	16 (13, 21)	21 (17, 28)	< 0.001
Days to catheter post-operative [d, M (P25, P75)]	7 (5, 10)	8 (6, 13)	< 0.001
Days to catheter post-operative [n, M (P25, P75)]	0 (0, 1)	1 (0, 1)	< 0.001
Fewer Fever time [d, M(P25, P75)]	1 (0, 3)	3 (1, 5)	< 0.001
Gender, *n* (%)			0.767
Female	71 (41.5)	55 (39.9)	
Male	100 (58.5)	83 (60.1)	
Postoperative fluid collections, *n* (%)			0.373
Yes	129 (75.4)	110 (79.7)	
No	42 (24.6)	28 (20.3)	
Postoperative fluid collections were indwelled catheters, *n* (%)			0.001
Yes	67 (39.2)	81 (59.3)	
No	104 (60.8)	57 (40.7)	

in the lesser sac, there was no statistically significant difference in the distribution of postoperative intra-abdominal fluid accumulation sites between the two groups since $p > 0.05$ (Table 2).

Interventional management of postoperative fluid collections under ultrasound guidance

There was a significant correlation between the echogenicity and septation of postoperative intra-abdominal fluid and the characteristics of the drainage fluid ($p < 0.001$) (Table 3). The incidence of

Table 2 Comparison of postoperative fluid collections after indwelling catheters between the LPD group and the OPD group

	LPD ($n=67$)	OPD ($n=81$)	p-value
The station of postoperative fluid collections after indwelling catheters, *n* (%)			0.321
Free postoperative fluid collections	7 (10.4)	13 (16.0)	
Limitation postoperative fluid collections	60 (89.6)	68 (84.0)	
The station of sound transmission of the ultrasound, *n* (%)			0.611
Good	8 (11.9)	12 (14.8)	
Poor	59 (88.1)	69 (85.2)	
The station of the separation of postoperative fluid collections, *n* (%)			0.048
No separation	59 (88.0)	58 (71.6)	
Less separation	5 (7.5)	13 (16.0)	
More separation	3 (4.5)	10 (12.4)	
The station of the Drainage fluid, *n* (%)			0.255
Clear	5 (7.5)	2 (2.5)	
Turbid	60 (89.5)	74 (91.4)	
Biliary	2 (3%)	5 (6.1)	
The common site of postoperative fluid collections, *n* (%)			0.249
Around the liver	22 (32.8)	23 (28.4)	
Small omental bursa	27 (40.3)	24 (29.6)	
Subphrenic	11 (16.4)	18 (22.2)	
Pelvic regions	7 (10.5)	16 (19.8)	
Hospital discharge with indwelling drainage tubes, *n* (%)	47 (70.1)	55 (67.9)	0.769
Extubation time [d, M (P25, P75)]	7 (5, 9)	9 (5, 12)	< 0.001

Extubation time is calculated as the cases discharged with tubes after removal

Table 3 Correlations were observed between the two groups in terms of postoperative fluid collections sound transmission of the ultrasound, the separation of postoperative fluid collections and the traits of drainage fluid

Group		The traits of drainage fluid	
		r	*p*
OPD group	Postoperative fluid collections sound transmission of the ultrasound	0.926	< 0.001
	The separation of postoperative fluid collections	0.058	< 0.001
LPD group	Postoperative fluid collections sound transmission of the ultrasound	0.980	< 0.001
	The separation of postoperative fluid collections	0.261	< 0.001

postoperative intra-abdominal fluid accumulation requiring intervention in the LPD group was significantly lower than in the OPD group (39.2% vs 59.3%, $p =$ 0.001). Among the postoperative intra-abdominal fluid accumulations requiring catheter drainage in the LPD and OPD groups, there was no significant difference in poorly echogenic fluid (88.1% vs 85.2%, $p =$ 0.611). However, there was a significant difference in the presence of multiple septations within the fluid (4.5% vs 12.4%, $p =$ 0.048). The drained fluid appeared yellow or brownish and turbid in both groups (89.5% vs 91.4%, $p =$ 0.255). The presence of localized fluid accumulation did not show a significant difference between the LPD and OPD groups (89.6% vs 84%, $p = 0.321$) (Tables 1, 2, 3).

Outcome, prognosis and complications

In this study, the length of hospital stay was shorter in the LPD group compared to the OPD group [16 (13, 21) vs. 21 (17, 28) days, $p < 0.001$]. In comparison to the OPD group, the LPD group had a shorter duration of fever [1 (0, 3) vs. 3 (1, 5), $p < 0.001$], an earlier initiation of catheter placement after surgery [7 (5, 10) vs. 7 (6, 12), $p < 0.001$], a lower number of catheters placed postoperatively [0 (0, 1) vs. 1 (0, 1), $p < 0.001$], and a shorter duration until catheter removal [7 (5, 9) vs. 9 (5, 12), $p < 0.001$]. The proportions of patients discharged with catheters in the LPD and OPD groups were similar (70.1% vs. 67.9%, $p =$ 0.769) (Tables 1 and 2). Ultimately, all patients were discharged home, and there were no surgery-related deaths in either group.

The possible complications included puncture-related hemorrhage, infection, lidocaine-related allergic shock, vasoneurotic reactions, tube insertion failure, tube breaking and accidental organ injury during tube placement. The incidence of the drainage procedure-related complications was rare. In this cohort study complications there were only two cases with puncture-related local hemorrhage which were controlled by local pressing and the tube placing continued when bleeding stopped and examined by ultrasonic flow imaging, there was one case with colon injury which recovered by another tube drainage without surgery intervention, there was one case with tube placing failure which was successfully given the same procedure the next day. No procedure-related death occurred in this group of patients.

Discussion

With the advancement of minimally invasive surgery, LPD has been routinely performed in some major pancreatic centers in recent years [7, 8]. However, pancreaticoduodenectomy (PD) remains a high-risk procedure with a relatively high incidence of severe postoperative complications, including a 90-day mortality rate as high as 9.2% [9, 10]. Postoperative intra-abdominal fluid accumulation is one of the most common complications following LPD or OPD, posing risks of increased infection rates and prolonged hospital stays for patients. The etiology of postoperative intra-abdominal fluid accumulation includes pancreatic leak, bile leak, inflammatory exudate, local vascular hypertension, hypoalbuminemia, malnutrition, cachexia, infection, hemorrhage, anastomotic leakage, lymphatic channel obstruction, and others. In this study, a total of 171 LPD patients and 138 OPD patients underwent abdominal ultrasound examination postoperatively. The incidence of postoperative intra-abdominal fluid accumulation requiring intervention was significantly lower in the LPD group compared to the OPD group (39.2% vs 59.3%, $p =$ 0.001). This difference in incidence may be attributed to the use of high-definition magnified laparoscopic imaging during LPD, which provides a finer operative perspective for pancreaticoduodenal surgery. Even small vascular structures can be clearly displayed, facilitating effective control of intraoperative bleeding and minimizing damage to surrounding tissues, along with smaller incisions.

Subjectively, the echogenicity of postoperative intra-abdominal fluid under ultrasound can be categorized as either good or poor. The septation of postoperative intra-abdominal fluid is classified as absent, few, or multiple. The characteristics of the drained fluid from postoperative intra-abdominal fluid include clear, turbid, or bile-like appearances. The echogenicity and septation of postoperative intra-abdominal fluid in both the LPD and OPD groups were significantly correlated with the characteristics of the drained fluid ($p < 0.001$) (Table 3). The clear appearance of postoperative intra-abdominal fluid may be caused by exudation, local vascular hypertension, hypoalbuminemia, lymphatic channel obstruction, or malnutrition. The turbid appearance of postoperative intra-abdominal fluid may be due to pancreatic leakage. The bile-like appearance of postoperative intra-abdominal fluid may be caused by bile leakage. Therefore, based on the characteristics of the drained fluid from postoperative intra-abdominal fluid, we can preliminarily infer the underlying causes of postoperative intra-abdominal fluid formation, providing clinical physicians with guidance on whether further treatment is necessary. Some studies have indicated that abdominal paracentesis drainage can reduce the concentrations of tumor necrosis factor-alpha, interleukin-6, IL-10, and other inflammatory factors in ascitic fluid, decreasing intra-abdominal pressure, thereby alleviating disease progression and improving patient prognosis [11].

Furthermore, the OPD group had a higher incidence of septate postoperative intra-abdominal fluid compared to the LPD group, which further demonstrates the advantages of LPD, including smaller trauma and a lower probability of developing adhesive septations within the abdomen postoperatively. Postoperative intra-abdominal fluid can potentially worsen the patient's nutritional status and increase susceptibility to infections. All of these factors contribute to repeated hospitalizations and significantly compromise the patients' quality of life. Therefore, timely and effective drainage of postoperative intra-abdominal fluid is crucial. In cases where postoperative intra-abdominal fluid accumulates in Douglas's pouch, it cannot be drained by percutaneous placement due to its low position and bowel coverage. Instead, it requires transvaginal cul-de-sac drainage guided by ultrasound, as shown in Fig. 2. Accurate drainage tube placement is a prerequisite for successful drainage of postoperative intra-abdominal fluid. Under ultrasound guidance, precise insertion of the drainage tube can be performed at the bedside or in the ultrasound suite.

In this study, the common sites of localized postoperative intra-abdominal fluid in both the LPD and OPD groups included the perihepatic region, lesser sac, subdiaphragmatic space, and pelvic cavity, with a higher rate of drainage tube placement observed in the lesser sac location, as shown in Fig. 1. This situation indicates the need for timely management of fluid accumulation in the lesser sac, as it is difficult to be reabsorbed spontaneously. It is challenging because of the unique anatomical location of the lesser sac, which is a potential space situated behind the lesser omentum, gastrocolic ligament, stomach and duodenal bulb, anterior and posterior pancreaticoduodenal fascia, and the anterior aspect of the left lobe of the liver, communicating with the more significant peritoneal cavity through the omental foramen. When there is inflammatory exudate, this passage can quickly become occluded, resulting in fluid accumulation. Additionally, the lesser sac is susceptible to changes influenced by surrounding organs and intra-abdominal pathologies. Inevitably, it is arduous to drain the effusion since the location of the lesser omental sac is deep. With its safety, non-invasiveness, and lack of radiation, ultrasound has become the preferred method for guiding percutaneous puncture and drainage tube placement [12]. In this study, for drainage of fluid in the lesser sac under ultrasound guidance, the left intercostal approach was chosen for cases with a larger volume of liquid. In contrast, the transhepatic approach was utilized for cases with a smaller volume, significantly reducing the risk of postoperative intra-abdominal fluid infection and shortening patient hospital stay.

Fig. 2 Posterior vaginal fornix catheterization guided by ultrasonography

In this study, postoperative intra-abdominal fluid drainage through tube placement resulted in several advantages for the LPD group compared to the OPD group. These advantages include shorter hospitalization duration, reduced fever duration, shorter time to initiate tube placement after surgery, fewer instances of tube placement, and shorter duration of tube removal. These findings, observed from an ultrasound perspective, highlight the relative benefits of LPD over OPD procedures. Minimally invasive surgeries, such as laparoscopic procedures, have been widely accepted and standardized as safe surgical approaches. When managing various diseases affecting intra-abdominal organs, they have shown comparable or even superior outcomes to traditional open surgeries [13–18].

LPD represents a promising alternative to OPD. Varela et al. reported that laparoscopic surgeries reduce the frequency of surgical site infections [19]. Effective control of postoperative intra-abdominal fluid can alleviate patient discomfort and improve their quality of life. For postoperative patients, early ultrasound examination is highly recommended; if fluid accumulation is detected, clinical doctors should perform timely ultrasound-guided tube placement and drainage. By avoiding the complications associated with postoperative intra-abdominal fluid, ultrasound-guided tube placement and drainage offer several advantages, including simplicity of operation, safety, speed, minimal trauma, reduced pain, and the ability to repeat procedures, which is practical, valuable, and is a minimally invasive treatment option for potential clinical applications.

In summary, ultrasound-guided postoperative intra-abdominal fluid drainage offers unique advantages in assessing and reducing or preventing complications such as postoperative pancreatic fistula, bile leakage, and bleeding. Postoperative intra-abdominal fluid accumulation is a common occurrence following pancreaticoduodenectomy, and ultrasound examination allows for initial assessment of fluid characteristics, including the location of fluid accumulation, echogenicity, and the presence of septations. With clinical presentation and ultrasound imaging features of postoperative intra-abdominal fluid, providers should perform timely tube placement and drainage under ultrasound guidance. In the future, it is important to optimize the selection of drainage tubes to reduce complications associated with postoperative intra-abdominal fluid accumulation. With the advancement of laparoscopic techniques and comprehensive utilization of adjunctive treatments such as ultrasound, clinics anticipate a wider clinical application of LPD.

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Author contributions
LZ wrote the main manuscript text, SZ, YY, CZ and LG acquisition, analysis, FL and JL design of the work, YG and GZ prepared Figs. 1–2. WZ have drafted the work or substantively revised it, All authors reviewed the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study was conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Approval was obtained from the Ethics Committee of Shandong Provincial Hospital for conducting research involving human subjects, and the study was carried out in compliance with the guidelines set forth in the Declaration of Helsinki (SWYX: NO.2023-211). All patient records were de-identified and protected.

Competing interests
The authors declare no competing interests.

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