Original Article

Right hepatic artery anomalies in pancreatoduodenectomy—a risk for arterial resection but not for postoperative outcomes

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Background: Pancreatoduodenectomy (PD) is a complex surgical procedure known for its significant morbidity rates, and the presence of an aberrant hepatic artery (AHA) introduces additional challenges. The impact of AHA on post-PD outcomes has been a subject of conflicting findings in the medical literature. This study aimed to investigate how variations in hepatic arterial anatomy influence intra-operative variables and postoperative morbidity.

Methods: A retrospective analysis was conducted on 113 PD cases. Patients with variant hepatic arterial anatomy (n=38) were categorized as Group 1, while those without vascular abnormalities comprised Group 2. Perioperative and postoperative outcomes were examined.

Results: Patients in Groups 1 and 2 exhibited similar characteristics, and no notable differences in surgical complications were observed. There was, however, a noticeable trend towards a higher incidence of postpancreatectomy hemorrhage (PPH) in Group 1 (31.6% *vs.* 20.0%; P=0.17). Furthermore, a statistically significant increase in the rate of arterial resections was noted in patients with vascular anomalies (10.5% *vs.* 1.33%; P=0.02).

Conclusions: The prevalence of vascular abnormalities in the hepatic arterial circulation is more frequent than initially anticipated. These anomalies present additional complexities to the already intricate PD procedure, leading to a heightened necessity for arterial resection, albeit without any discernible impact on postoperative complications.

Keywords: Pancreatoduodenectomy (PD); hepatic artery; vascular abnormalities; right hepatic artery

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Introduction

Pancreatoduodenectomy (PD) represents a complex surgery, associated with not negligible morbidity rates (1) and the presence of peripancreatic vascular anomalies adds challenges to this procedure (2).

Variations in the hepatic arterial supply are the most frequent and significant vascular variations encountered by pancreatic surgeons in their daily practice.

Hepatic arterial supply usually arises from a common hepatic artery (CHA) that originates from the celiac trunk. The origin of the gastroduodenal artery (GDA) defines the passage between the CHA and the proper hepatic artery (PHA) that divides into a right branch (RHA) and a left branch (LHA) and then arborizes the liver parenchyma.

The two most widely accepted classifications of aberrant hepatic arterial patterns are those proposed by Hiatt *et al.* (3), which is based on a comprehensive analysis of 1,000 angiographic studies, and Michels, which is derived from an extensive study of 200 autopsies (4).

In 2020, Yan *et al.* (5) introduced a new classification for hepatic artery anatomy. This classification is based on the identification and systematization of vascular anomalies of the hepato-gastric and spleno-mesenteric trunk using three-dimensional visualization and evaluation. It results in a complex classification system comprising nine classes of anomalies. While the complex classification introduced by Yan *et al.* is highly valuable and essential in living liver donor surgery, it is worth noting that the previously established classifications remain more widely adopted worldwide for describing vascular anomalies in pancreatic surgery.

In both these analyses, the most frequent abnormality reported is an aberrant right hepatic artery (aRHA). Michels also made a distinction between a replaced RHA (rRHA) and an accessory RHA (accRHA). In the first case, the vessel originates usually from the superior mesenteric artery. An accRHA follows the same route as the rRHA, in addition to a normal RHA. The incidence of an rRHA has been estimated in 8–14% of the cases while an accRHA has been reported in 7%. In the Hiatt classification, both rRHA and accRHA are classified as aRHA, and reported incidences to vary from 7% to 21% (3,4).

The impact of vascular abnormalities on oncological outcomes in patients who underwent PD has been documented in the literature, with conflicting findings. Some authors have reported that the presence of aberrant arterial anatomy does not compromise the radical intent of the resection, while others have described a potential risk of local recurrence in the presence of aRHA (6,7). Furthermore, contradictory results have been reported when post-PD outcomes have been analyzed. Many authors did not document a significantly higher incidence of postoperative complications in presence of aberrant hepatic artery (AHA) (8-11). However, a more recent paper by Mansour *et al.* reports higher rates of intraoperative bleeding in the AHA group (12). This may be due to the presence of arterial collateral circles that even in the case of major vascular lesions guarantee an adequate reserve. Some experiences, however, reported a significant increase in terms of morbidity in this last group of patients (13).

To the best of our knowledge, there is insufficient data regarding the impact of arterial vascular anomalies, especially those involving the right hepatic artery, on intraoperative management and postoperative outcomes. Therefore, this study aims to analyze the impact of these types of anomalies during pancreatoduodenectomies. We present this article in accordance with the STROBE reporting checklist (available at https://jgo.amegroups.com/article/view/10.21037/jgo-23-191/rc).

Highlight box

Key findings
- The presence of a vascular anomaly in patients undergoing pancreaticoduodenectomy (PD) does not impact postoperative outcomes. However, its presence is associated with a higher incidence of arterial vascular resections.

What is known and what is new?
- The impact of the presence of vascular anomalies in patients undergoing PD is a subject of debate. However, an increased incidence of postpancreatectomy hemorrhage has been reported.
- We have confirmed that the presence of vascular anomalies does not influence postoperative outcomes. However, we have highlighted how the presence of a vascular anomaly represents a risk factor for arterial vascular resection.

What is the implication, and what should change now?
- The presence of a vascular anomaly increases the risk of arterial vascular resection. For this reason, thorough vascular imaging in preoperative assessment is crucial. If identified, the surgeon should possess the skills to approach potential arterial resection and reconstruction.

Methods

A prospective database of all PD performed at the General Surgery Unit of the Fondazione Policlinico Universitario Campus Bio-Medico, from 2015 to 2021,

Table 1 Demographic characteristics: all the series

Characteristics	Statistical results
Age, years	75 [52–88]
Gender	
Female	51 (45.1)
Male	62 (54.9)
BMI, kg/m^2	24.59 [15.4–35.3]
Diabetes	29 (25.7)
Blood hypertension	54 (47.8)
ASA score	
I–II	50 (44.2)
III–IV	63 (55.8)
Smoke habit	45 (39.8)

Data are presented as n (%) or median [range]. BMI, body mass index; ASA, American Society of Anesthesiologists.

has been retrospectively analyzed. Inclusion criteria were age >18 years-old, PD performed for upfront resectable peri-ampullary tumors, and therefore not subjected to neoadjuvant therapy. All patients candidates to PD in our center have been performed a preoperatory computer tomography (CT) with intravenous contrast for their staging. However, for this study only patients with CT images available at the time the enrollment in this research were included.

Of 247 patients underwent PD in this period, only 113 met the inclusion criteria of the study. Patients with vascular abnormalities were identified by reviewing operation reports and preoperative CT with intravenous contrast. All the procedures have been performed according to what previously was reported (14) by the same senior surgeon assisted by the same surgical team. Data regarding demographic and clinical characteristics such as sex, age, body mass index (BMI) (15), comorbidities, American Society of Anesthesiologists (ASA) score (16), and tumor histology have been analyzed. Diabetes and hypertension diagnosis were considered patients with ongoing pharmacological treatments for these diseases. Intraoperative data regarding surgical time, blood transfusions, and intraoperative complications have been analyzed. Postoperative complications were reported following the Clavien-Dindo (CD) classification (17). According to the guidelines proposed by the International Study Group on Pancreatic Surgery (ISGPS), the following postoperative complications have been considered: postoperative pancreatic fistula (POPF) (18) delayed gastric emptying (DGE) (19) and postpancreatectomy hemorrhage (PPH) (20). Only patients with available surgical reports and pre-operative radiological imaging have been selected for the analysis. According to the Hiatt classification (3), the case series has been divided in two groups: the variant hepatic arterial anatomy group (Group 1) and the normal anatomy group (Group 2).

Ethical statement

The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Ethics Committee of the University Campus Bio-Medico (No. 104.20 OSS ComEt CBM). Patient consent was waived due to the retrospective design of the study and considering that data are de-identified.

Statistical analysis

Quantitative values are expressed as median (with range). Qualitative variables are expressed as absolute and relative frequencies. For continuous and categorical variables, the χ^2 test for proportions was used. A P value of <0.05 was considered to indicate statistical significance.

Results

All the series

One hundred and thirteen patients satisfied the inclusion criteria.

The demographic characteristics of all the series are summarized in *Table 1*. The median age was 75 years (range, 52–88 years). The median BMI was 24.59 kg/m^2 (range, 15.4–35.3 kg/m^2). Fifty-one patients were females (45.1%). Fifty patients were ASA I–II (44.2%). Sixty-three patients were ASA III–IV (55.8%). Forty-five (39.8%) patients had smoking habits, 54 (47.8%) subjects had blood hypertension and 29 (25.7%) presented had diabetes.

The most common diagnosis was pancreatic ductal adenocarcinoma (PDAC) in 90 (79.6%) of patients. The median dimensions of tumors in the two groups were similar and showed no statistically significant differences. The median operative time (OT) was 379 minutes (range, 215–645 minutes). Clear resection margin (R0) was

Table 2 Clinical and histopathological characteristics: all the series

Characteristics	Statistical results
Operative time, min	379 [215–645]
Histopathological type	
PDAC	90 (79.6)
Cholangiocarcinoma	6 (5.3)
IPMN	9 (8.0)
NET	5 (4.4)
Ampullary carcinoma	3 (2.7)
R0	83 (73.5)
Vascular resections	
Vein resections	29 (25.7)
Arterial resections	5 (4.4)

Data are presented as n (%) or median [range]. PDAC, pancreatic ductal adenocarcinoma; IPMN, intraductal papillary mucinous neoplasm; NET, neuroendocrine tumor; R0, clear resection margin.

Table 3 Classification of aberrant hepatic arterial: all the series (3)

Hiatt's type	AHA type	N (%)
I	Normal	75 (66.6)
II	Replaced or accessory LHA	11 (28.95)
III	Replaced or accessory RHA	18 (47.37)
IV	Replaced or accessory LHA + replaced or accessory RHA	3 (7.89)
V	CHA from SMA	4 (10.53)
VI	CHA from AO	2 (5.26)

AHA, aberrant hepatic artery; LHA, left hepatic artery; RHA, right hepatic artery; CHA, common hepatic artery; SMA, superior mesenteric artery; AO, abdominal aorta.

obtained in 83 (73.5%) of cases. Thirty-four (30.0%) patients needed vascular resections during PD (*Table 2*).

According to Hiatt's classification (3), the most frequent vascular anomaly in our series was an 'rRHA' and 'accRHA' (*Table 3*).

Surgical complications were detected in 64 patients (56.6%), in particular, CD major complications (above grade 3) occurred in 31.0% of the patients. Twenty-seven (23.9%) developed a clinically relevant POPF (CR-POPF); 38 (33.6%) patients developed DGE; 22 (19.5%) patients developed a biliary fistula and 27 (23.9%) patients developed PPH; 15 (13.3%) patients developed PPH grade B/C. Thirty-three (29.2%) patients needed blood transfusions. Nineteen (16.8%) patients needed reoperation (*Table 4*).

Table 4 Postoperative outcomes: all the series

Characteristics	N (%)
Blood transfusion	33 (29.2)
Clavien-Dindo classification	
<3A	78 (69.0)
≥3A	35 (31.0)
Clinically relevant POPF	27 (23.9)
DGE	38 (33.6)
PPH	27 (23.9)
Grade B/C PPH	15 (13.3)
Biliary fistula	22 (19.5)
Re-operation	19 (16.8)

POPF, postoperative pancreatic fistula; DGE, delayed gastric emptying; PPH, postpancreatectomy hemorrhage.

Group 1 vs. Group 2

In Group 1, we identified 38 patients, while Group 2 consisted of 75 patients. The two groups had similar patient populations.

In Group 1, the median age was 74.87 years (range, 56 to 84 years). Among these patients, 14 were females, and the median BMI was 24.57 kg/m^2 (range, 17.5 to 34.6 kg/m^2). About 42.1% of them had an ASA score of I–II, and 57.9% were classified as ASA III–IV (*Table 5*). The primary pathological diagnosis was PDAC in 81.6% of patients (*Table 6*). The median surgery time was 404.79 minutes, and 34.2% of patients required blood transfusions. Vascular resections were necessary for 10 (26.3%) patients, including venous and arterial resections. Three patients underwent resection with end-to-end reconstruction of the rRHA, and one patient underwent accRHA ligation (*Table 6*). The percentage of R1 resections in Group 1 was 24.7%.

Surgical complications were observed in 15 (39.5%) patients, with CD major complications occurring in 39.5% of them. Eight (21.1%) patients developed CR-POPF, and 14 (36.8%) developed DGE. Additionally, 7 (18.4%) patients reported PPH grade B/C and also in 7 (18.4%) patients a surgical reoperation was required (*Table 7*).

Table 5 Demographic characteristics

Characteristics	Group 1 (n=38)	Group 2 (n=75)	P value
Age, years	74.87 [56–84]	72.68 [52–88]	0.19
Gender			
Female	14 (36.8)	37 (49.3)	0.20
Male	24 (63.2)	38 (50.7)	0.20
BMI, kg/m^2	24.57 [17.5–34.6]	24.82 [15.4–35.3]	0.75
Diabetes	10 (26.3)	19 (25.3)	0.91
Blood hypertension	16 (42.1)	38 (50.7)	0.38
ASA score			
I–II	16 (42.1)	34 (45.3)	0.74
III–IV	22 (57.9)	41 (54.7)	0.74
Smoke habit	15 (39.5)	30 (40.0)	0.95

Data are presented as n (%) or median [range]. Group 1, patients with variant hepatic arterial anatomy; Group 2, patients with normal anatomy. BMI, body mass index; ASA, American Society of Anesthesiologists.

Table 6 Clinical and histopathological characteristics

Characteristics	Group 1 (n=38)	Group 2 (n=75)	P value
Operative time, min	404.79 [240–595]	393.43 [215–645]	0.54
Pathological diagnoses			
PDAC	31 (81.6)	59 (78.7)	0.65
Cholangiocarcinoma	0	6 (8.0)	0.93
IPMN	4 (10.5)	5 (6.7)	0.65
NET	3 (7.89)	2 (2.7)	0.76
Ampullary carcinoma	0	3 (4.0)	0.56
Vascular resections			
Vein resections	6 (15.8)	23 (30.7)	0.08
Arterial resections	4 (10.5)	1 (1.33)	0.02*

Data are presented as n (%) or median [range]. *, P<0.05 was considered statistically significant. Group 1, patients with variant hepatic arterial anatomy; Group 2, patients with normal anatomy. PDAC, pancreatic ductal adenocarcinoma; IPMN, intraductal papillary mucinous neoplasm; NET, neuroendocrine tumor.

In Group 2, the median age was 72.68 years (range, 52 to 88 years), with 37 (49.3%) females, and a median BMI of 24.82 kg/m^2 (range, 15.4 to 35.3 kg/m^2). About 45.3% had an ASA score of I–II, and 41 (54.6%) were classified as ASA III–IV (*Table 5*). The primary pathological diagnosis was PDAC in 78.6% of patients (*Table 6*). The median surgery time was 393.43 minutes, and 20 (26.6%) patients required postoperative blood transfusion. Vascular resections were necessary for 24 (32.0%) patients, including venous and arterial resections. One patient required hepatic artery resection with end-to-end reconstruction (*Table 6*). The percentage of R1 resections in Group 2 was 28%. Surgical complications were observed in 41 (54.6%) patients, with CD minor complications occurring in 73.3% of them. Nineteen patients (25.3%) developed CR-POPF, 24 (32.0%) developed DGE and 8 (10.7%) with PPH grade B/C.

Table 7 Post-PD outcomes

Characteristics	Group 1 (n=38)	Group 2 (n=75)	P value
Blood transfusion	13 (34.2)	20 (26.6)	0.40
Clavien-Dindo classification			
<3A	23 (60.5)	55 (73.3)	0.59
≥3A	15 (39.5)	20 (26.6)	0.68
Clinically relevant POPF	8 (21.1)	19 (25.3)	0.61
DGE	14 (36.8)	24 (32.0)	0.60
PPH	12 (31.6)	15 (20.0)	0.17
Grade B/C PPH	7 (18.4)	8 (10.7)	0.25
Biliary fistula	8 (21.1)	14 (18.7)	0.76
Re-operation	7 (18.4)	12 (16.0)	0.74

Data are presented as n (%). Group 1, patients with variant hepatic arterial anatomy; Group 2, patients with normal anatomy. PD, pancreatoduodenectomy; POPF, postoperative pancreatic fistula; DGE, delayed gastric emptying; PPH, postpancreatectomy hemorrhage.

Twelve (16.0%) patients required reoperation (*Table 7*).

Statistical analysis did not reveal any significant differences in demographic characteristics, intraoperative variables intensive care unit (ICU) stay and total postoperative length of stay between the two groups.

Notably, there was a greater need for arterial vascular resections in Group 1 compared to Group 2 [Group 1: 4 (10.5%), Group 2: 1 (1.33%), P=0.02] (*Table 6*). The R1 resection rates were comparable between the two groups. When looking at postoperative complications, none of the examined variables showed a statistically significant difference (*Table 7*). However, both groups exhibited a higher tendency for postoperative bleeding in Group 1. Specifically, 31.6% of patients in Group 1 developed PPH compared to 20.0% in Group 2 (P=0.17). Furthermore, PPH grade B/C was more frequent in Group 1, with 18.4% compared to 10.7% in Group 2 (P=0.25) (*Table 7*).

Discussion

The RHA represents the most common type of arterial vascular anomaly detected during PD. When an AHA is present, its impact on post-PD outcomes is controversial.

Some authors reported worse postoperative outcomes since the presence of vascular abnormality can expose to an increased risk of complications through multiple mechanisms. A damage or ligation of an aberrant vessel can determine hepatic or biliary tract ischemia and therefore organ dysfunction or anastomotic leakage. Furthermore, as reported by Traverso *et al.* in a cornerstone paper, an excessive manipulation of the vessel to preserve it can lead to damage of its adventitia weakening the vessel itself with increased risk of the formation of a pseudoaneurysm and PPH (2,17,21).

In our series, the presence of AHA did not affect the postoperative course; these data are consistent with what has been shown by other recent studies (11,12). Mansour *et al.* have analyzed a series of 202 patients identifying 41 subjects carrying vascular abnormality. In this study, the overall rate of PPH was 9% in the anatomical variant group and 7% in the control group, with no statistically significant difference. There were also no differences in rates of other PD-related complications (12).

Alexakis *et al.*, similarly, on a matched-pair analysis of 105 patients, found no differences in surgical complications in the aberrant artery group with the normal artery group (11). We must note, however, that in our series we found a higher incidence of PPH in the group of patients with vascular abnormalities, albeit in the absence of statistical significance._We cannot exclude that a significant association between AHA and PPH could result analyzing larger series. This data, although being not supported by statistical significance, is in contrast with what previously reported by other Authors (10,11,22).

Notably, we also found a significant increase in the rate of arterial resections in the group of patients with vascular anomalies. To the best of our knowledge, this is the first report on this aspect that has been previously analyzed only as raw data. As an instance, Rammohan *et al.* reported the type of surgical management in the case of AHA but did not focus on the vascular anomalies (8).

According to this finding, it is clear that the presence of vascular anomaly, increasing the need for arterial resection, could influence the intraoperative management of PD, challenging an already complex procedure and requiring more commitment from the surgeon.

These results lead to a series of considerations, both on a technical and oncological management level. Starting with the technical aspect, an anomaly of the right hepatic artery, whether rRHA or accRHA, runs behind the head of the pancreas and can easily come into proximity to or be infiltrated by even small-sized tumors. In cases where it is impossible to perform arterial devascularization to achieve cancer-free resection margins, arterial resection can become necessary. In cases where dealing with an rRHA, reconstruction will often be necessary to avoid compromising the patient's liver function. In cases where the anomaly is constituted by an accRHA, vessel ligature may also be considered without postoperative liver damage. Therefore, both the choice of reconstruction type and the complexity of the reconstruction that often follows are further evidence that pancreatic surgery, even in cases of preoperatory staged upfront resectable tumors, should be performed in centers where surgeons are experienced in vascular resections or have the expertise of vascular and/or transplant surgeons available.

In our series, none of the arterial resections were performed due to intraoperative surgical damage but always achieved a negative resection margin in patients with intraoperative suspicion of arterial vascular infiltration. In fact, this is the second point of discussion that emerges from our study.

Vascular arterial resections are a highly debated topic in the pancreatic surgery literature. What is without question is that patients with the mere suspicion of PDAC with arterial vascular infiltration, and recently even venous infiltration, must absolutely undergo neoadjuvant treatments before undergoing surgery to improve oncological outcomes. However, the patients in this study had all been judged as upfront resectable without suspicion of arterial vascular infiltration of major arterial axes, and not even involving the anomalous vessel of the RHA. Arterial resections were performed based on intraoperative suspicion of neoplastic infiltration.

This data could mean that there is a risk that the staging we currently perform may not be sufficient to detect possible arterial vascular infiltrations of these anomalous vessels, exposing patients to the risk of arterial vascular resection without having undergone neoadjuvant treatments, which represent the gold standard for these patients.

In our opinion, this aspect is even more interesting considering the high rate of AHA we detected in our series (33.6%). This rate is similar to that historically reported by Michels during autopsies but higher than the rate that Hiatt reported in the angiographic series. If these data were confirmed in larger series, this would mean that if rates of AHA are higher than expected according to the preoperative radiological assessment, the pancreatic surgeons could deal with the need for arterial resection in almost one-third of PDs (23,24).

As a result, there is a *non-negligible* risk that a significant number of patients may not receive the oncologically appropriate treatment due to preoperatory occult arterial involvement.

This study is not without limitations that are mainly linked to its retrospective and to the small series analyzed.

Furthermore, the inability to perform a re-lecture of all the CT images of all the resected patients in our center has been a significant limitation, leading us to exclude a substantial number of patients. A larger sample size would undoubtedly have contributed to strengthening our results. Last, there is a disparity in the two groups regarding the number of venous vascular resections that can lead to bias in the comparison of the postoperative outcomes.

Conclusions

In conclusion, the incidence of vascular abnormalities in the hepatic arterial circulation, especially RHA, is more common than anticipated and with potentially underestimated tumor involvement in comparison to preoperative radiological staging. These anomalies add complexity to an already challenging procedure such as PD, potentially increasing the necessity for arterial resection. However, this increased complexity does not significantly affect postoperative complications in well-established pancreatic surgery centers.

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Footnote

Reporting Checklist: The authors have completed the STROBE reporting checklist. Available at https://jgo.amegroups.com/article/view/10.21037/jgo-23-191/rc

Data Sharing Statement: Available at https://jgo.amegroups.com/article/view/10.21037/jgo-23-191/dss

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://jgo.amegroups.com/article/view/10.21037/jgo-23-191/coif). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved. The study was conducted in accordance with the Declaration of Helsinki (as revised in 2013). The study was approved by the Institutional Ethics Committee of the University Campus Bio-Medico (No. 104.20 OSS ComEt CBM). Patient consent was waived due to the retrospective design of the study and considering that data are de-identified.

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