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MDCT Angiographic Evaluation of Celiac Axis, Common Heaptic Artery And its Branches

KEYWORDS: Multidetector Computed Tomography, Celiac Axis, Common Hepatic Artery, Right Hepatic Artery, Left Hepatic Artery, Volume Rendered

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ABSTRACT *Purpose of the study is to identify and evaluate the spectrum and prevalence of celiac axis (CA) and common hepatic artery (CHA) variations by using MDCT.*

Materials and Methods: A retrospective review of multidetector computerised tomographic (MDCT) angiography scan of patients sent for various liver and abdominal pathologies between July 2015 and December 2015 was performed. CHA, ambiguous celiac axis, course and divisions of CHA, replaced hepatic artery, accessory hepatic artery and middle hepatic artery were analysed based on the definitions proposed by Song et al.(1), Convey et al.(2) and Wang et al.(3). The patterns of aortic origin of celiac axis, common hepatic artery and its branches were analysed.

Results: Six types of anatomic variations of celiac axis were identified. A total of 270 out of 300 patients had a normal celiac axis anatomy. Anatomic variations were seen in 10% patients. Ambiguous anatomy was observed in 2.66% patients. 92.6% patients have CHA originated from celiac axis. Variations of origin of CHA were seen 7.4% cases. Normal suprapancreatic preportal course of CHA was seen in 94.23%, transpancreatic preportal in 2.03%, suprapancreatic retroportal in 1.69%, infrapancreatic preportal in 1.33% and infrapancreatic retroportal in 0.67% of the patients. Normal origin of right hepatic artery(RHA) from HAP was seen in 86%. Replaced origin of RHA was seen in 14% patients. Accessory origin of RHA was seen in 0.33% patients. Normal origin of Left hepatic artery (LHA) from HAP was seen in 83.66% patients. Replaced origin of LHA was seen in 16.33% patients. Accessory origin of LHA was seen in 1% patients. Middle hepatic artery (MHA) originated from RHA in 40% cases, LHA in 27.3% cases and CHA in 6% cases. Origin of MHA could not be defined in 26.6% cases. GDA (Gastroduodenal artery) originated from CHA in 97% cases, from celiac axis in 0.66% cases, from SMA in 1.33% cases and from LHA in 0.66% cases. Origin of GDA could not be defined in 0.33% cases.

Conclusion: CT Angiography is highly sensitive and accurate modality for the evaluation of arterial anatomy and its variants.

INTRODUCTION:

Because of the development of interventional techniques in the management of hepatic tumours and liver transplantation, the accurate depiction and definition of the celiac trunk and its branches have significant implications. With the recent advent of CT technology, MDCT has become a valuable tool for the analysis of celiac trunk and its branches. Reformatted three dimensional MDCT images allow detailed analysis of complex vascular anatomy.

The aim of the present study is to illustrate the normal anatomy and variations of celiac trunk, common hepatic artery and its branches by using MDCT.

Knowledge of anatomy and anatomical variants of celiac axis, common hepatic artery and its branches is prerequisite for effective interventional procedures or surgery for hepatobiliary and pancreatic malignancies.

In his 1955 text, Michels[4] described classification scheme for describing anatomic variation in the hepatic arterial blood supply based on the results of dissecting 200 cadavers.

In 1969, Vandamme et al.[5] published their experiences of hepatic arterial anomalies with 156 postmortem angiograms.

In 1971, Suzuki et al.[6] published an article on the anatomic variants of hepatic artery in 200 patients based on angiography.

In 2002, Anne M. Convey contributed an article on hepatic arterial anatomy and its variants in 600 patients on angiography. Visceral angiography is an essential part of preoperative evaluation for some hepatobiliary surgeries and many interventional procedures. Preoperative knowledge of hepatic vascular anatomy and variants is mandatory for surgical planning and to help reduce post operative complications in both the donor and recipients.[2]

In 2010, Song et al., published an extensive series of their work in celiac axis and hepatic artery variations of 5002 patients.[1]

3 DCT angiography is as accurate as conventional angiography in the assessment of arterial supply to the liver in preoperative evaluation of patients of hepatic tumours and

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liver transplantation.[7]

MATERIAL AND METHODS:
Institutional ethics committee approval was obtained. MDCT abdominal angiography scans were reviewed in patients sent for various liver and abdominal pathologies in which biphasic contrast enhanced CT scan was done. Study period is from July 2015 to December 2015.A total of 300 patients were evaluated. The study population comprised 155 men and 145 women. (Mean age is 41 years).The present study excluded patients with a history of major upper abdominal surgery.

CT EXAMINATION PROTOCOL:
MDCT Angiography was performed on GE (General Electrical systems) Bright Speed 16 slice, after injecting a maximum of 120ml of non ionic iodinated contrast material (Iodine concentration of 370 mg/dl) through 18-20 gauge antecubital intravenous cannula at the rate of 5-7ml/sec. Imaging was done in arterial and venous phase. Scan delay for arterial phase is 20-25 sec after the start of the bolus injection. Scanning was automatically triggered at 125 HU in the Aorta at the celiac axis and 1-2mm thick sections were obtained. Imaging was done at 120-140 kVp and 200-280 mA in arterial and venous phase. Venous phase is 60-65 sec after the start of the bolus injection. Image reconstruction thickness is 1-2mm with 50% overlap.

IMAGE INTERPRETATION:
The raw data obtained from MDCT were processed on work station for multiplanar reconstruction and 3D reconstruction with maximum intensity projection (MIP) and volume rendering (VR). Abbreviations used in the study are listed in Table 1. Analysis of the origin of CA, CHA, SpA, LGA and SMA were done apart from the origin of RH, LH, MHA and GDA. The course and relationship of CHA to head and uncinate process of pancreas and portal vein was analysed. The key definitions described by various authors for evaluating these arterie used in the present study are outlined as follows.

KEY DEFINITIONS:
*Typical celiac axis[1] : Arterial trunk that gives rise to the common hepatic, left gastric and splenic arteries.

*CHA[4]: Artery giving rise to RHA or LHA and the GDA, irrespective of its origin and course.

*Ambiguous celiac axis[1]: Congenital absence CHA or congenital presence of an anastomotic channel connecting the celiac axis and superior mesenteric artery SMA or anastomotic channel connecting the CHA to the celiac axis and the SMA.

*Replaced[1]: Replaced origin of hepatic arteries refers to the arterial blood supply from an ectopic location.

*Accessory[1]: Accessory origin of hepatic arteries refers to the arterial blood supply from typical as well as ectopic location.

*Suprapancreatic[1]: CHA running along the upper border of pancreas.

*Transpancreatic[1]: CHA running through pancreatic parenchyma.

*Infrapnacreatic[1]: CHA coursing inferior to head and uncinate process of pancreas.

*Preportal[1]: Hepatic artery anterior to main portal vein.

*Retroportal[1]: Hepatic artery posterior to main portal vein.

*MHA[3]: Hilar artery that primarily supplies hepatic segment 4.

RESULTS:
Celiac axis variations:
A total of 270 (90%) out of 300 patients had a normal celiac axis anatomy i.e hepatogastrosplenic trunk and SMA originating separately from the aorta.

Six types of celiac axis anatomic variations were identified in our study (Table 2). These were seen in 30 (10%) of the patients. Ambiguous anatomy was seen in 8 patients (2.66%).

CHA Variations:
CHA originated from celiac axis in 278 (92.66%) patients. Variations in the anatomic origin of CHA were seen in nine patients (origin from SMA in seven and from aorta in two patients). Hepatomesenteric trunk was seen in 8 (2.66%) patients. No CHA was seen in 5 patients.

Normal suprapancreatic (Sp) preportal course of CHA was identified in 278(94.23%) cases. Sp retroportal in 5 (1.69%) transpancreatic preportal in 6 (2.03%), Infrapancreatic preportal in 4 (1.33%) and infra pancreatic retroportal in 2 (0.67%) patients.

RHA, LHA, MHA and GDA variations:
Normal origin of RHA from hepatic artery proper (HAP) was seen in 258(86%) patients. Replaced origin of RHA was seen in 42 (14%) patients and accessory origin of RHA was seen in 1(0.33%) patient. LHA originated from HAP in 251 (83.66%) patients. Replaced origin of LHA was seen in 49 (16.33%) patients and accessory origin of LHA was seen in 3 (1%) patients. MHA originated from RHA, LHA and CHA in 120 (40%), 82 (27.3%) and 18 (6%) patients respectively. Origin of MHA could not be defined in 80 (26.6%) patients. GDA originated from CHA, celiac axis, SMA and LHA in 292 (97.3%), 2 (0.66%), 4 (1.33%) and 2 (0.66%) respectively. GDA not seen in 1 (0.33%) patients.

DISCUSSION:
By using clear definitions regarding the origin and course of these vessels as already mentioned, we performed systematic analysis of CT angiography images and was performed to identify and classify the spectrum of celiac axis, CHA, RH,MH,LH and GDA variations. Regarding the embryonic development of the celiac axis and the SMA, Trandler et al.[8] stated that four primitive ventral branches arise from abdominal aorta during early embryogenesis and the branches would be interconnected by anastomotic channel. Regression or continuous growth of these primitive vascular channels lead to the development of variations of celiac axis and SMA .According to this hypothesis, 15 variations are possible[9] and six of these 15 types were found in this study. According to Michels[4], the prevalence of a normal celiac axis anatomy is 89%.In our study, normal celiac axis anatomy was seen in 90% of the cases. The most common anatomic variation was of hepatosplenic trunk with separately originating LGA and SMA(3.33%).This result was consistent with the results obtained by Song et al . The next most common anatomic variation in our study was gastrosplenic and a common hepatomesentric trunk (2.66%) which is again similar to Song et al. study. Ambiguous anatomy of celiac axis has the same incidence as GSP+HM variant (2.6%).This variation was more frequently seen in our study

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as compared to Song et al. Ambiguous anatomy due to absent CHA was seen in 5 patients and due to anastomotic channel was seen in 3 patients. This anastomotic channel (Arc of Buchler) is a remnant of a ventral anastomosis that inter connects embryonic ventral segmental arteries.[8,10,11]

Normal CHA origin was seen in 278 (92.66%) patients. Normal supra pancreatic preportal course of CHA was seen in 278 (94.23%) patients. SMA has been known as the most common origin site of a variant CHA. In the present study also similar results were found with seven cases of CHA arising from SMA. The CHA after arising from the SMA has pathways relative to the head and uncinate process of pancreas- supra, trans, infra pancreatic courses as described by Song et al. The suprapancreatic and retroportal course was most common type of variant of CHA arising from SMA. Out of these seven cases, five were CHA originating from SMA with Sp- retroportal course, one with Tp- preportal course and the other with infrapancreatic preportal course. A separate origin of CHA from aorta is a rare variation and prevalence of this variation in this study was only 0.66%.The reported prevalence of this anomaly in Song et al. is 0.22% and in two previous dissection studies were 0.2% and 0.7% respectively.[12,13] All variant CHAs arising from the aorta had a normal pathway along a suprapancreatic preportal course.

RHA origin from HAP was seen in 258 (86%) patients. Replaced origin of RHA was seen in 42 (14%) patients. Most common site of origin of replaced RHA was from SMA (12%) followed by celiac axis (1.33%) and then from Aorta (0.33%) and LGA (0.33%). Accessory origin of RHA was seen in 0.33% cases and that was from SMA. LHA origin from HAP was seen in 251 (83.66%) patients. Replaced origin of LHA was seen in 49 (16.33%) patients. Most common site of origin of LHA was from LGA (16%), followed by celiac axis (0.33%). Accessory origin of LHA was seen in 1% cases with all of them arising from LGA in our study. In our study, all replaced and accessory LHA had course through ligamentum venosum and RHA had retroportal course.

Michels[14] characterised the MHA as an artery in the umbilical fossa that supplies the segment 4. In our study MHA originated from RHA in 120 (40%) patients, from LHA in 82 (27.3%) and from HAP in 18 (6%) patients. In case of replaced LHA origin, the most common site of origin of MHA was from RHA. In case of replaced RHA origin most common site of origin of MHA was from LHA.

Normal origin of GDA was seen in 291(97%) cases. In two cases, GDA origin was directly from celiac axis (0.66%) and in four cases from SMA (1.33%) and in two cases from LHA (0.66%). GDA was not defined in one case (0.33%).

In advanced interventional procedures like Transcatheter Arterial Chemoembolisation (TACE), Trans arterial Radionuclide therapy(TART) and placement of infusion pumps, the anatomic variations have significant relevance. Catheters are generally positioned in the HAP to infuse both hepatic arteries. In case of anatomic variations an alternate catheter position or more than one catheter must be taken into consideration preoperatively for adequate tumour infusion.[15,16]

In live donor transplantation, right lobe of liver is resected and the left lobe is left behind in living adult donors. But in children, the left lobe is resected. Hepatic arterial variants that are important in donors are MHA arising from the RHA, as the hepatectomy plane would cut this artery, which may lead to a reduction in the functional volume of left hepatic lobe and a decrease in the blood supply to the bile ducts of this lobe. Other arterial variations significant in donors are trifurcation of CHA and early branching of RHA/LHA. Arterial variants that are important for recipients are short RHA, Celiac axis stenosis, replaced RHA/LHA and a replaced hepatic trunk from SMA, as these variations increase complexity during the surgery. MHA variants are not of significance in recipients as their entire liver is resected.

Small caliber CHA frequently co exists with variant hepatic arterial anatomy. Post transplantation hepatic artery complications like stenosis and thrombosis are more common in variant hepatic artery anatomy due to co existing small caliber of CHA in these patients.[17]

Knowledge of anatomic variations before the surgery would help surgeons to avoid extensive dissection and vascular damage. Information about the presence or absence of replaced RHA is necessary for carcinoma head/uncinate process of pancreas surgeries as hepatic necrosis is common in these patients, if artery is injured[18]. Replaced RHA origin from aorta or celiac axis and anomalous course of CHA are more prone for iatrogenic injury.

CONCLUSION:

Multidetector CT Angiography provides excellent delineation of celiac and hepatic arterial anatomy and variants which is necessary in pancreatic and hepatobiliary surgeries.

Some of the limitations in our study were that, it was retrospective in nature and as it was based on analysis of CT images, fine arterial network analysis was beyond the resolution of CT.

This study was not assessed on the interventional and surgical procedures by us.

In present scenario, CT Angiographic preoperative evaluation of arteries is necessary before hepatobiliary, pancreatic surgeries and interventional procedures to prevent life threatening complications.

Table 1: Abbreviations used in this study

Abbreviation	Description
CHA	Common hepatic artery
HAP	Hepatic artery proper
SMA	Superior mesenteric artery
LGA	Left gastric artery
RHA	Right hepatic artery
LHA	Left hepatic artery
MHA	Middle hepatic artery
GDA	Gastroduodennal artery
SpA	Splenic artery
HM trunk	Hepatomesenteric trunk
HSptrunk	Hepatosplenic trunk
GSp trunk	Gastrosplenic trunk
CM trunk	Celiacomesenteric trunk
HSpM trunk	Hepatosplenomesenteric trunk
Sp	Suprapancreatic
Tp	Transpancreatic
Ip	Infrapancreatic

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Table2: Celiac axis variations in 300 patients

Celiac axis anatomy type	No. of patients (N=300)
Normal anatomy	270(90%)
Anatomic variation	30(10%)
HSp+LG+SMA	10(3.33%)
GSp+CH+SMA	2(0.66%)
GH+Sp+SMA	1(0.33%)
CM trunk	1(0.33%)
GSp+HM	8(2.66%)
Ambiguous anatomy	8(2.66%)

Normal anatomy refers to hepatogastrosplenic trunk plus SMA. All other abbreviations are expanded in Table 1.

Table 3: CHA anatomy and course in 300 patients

CHA origin	No of patients (n=300)	Course of CHA	No of patients (n=295)
Celiac axis	278(92.66%)	Normal Sp-preportal	278 (94.23%)
SMA	7(2.33%)	Sp-retroportal	5(1.69%)
Aorta	2(0.66%)	Tp preportal	6(2.03%)
Ambiguous: HM trunk	8(2.66%)	Ip-preportal	4(1.33%)
Absent CHA	5(1.66%)	Ip- retroportal	2(0.67%)

Table 4: RHA, LHA, GDA, and MHA origins

RHA, LHA, GDA and MHA origins	No. of Patients (N=300)
RHA origin	
HAP	258(86%)
Replaced	42(14%)
SMA	36(12%)
Celiac axis	4(1.33%)
Aorta	1 (0.33%)
LGA	1 (0.33%)
Accessory	1(0.33%)
SMA	1(0.33%)
LHA origin	
HAP	251 (83.66%)
Replaced	49 (16.33%)
LGA	48(16%)
Celiac axis	1(0.33%)
Accessory	3(1%)
GDA origin	
CHA	291(97%)
Celiac axis	2(0.66%)
LHA	2 (0.66%)
SMA	4 (1.33%)
Not defined	1(0.33%)
MHA origin	
RHA	120(40%)
LHA	82(27.3%)
CHA	18(6%)
Not defined	80(26.6%)

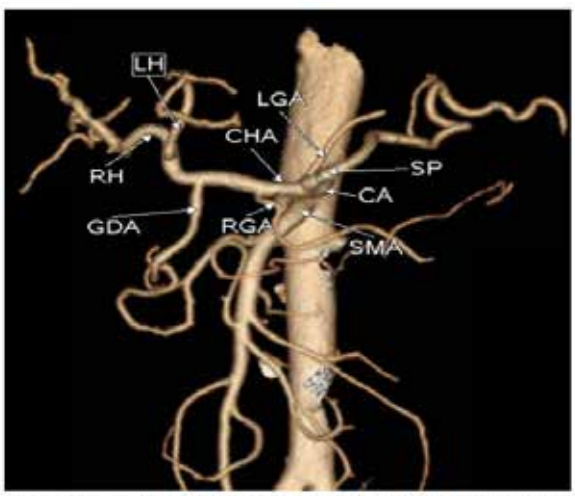

Fig 1: VR image shows normal Celiac axis Anatomy

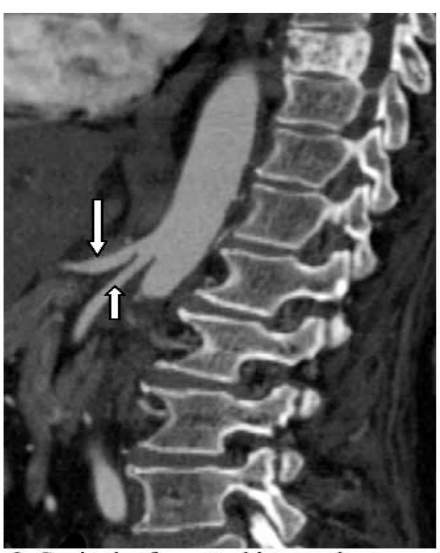
Fig 2: Sagittal reformatted image shows common

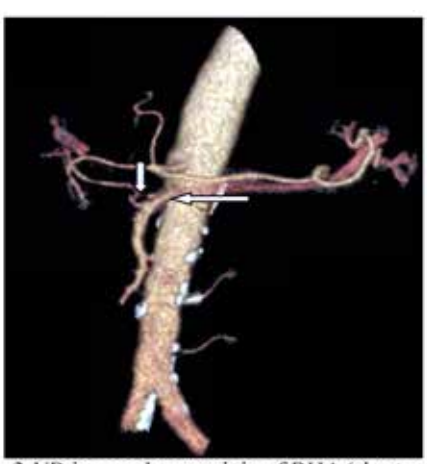
Fig 3: VR image shows origin of RHA (short arrow) from SMA(long arrow)

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Fig 4: VR image shows origin of LGA (arrow) from Aorta.

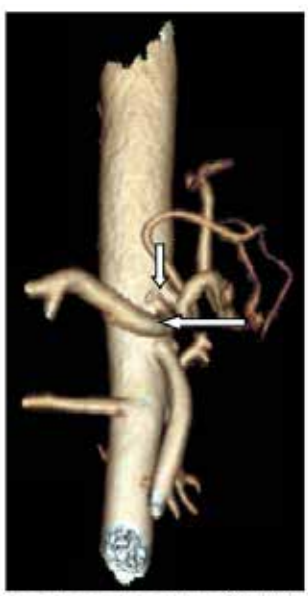

Fig 5: VR image shows the origin of CHA (long arrow) from Aorta (short arrow shows origin of GSP trunk.

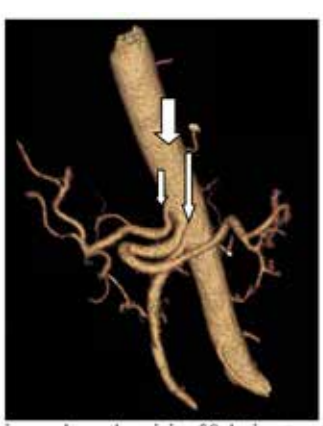

Fig 6: VR image shows the origin of Splenic artery (long arrow) from Aorta (large arrow).short arrow shows the origin of hepatogastric trunk.

Fig7: VR image shows the origin of RHA (short arrow) from CA (long arrow)

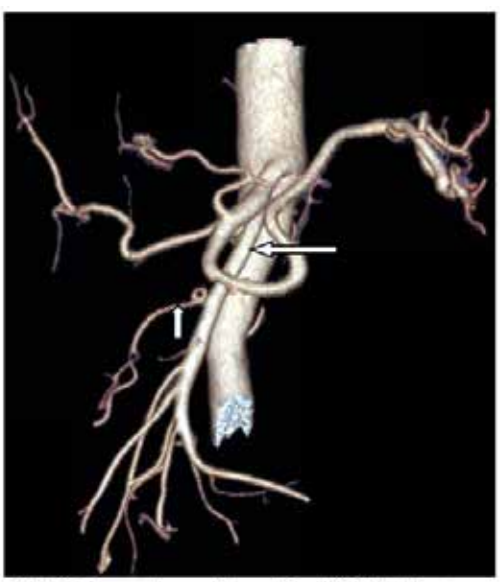

Fig 8: VR image shows the origin of GDA(short arrow) from SMA(long arrow) with absent CHA

Fig 9: VR image shows origin of GDA (Small arrow) from CA and origin of RHA (curved arrow) from SMA (Long arrow)

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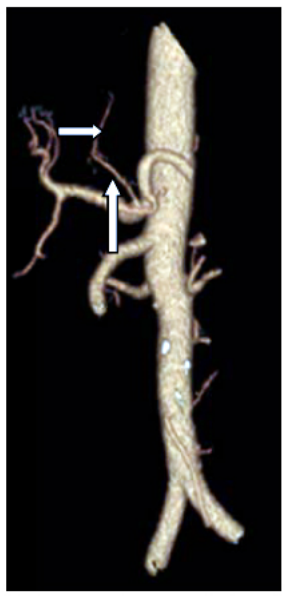

Fig 10: VR image shows origin of Accessory LHA (small arrow) from LGA (long arrow)

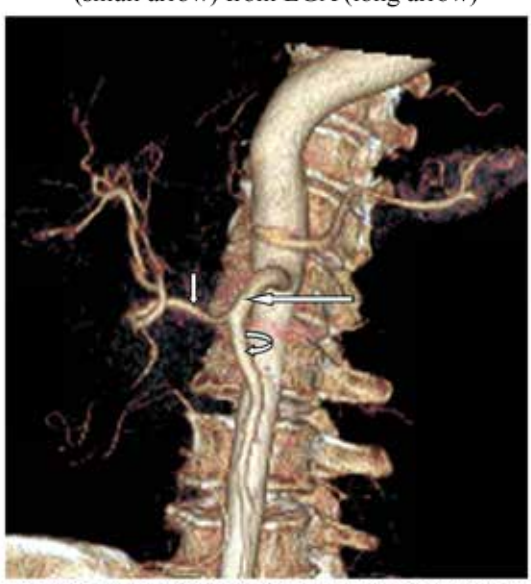

Fig 11: VR image shows hepatomesenteric trunk (long arrow) from aorta. CHA (short arrow) and SMA(curved arrow).

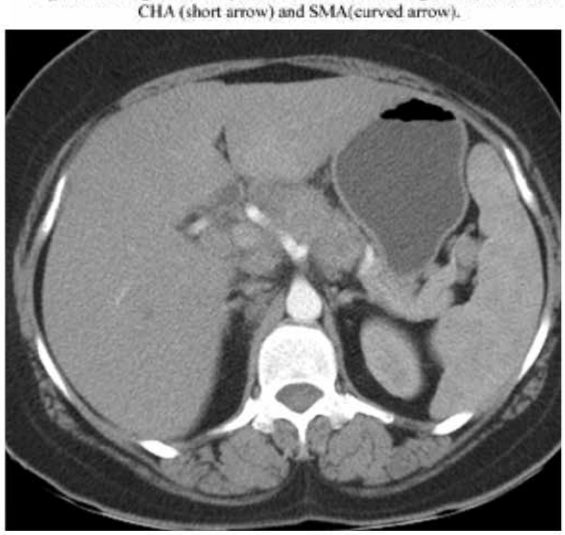

Fig12: CT axial image shows intrapancreatic course of CHA

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