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Original Article

Surgery Section

Impact of Hepatic Arterial Anomalies on Postoperative Outcomes following Pancreaticoduodenectomy: A Retrospective Case-control Analysis

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ABSTRACT

Introduction: Arterial anomalies are frequent occurrences and pose challenges during major surgeries like Pancreaticoduodenectomy (PD), especially during gastroduodenal artery ligation and lymph node dissection.

Aim: To analyse the influence of arterial anomalies on mortality and morbidity, as well as oncological adequacy in terms of R0 rate and lymph node retrieval.

Materials and Methods: A The present retrospective analysis included a total of 25 patients with vascular anomalies reported on Computed Tomography (CT) angiography who underwent PD over a period of four years (January 2020-December 2023) and were compared with 25 patients without vascular anomalies. This analysis was conducted from January 2024 to March 2024. Intraoperative events such as blood loss, blood transfusion requirements and operative time were compared between both the groups. Postoperative complications, including pancreatic leak, Hepaticojejunostomy (HJ) leak, delayed gastric emptying, postpancreatectomy haemorrhage, relaparotomy and mortality, were also compared. Fisher's two-tailed exact test, t-test and Chi-square tests were employed, with p-value <0.05 considered significant.

Results: The two groups were evenly matched regarding patient demographics. The most common variation was the Replaced Right Hepatic Artery (RRHA) (48%) arising from the Superior Mesenteric Artery (SMA), followed by the Replaced Common Hepatic Artery (CHA) (20%) arising from the SMA. There was no significant difference (p-value >0.05) in blood loss, the need for blood transfusion, or operative time. Postoperative morbidity due to pancreatic leak, bile leak, postoperative haemorrhage, relaparotomy rate and 30-day mortality was also not significantly different. There was no difference in resection margins (R0) and lymph node yield (10 vs 11) between the two groups.

Conclusion: Aberrant hepatic arteries do not significantly increase morbidity or compromise oncological safety in patients undergoing PD by experienced surgeons.

Keywords: Computed tomography angiography, Pancreatic cancer, Replaced hepatic arteries, Whipples procedure

INTRODUCTION

The PD is one of the most difficult and challenging abdominal surgeries performed for periampullary, head of the pancreas and duodenal malignancies. Hepatic artery anomalies are frequent occurrences [1,2], seen in at least half the population. The most common variation is RRHA arising from the SMA. Usually, the replaced hepatic artery runs behind the pancreatic head, but in 20% of patients, it runs intrapancreatic [2]. If unrecognised, injury to this artery during pancreatic transection can result in excessive blood loss, anastomotic leaks and postoperative ischaemic complications, making it difficult for surgeons during resection, lymph node dissection and the reconstruction phase [3]. However, previous studies have shown that the existence of hepatic artery variations does not influence perioperative outcomes [3,4]. The present study aimed to assess the influence of arterial anomalies on the outcomes of the Whipple's procedure in terms of morbidity and mortality, as well as the oncological adequacy of the resected specimen in terms of resection margins and lymph node yield.

MATERIALS AND METHODS

A retrospective case-control study was conducted in the Department of Surgical Gastroenterology at Rajiv Gandhi Hospital, Chennai, Tamil Nadu, India. The study population consisted of 50 patients who underwent PD from January 2020 to December 2023. Retrospective analysis was performed from January 2024 to March 2024.

Inclusion criteria: Preoperative CT abdominal angiography was conducted to detect vascular anomalies, which were documented. Patients with reported hepatic arterial anatomy on CT angiography were considered as cases (n=25) and compared with patients with no reported anomalies, who were taken as the control group (n=25) and were included in the study.

Exclusion criteria: Patients with high bilirubin levels (>15 mg/dL), cholangitis, or anticipated delays in surgery underwent Endoscopic Retrograde Cholangiopancreatography (ERCP) stenting, followed by surgery after four weeks, patients with otherwise resectable disease underwent upfront surgery were excluded from the study.

Study Procedure

The aberrant hepatic arteries were dissected and followed to identify their origin. Lymph nodal dissection was performed around the hepatoduodenal ligament, hepatic arteries, periportal area, retro-pancreatic region and around the coeliac axis. Reconstruction was carried out using a Roux-en-Y jejunal loop. Pancreaticojejunostomy was performed using the Buchler technique with 5-0 PDS sutures. Subsequently, hepaticojejunostomy was conducted using a modified Blumgart technique with 3-0 Vicryl sutures. Gastrojejunostomy was constructed in two layers using Vicryl 3-0 for the inner layer and Silk 3-0 for the outer layer, in an antecolic and retrogastric fashion.

During surgery, the tumour site, vessel involvement and arterial variations were noted. The amount of blood loss, blood transfusion and operative time were also recorded. The International Study

Group of Pancreas Surgery (ISGPS) definitions [5] for pancreatic fistula (leak), bile leakage, delayed gastric emptying and postpancreatectomy haemorrhage were used. Postoperative mortality was defined as death within 30 days of surgery. The histopathological report was followed for histology, margin status and lymph node status. An R1 resection was defined as microscopic evidence of tumour less than or equal to 1 mm from a resection margin.

STATISTICAL ANALYSIS

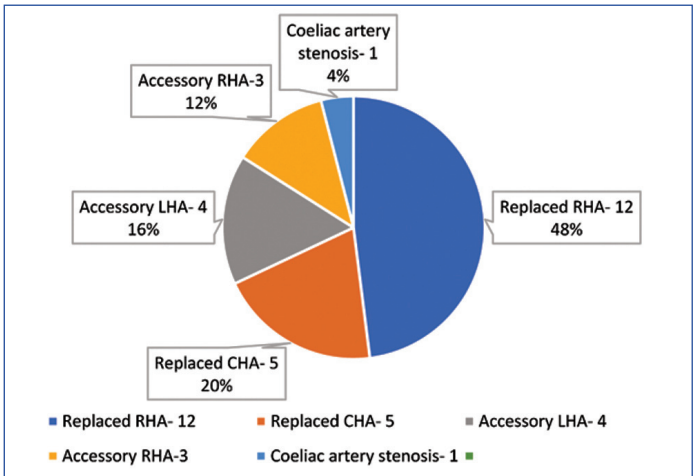
Continuous values were expressed as means and Standard Deviations (SD) or medians (with ranges). Categorical variables were expressed as absolute and relative frequencies. The Fisher's two-tailed exact test, Chi-square test and t-test were used. A p-value of <0.05 was considered significant. Statistical Package for the Social Sciences (SPSS) software version 20.0 was employed for analysis.

RESULTS

There were no significant differences in age, sex, American Society of Anaesthesiologists (ASA) score, presence of co-morbidities, ERCP stenting, pancreatic consistency and pancreatic duct diameter between both groups [Table/Fig-1]. Hepatic arterial anomalies are shown in [Table/Fig-2]. The most common variation was a RRHA arising from the SMA.

Patients	Aberrant hepatic artery group (n=25)	Normal hepatic artery group (n=25)	p-value
Age (in years)	52.52±11.65	53.60±11.13	0.78*
Males n (%)	15 (25)	16 (64)	0.65
Co-morbidities n (%)	7 (28)	6 (24)	0.75
ASA 2 n (%)	17 (68)	16 (64)	0.78
ASA 3 n (%)	8 (32)	9 (36)	0.68
ERCP stenting n (%)	13 (52)	12 (48)	0.72
Soft pancreas n (%)	17 (68)	16 (64)	0.78
Pancreatic duct diameter (mm)	4.28	4.32	0.91*

[Table/Fig-1]: Patient demographics.
*t-test was used. For rest Chi-square test was used



[Table/Fig-2]: List of variant hepatic arterial anatomy.

Median arcuate ligament release for patients with coeliac artery stenosis was performed. Intraoperatively, Doppler ultrasound was done to confirm the flow through the CHA. Unfortunately, a patient had increasing Liver Function Test (LFT) results on postoperative day 1, prompting a CT angiography that revealed necrosis of the liver and pancreatic remnant. The patient was re-explored and an attempt was made to salvage the situation with an aorto-hepatic graft, but the patient died the next day.

Pancreatic ductal adenocarcinoma was the most common histological diagnosis, occurring in 56% of cases [Table/Fig-3]. All patients underwent classic PD. Careful dissection was performed in both groups. There was no vascular involvement in any patient. In all patients of the hepatic artery anomaly group, the aberrant artery was preserved without any injury.

Histology	Hepatic artery anomaly group n (%)	Normal hepatic artery group n (%)
Pancreatic adenocarcinoma	14 (56)	15 (60)
Distal cholangiocarcinoma	5 (20)	5 (20)
Ampullary carcinoma	2 (8)	3 (12)
Solid Pseudopapillary Neoplasm (SPEN)	1 (4)	1 (4)
Intraductal Papillary Mucinous Neoplasm (IPMN)	1 (4)	0
Duodenal adenocarcinoma	1 (4)	1 (4)
Serous cystadenoma	1 (4)	0

[Table/Fig-3]: Histology of PD specimen.

Intraoperative events such as blood loss, blood transfusion requirements and operative time were compared between both groups and are described in [Table/Fig-4]. There was no significant difference between these groups.

Intraoperative event	Hepatic artery anomaly group	Normal hepatic artery group	Significance
Blood loss (in mL)	460±206.15	416±188.03	0.43*
Median units of blood transfused	1.36 PRBC	1.28 PRBC	0.68
Operative time (in mins)	417.60±42.35	410±40.69	0.19

[Table/Fig-4]: Comparison of intraoperative event between two groups.
*t test was used

Postoperative complications [Table/Fig-5], such as pancreatic leaks, HJ leaks, delayed gastric emptying, postpancreatectomy haemorrhage, relaparotomy and mortality were compared. No significant difference was observed in any of these parameters between the two groups. Postpancreatectomy haemorrhage was seen in one patient in the vascular anomaly group, which necessitated relaparotomy for haemostasis. Relaparotomy was performed in three patients in the normal group and five patients in the anomaly group. The most common relaparotomy procedure was lavage, primarily for pancreatic leaks and bile leaks. In-hospital mortality was 8% compared to 4% in the normal artery group. The most common cause of mortality was sepsis.

Postoperative complication	Hepatic artery anomaly group n (%)	Normal hepatic artery group n (%)	Significance
Pancreaticojejunostomy (PJ) leak (grade A)	9 (36)	5 (20)	0.44
PJ leak (grade B)	0	0	
PJ leak (grade C)	2 (8)	2 (8)	
Hepaticojejunostomy leak	4 (16)	5 (20)	0.713
Delayed gastric emptying	8 (32)	7 (28)	0.75
Rise in liver function test	2 (8)	1 (4)	0.55
Postpancreatectomy haemorrhage	1 (4)	0	0.312
Relaparotomy	5 (20)	3 (12)	0.44
Mortality	2 (8)	1 (4)	0.552

[Table/Fig-5]: Postoperative complications.
Chi-square test was used

One patient had normal angiography reported but was found intraoperatively to have a replaced CHA from the SMA. Dissection in this patient was difficult, resulting in more blood loss, a greater blood transfusion requirement and a longer operative time than average. The patient also experienced an increase in LFT postoperatively but settled with conservative management.

Resection margins, lymph node yield and the number of positive lymph nodes were examined. There was no significant difference in R1 status and lymph node yield between both groups [Table/Fig-6].

Oncological parameter	Hepatic artery anomaly group n (%)	Normal hepatic artery group n (%)	Significance
R1 status	2 (8)	1 (4)	0.552
Average lymph node yield	10 (40)	11 (44)	0.45

[Table/Fig-6]: Oncological outcome.
Fischer-exact test was used

There was no difference regarding postoperative complications, except for the patient with coeliac artery stenosis who died. Therefore, coeliac artery anomalies may be considered to be a high-risk variation among all anomalies, which necessitates preoperative intervention, such as endovascular stenting or median arcuate ligament release, to mitigate the associated risks [Table/Fig-7].

Anomaly	PJ leak	HJ leak	Delayed Gastric Emptying (DGE)	Rise in liver function tests	Relaparotomy	Mortality
Replaced RHA (n=12)	6	1	4	1	2	1
Replaced CHA (n=5)	2	1	2	1	1	-
Accessory LHA (n=4)	2	1	1	-	1	-
Accessory RHA (n=3)	1	1	1	-	-	-
Coeliac artery stenosis (n=1)	-	-	-	-	1	1

[Table/Fig-7]: Subgroup analysis among various anomalies.

DISCUSSION

Hepatic artery variation is seen in 40-45% of the normal population [6]. Multiple classifications have been described, but the most commonly used is Michel's classification [6]. According to the literature, the most common variant is the RRHA [6]. In present study, the most common variant was also RRHA (48%) arising from the SMA.

In relation to the pancreatic head, there are two distinct CHA/RRHA pathways arising from the SMA [1]: the extraparenchymal route (outside the pancreatic head) and the intraparenchymal route (within the pancreatic head). In the extraparenchymal route, the CHA/RRHA emerges from the SMA and passes posterior to the pancreatic head before reaching the liver. In this case, the artery can be dissected from the pancreatic head easily if its course is known preoperatively [2]. In the intraparenchymal route, the CHA/RRHA emerges from the SMA and travels through the pancreatic head parenchyma to the liver hilum. In this scenario, it may be difficult to preserve the CHA/RRHA, necessitating reconstruction by anastomosing it to the aorta or Left Gastric Artery (LGA) [7] with a graft. The presence of these anatomical variations may increase the risk of complications through direct (bleeding due to iatrogenic intraoperative vessel injury) or indirect (postoperative ischaemia of tissues and anastomotic leakage) mechanisms. Additionally, replaced hepatic arteries, which are the sole arterial supply to the liver, when injured, can cause liver ischaemia, necrosis, increases in LFT and interfere with anastomotic (HJ) healing, leading to significant morbidity for the patient. They can also increase the risk of postoperative complications such as anastomotic leaks [8], postpancreatectomy haemorrhage, delayed gastric emptying and a higher chance of relaparotomy, which can lead to increased morbidity and mortality for the patient.

In present study, there were no significant differences in surgical and postoperative complications between patients in the vascular anomaly group compared with the normal artery group. This could be attributed to preoperative CT angiography, which provides a roadmap for surgeons, as well as the experience and skill of the surgeons during dissection.

Vascular anomalies can also complicate achieving R0 resection due to their involvement or their course through the tumour. They can also hinder the harvesting of lymph nodes for adenocarcinoma. If the replaced right hepatic artery is found to be completely encased in tumour, a viable strategy to increase the R0 resection rate is to perform angiographic embolisation of the variant vessel. This allows for sufficient preoperative collateralisation to prevent ischaemia of the right liver and the bilio-enteric anastomosis [9].

In a similar study by Alexakis N et al., who compared outcomes in 105 patients, no statistically significant difference was observed between the two groups [10]. In the study by Mansour S et al., increased blood loss was identified in the vascular anomaly group, but no significant differences were found among other outcomes [11]. Similar studies conducted by Wang J et al., [12] in patients who underwent laparoscopic PD, and Nguyen TK et al., [13] in patients who underwent robotic PD, also showed no statistically significant differences in outcomes for patients with arterial anomalies. A study by La Vaccara V et al., concluded that arterial anomalies are not a risk factor for postoperative complications after PD [14]. CT angiography accurately identified anomalies, except in one case, and thus serves as a useful tool prior to Whipple's surgery.

Limitation(s)

The main limitation of the study was the low sample size and the retrospective nature of the research. Studies with a larger sample size are needed to draw conclusions regarding the utility of CT angiography in detecting anomalies, as well as to identify postoperative complications.

CONCLUSION(S)

The present study confirmed that although vascular anomalies are common, they do not significantly increase morbidity or compromise oncological safety in patients undergoing PD. Coeliac artery stenosis is considered a high-risk variation and requires special attention. HPB surgeons and radiologists should be aware of various arterial anomalies, their frequency and strive to identify them preoperatively and intraoperatively whenever possible. During dissection of the hepatoduodenal ligament and prior to transection of the bile duct, the surgeon must ensure that there is no variant hepatic artery present to prevent significant morbidity and mortality. If there are any doubts regarding an anomaly, intraoperative Doppler ultrasound can be employed. Patients with arterial anomalies can be managed using a minimally invasive approach if identified preoperatively. This study also advocates for the routine use of CT angiography before undergoing PD.

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