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BRIEF ARTICLE

Implications of the presence of an aberrant right hepatic artery in patients undergoing pancreaticoduodenectomy

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Abstract

AIM: To analyze the differences in outcomes and the clinical impact following pancreatoduodenectomy (PD) in patients with and without aberrant right hepatic artery (aRHA).

METHODS: All patients undergoing PD between January 2008 and December 2012 were divided into two groups, one with aRHA and the other without. These groups were compared to identify differences in the intraoperative variables, the oncological clearance and the postoperative morbidity, mortality and hospital stay.

RESULTS: A total of 225 patients underwent PD, of which 43 (19.1%) patients were found to have either accessory or replaced right hepatic arteries (aRHA group). The aRHA was preserved in 79% of the patients. There was no significant difference in the intraoperative blood loss but operative time was prolonged, reflecting the complexity of the procedure [420 ± 44 (240-540) min *vs* 480 ± 45 (300-600) min, $P < 0.05$)]. There were no differences in the incidence of postoperative complications (pancreatic leak, pancreatic fistula, delayed gastric emptying and mortality) and hospital stay. Oncological clearance in the form of positive resection margins [13 (7.1%) *vs* 3 (6.9%)] and lymph node yield were also similar in the two groups.

CONCLUSION: An aRHA is found in approximately one fifth of patients undergoing PD. Preservation is technically possible in most patients and can increase the operative complexity but does not negatively affect the safety or oncological outcomes of the procedure.

Key words: Pancreatoduodenectomy; Aberrant right hepatic artery; Arterial anomalies; Outcomes

Core tip: Appreciation and study of hepatic arterial anatomical variability is essential to the successful performance of complex pancreaticobiliary procedures. An aberrant right hepatic artery (aRHA) represents the vascular anomaly encountered most frequently during pancreatoduodenectomy (PD) and, because of its course, is most susceptible to intraoperative damage and tumor involvement. When an aRHA is present, the challenge in peripancreatic malignant disease is to balance its preservation and the need to achieve oncological clearance. In this study, we analyzed the incidence of aRHA and its relationship with the operative complexity, occurrence of complications and oncological clearance in a large cohort of patients undergoing PD.

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INTRODUCTION

Even although well described in the literature, the surgical anatomy of the hepatic arteries is notoriously variable. Appreciation and study of hepatic arterial anatomical variability is essential to the successful performance of complex pancreaticobiliary procedures, such as the pancreaticoduodenectomy (PD). Although anatomically interesting, the presence of aberrant hepatic arterial anatomy raises the surgical complexity and increases the potential risk of injury to the hepatic arterial supply during a PD[1]. The two most widely accepted classifications of hepatic arterial variations are those by Michels[2], based on 200 autopsies, and Hiatt, based on 1000 donor livers[2,3]. In both series, the most commonly reported vascular anomaly is an aberrant right hepatic artery (aRHA)[2,3].

An aRHA represents the vascular anomaly encountered most frequently during PD. It may have a suprapancreatic, intrapancreatic or rarely transpancreatic course, and, because of its course, it is most susceptible to intraoperative damage and tumor involvement[4,5]. The incidence of an aRHA identified in patients undergoing PD varies from 11%-26.5%[1,6]. When an aRHA is present, the challenge in peripancreatic malignant disease is to balance between its preservation and the need to achieve oncological clearance, which represents the only chance for prolonged survival[1,5,7]. The presence of an aRHA leads not only to an alteration in the surgical approach, but may also adversely affect the outcomes of the surgical procedure[5,8]. In this study, we analyzed the incidence of aRHA and its relationship with the operative complexity, occurrence of complications and oncological clearance in a large cohort of patients undergoing PD.

MATERIALS AND METHODS

The study was conducted over a five year period (2008-2012) which included all patients who underwent a PD by a single surgical team in a tertiary care center. Detailed information regarding their demography, characteristics, imaging, intraoperative findings and operative details were maintained on a prospective database. Demography and patient characteristics were carefully recorded. The details of the arterial anatomy, variations and the operative complexities, including duration of surgery and blood loss, were noted. In the specimen, the arterial margin was inked in addition to the resection margins. Postoperative course was recorded, with death during the same hospital stay or within 30 d of surgery being considered as operative mortality. Histopathology, along with resection margin status and lymph nodal yield, was also documented.

Table 1 Patient demography *n* (%)

Patient characteristics	No arterial anomaly *n* = 182	Arterial anomaly *n* = 43	*P* value
Age	52.1 ± 10.9	52.4 ± 11.2	NS
Males/females	135/53	32/11	NS
ASA			
Ⅰ	45 (24.7)	11 (25.6)	NS
Ⅱ	115 (63.2)	27 (62.7)	NS
Ⅲ/Ⅳ	22 (12.1)	5 (11.6)	NS

ASA: American Society of Anesthesiologists.

Definitions

Normal anatomy was defined as when the celiac axis trifurcated into the left gastric artery, the splenic artery and the common hepatic artery, with the common hepatic artery continuing as a hepatic artery proper after the branching off of the gastroduodenal artery, finally bifurcating into the right and left hepatic arteries. The term anomalous or aberrant encompassed both the "accessory" and the "replaced" vessels. An extra right hepatic artery that supplied the liver, which also received blood supply from a normally located right hepatic artery, was termed an accessory right hepatic artery. If the liver received its primary blood supply from the aberrant right hepatic artery, it was called a replaced hepatic artery.

Statistical analysis

Data are reported as frequencies or mean ± SD and ranges. SPSS version 20.0 (SPSS, Inc., Chicago, IL, United States) software was used for data analysis. The Student *t* test was used to test significance for continuous variables and the Fisher's exact test was used for categorical variables. *P* values less than 0.05 were considered significant.

RESULTS

Between January 2008 and December 2012, two hundred and twenty-five consecutive patients who underwent PD were included in the study. No significant differences were noted in terms of age, gender, American Society of Anesthesiologists class and indication for pancreaticoduodenectomy (Tables 1 and 2). The most common indication for surgery was ampullary adenocarcinoma, followed by distal cholangiocarcinoma. There were 43 (19.1%) arterial anomalies detected during the procedure. The spectrum of arterial anomalies is shown in Table 3. Replaced RHA from superior mesenteric artery (SMA) was the most common anomaly noted. The artery could be preserved in 79% of the cases (Table 4). In eight patients (6%) with aRHA, the aberrant vessel was sacrificed for oncological ($n = 6$) or technical ($n = 2$) reasons. While in 6, the aberrant artery was found to be accessory and was ligated. In two patients, there was an inadvertent

Table 2 Underlying disease in patients with and without arterial anomaly *n* (%)

Indication	No arterial anomaly *n* = 182	Arterial anomaly *n* = 43	*P* value
Ampullary adenocarcinoma	99 (54.4)	23 (53.5)	NS
Distal cholangiocarcinoma	43 (23.6)	10 (23.2)	NS
Pancreatic adenocarcinoma	25 (13.7)	6 (13.9)	NS
Duodenal carcinoma	15 (8.2)	3 (7.0)	NS
GIST	0	1 (2.3)	-

GIST: Gastrointestinal stromal tumor.

Table 3 Hepatic arterial variations observed during pancreaticoduodenectomy *n* (%)

Arterial variations	*n* = 43
Replaced RHA from SMA	31 (72.1)
Accessory RHA from SMA	10 (23.2)
Replaced CHA from SMA	1 (2.3)
Accessory RHA from GDA	1 (2.3)

RHA: Right hepatic artery; SMA: Superior mesenteric artery; GDA: Gateway design automation.

Table 4 Intraoperative management of aberrant artery *n* (%)

Management	*n* = 43
Dissection and preservation	34 (79)
Ligation	8 (18.6)
Dissection and primary anastomosis	1 (2.3)

Table 5 Intraoperative and postoperative comparison in patients with or without arterial anomalies *n* (%)

Variables	No arterial anomaly *n* = 182	Arterial anomaly *n* = 43	*P* value
Duration of surgery (min)	420 ± 44 (240-540)	480 ± 45 (300-600)	< 0.05
Blood loss (mL)	360 ± 52 (200-630)	390 ± 45 (300-650)	NS
Postpancreatectomy hemorrhage	4 (2.1)	1 (2.3)	NS
Postpancreatectomy fistula	9 (4.9)	2 (4.65)	NS
Delayed gastric emptying	98 (53.8)	23 (53.4)	NS
Length of hospital stay	13.6 ± 6.0	13.1 ± 5.1	NS
Mortality	3 (1.7)	1 (2.3)	NS
Positive margin	13 (7.1)	3 (6.9)	NS
Lymph node yield	12 ± 4	12 ± 5	NS

ligation which did not result in any ischemia of the liver; following an intraoperative Doppler confirmation, no reconstruction was undertaken. In one patient, the replaced right hepatic artery was resected for oncological reasons and a primary anastomosis was performed. Apart from an increase in operating time by approximately an hour, there were no other significant differences in intraoperative variables between the two groups (Table 5). There were also no differences in the overall rates of postpancreatectomy hemorrhage, postpancreatectomy fistula, delayed gastric emptying, positive resection margin, length of hospital stay and mortality between the two groups (Table 5). Seven point one percent of the patients undergoing PD had positive resection margins, 10 of them with their SMA margin positive for tumor. None of the arterial margins were positive for tumor (Table 5).

DISCUSSION

The significance of the aberrant arterial anatomy is enormous during surgery, especially PD. The artery could necessitate altering the surgical approach by interfering with the resection and/or lymphadenectomy. These anomalous vessels may interfere with reconstruction of the pancreatic remnant, precluding safe pancreatic stump drainage. Aberrant anatomy increases the risk of injury to the hepatic arterial supply, leading to unexpected bleeding (intra- or postoperative) and ischemia[1,5,7,9-11]. The extrahepatic biliary tree receives a substantial portion of its blood supply from the RHA. Any ischemia secondary to hepatic artery injury will lead to ischemia of the biliary anastomosis, resulting in a biliary anastomotic leak. Ischemic liver dysfunction may also manifest in the form of elevations in hepatic enzymes[1,5,7,9,10]. During dissection of these arteries, excessive handling of the vessel should be avoided as it may damage the vessel adventitia, thereby increasing the chances of pseudoaneurysm. This can lead to catastrophic complications in the event of pancreatic anastomotic leak[1,5,7,10,11].

A precise knowledge of normal hepatic arterial anatomy is necessary to appreciate abnormal anatomy. Preoperative imaging can detect up to 60%-80% of all arterial anomalies. If the anomaly is detected preoperatively, embolization of the vessel can be performed with microcoils[12-14]. It also helps to forewarn the surgeon, thereby preventing inadvertent injury to the RHA[1,7]. Multidetector row computed tomography (CT) (MDCT) scan shows enhanced delineation of the pancreatic lesion and vascular structures along with the benefit of CT angiography in preoperative delineation of the arterial anatomy[4,15]. A visceral angiography is recommended only when very rare or complex visceral arterial anomalies are encountered on noninvasive imaging[15,16]. Although advance planning is ideal, extemporaneous decisions may be required intraoperatively[1,7,10,11]. In our series, imaging picked up the anomalies preoperatively in 58% of the cases. Interestingly, Perwaiz *et al*[11] have shown that the duration of the surgery did not differ significantly between those patients whose arterial anomalies were detected preoperatively compared to those detected intraoperatively. A recent study from The Netherlands has shown that preservation of an aRHA is technically possible in most patients and does not negatively impact on outcomes in patients undergoing PD. Surgical morbidity is also not higher in patients with an aRHA[6]. Another study, a series from India, has shown that while oncological outcomes and safety of the procedure are not compromised, there is an increased operative complexity[11]. This is in concurrence with our study results. A report by Jah *et al*[17] showed a trend towards prolonged operative

times and blood loss but these did not reach statistical significance. This is mirrored in a study by Yang *et al*[18], whose incidence of postoperative complications, operating time and blood loss is similar to ours.

Prevention of the injury is the best policy. Hence, an early step in every PD should be a conscious attempt to define the vascular anatomy. After a complete kocherisation and opening of the pars flaccida, the porta hepatis should be palpated to determine the location of the arterial pulsation[1,5,7,10,11,19-24]. Any variation in the normal location of the proper hepatic artery pulsations should raise the suspicion of an aberrant artery. Performing intraoperative liver Doppler ultrasonography is recommended to ensure the results of the arterial sacrifice or reconstruction and to prevent postoperative complications[1,5,7,10,11,25,26]. Surgical expertise is a key factor in reducing morbidity so these patients should be managed in high volume centers where arterial reconstructions are routinely performed[19,27].

An all-important factor in the management of vascular anomalies is its recognition. There are multiple approaches to deal with an anomalous vessel interfering with the pancreatic resection. These include avoidance, ligation, dissection and traction away from the site of dissection, and division and anastomosis. Preservation is technically possible in most patients; this increases the operative complexity but does not negatively affect the safety or oncological outcomes of the procedure. A high index of suspicion in every patient along with an awareness of the normal and aberrant anatomy is a sine qua non to the performance of a safe pancreaticoduodenectomy.

COMMENTS

Background

An aberrant right hepatic artery (aRHA) is the most frequently encountered vascular anomaly during pancreatoduodenectomy (PD) which necessitates control of various arcades of the upper gastrointestinal tract. When an aRHA is present, the challenge in peripancreatic malignant disease is to balance its preservation and the need to achieve oncological clearance which represents the only chance for prolonged survival. The presence of an aRHA leads not only to an alteration in the surgical approach, but may also adversely affect the outcomes of the surgical procedure. This study was performed to analyze the differences in outcomes and the clinical impact following PD in patients with and without aRHA.

Research frontiers

Although well described in the literature, the surgical anatomy of the hepatic arteries is notoriously variable. Appreciation and study of hepatic arterial anatomical variability is essential for the successful performance of complex pancreaticobiliary procedures, such as the PD. Although anatomically interesting, the presence of aberrant hepatic arterial anatomy raises the surgical complexity and increases the potential risk of injury to the hepatic arterial supply during a PD.

Innovations and breakthroughs

There are multiple approaches to deal with an anomalous vessel interfering with the pancreatic resection. These include avoidance, ligation, dissection and traction away from the site of dissection, and division and anastomosis. Preservation is technically possible in most patients; this increases the operative complexity in the form of operating time but does not negatively affect the safety or oncological outcomes of the procedure.

Applications

An all-important factor in the management of vascular anomalies is its recognition. A high index of suspicion in every patient along with an awareness of the normal and aberrant anatomy is a sine qua non to the performance of a safe pancreaticoduodenectomy.

Terminology

The term anomalous or aberrant artery encompasses both the "accessory" and the "replaced" vessels. An extra right hepatic artery that supplies the liver, which also receives blood supply from a normally located right hepatic artery, is termed an accessory right hepatic artery. If the liver receives its primary blood supply from the aberrant right hepatic artery, it is called a replaced hepatic artery.

Peer review

This is a brief article that analyzed 225 patients who had a pancreaticoduodenectomy during the last 5 years. The content is interesting and it implies that aberrant right hepatic artery can be handled with no adverse consequences when treated in high volume centers.

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