Anatomical Variations of Celiac Trunk: An Angiographic Study

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Abstract

Background: Anatomical variations of the hepatic arteries and celiac trunk are of considerable importance in liver transplants, laparoscopic surgery, radiological abdominal interventions and penetrating injuries to the abdomen. Understanding and classifying the variations in CTA is imperative in view of its relevance in various clinical and surgical cases. Knowledge of the existence of variations in the hepatic arteries is useful for planning and conducting surgical or radiological procedures of the upper abdomen. It is important during biliary tract operations, liver transplants, chemo-embolization of a liver neoplasm.

Objective: The purpose of this study is to examine the anatomical variations that occur in the celiac trunk and its branches using multidetector CT (MDCT) and dissecting cadavers as well as assess prevalence of the different variations in the Egyptian population.

Patient and Methods: This is a retrospective study carried out in Cairo university hospital and private radiology center from August 2013 to May 2015. It included 12 adult cadavers done at the Department of Anatomy of Cairo university hospital and 131 adult patients underwent abdominal dynamic enhanced MDCT and angiography at Radiology Department of Cairo University hospital.

Results: Out of 143 cases, 97 cases (67.8%) showed the classic trifurcation of the celiac trunk without any anatomical variations; sixty males and thirty seven females. Statistical analysis showed insignificant difference between both sexes. The most frequent variations of the branches of the celiac trunk observed in this study was right hepatic artery from superior mesenteric artery (12.6%), while the least common variations observed were the common hepatic artery from superior mesenteric artery and left hepatic artery from celiac trunk (1.4%).

Conclusion: Anatomical variations of the celiac trunk are not infrequent and are of considerable importance in liver transplants, laparoscopic surgery, radiological abdominal interventions and penetrating injuries to the abdomen. Reformatted three-dimensional MDCT images allow detailed visualization of the complex vascular anatomy. Therefore, small vessel abnormalities may be detected with greater frequency in symptomatic and asymptomatic patients using these techniques.

Key Words: Celiac trunk – Variation – CTA.

Introduction

GREAT variability in the vasculature of the abdominal organs makes the pre-operative evaluation of arterial anatomical conditions extremely important and helpful. Evaluation of arteries branching from the abdominal aorta (the level of their divergence, presence of atypical variants of a common origin of arteries or presence of additional arteries) plays an important role in the diagnostics of many abdominal disorders. Nowadays, it is possible owing to a minimally invasive examination-multidetector computed tomography angiography [1].

The celiac trunk and the superior mesenteric artery are accepted as the most important ventral visceral branches of the abdominal aorta with regard to their vascularization field [2].

The celiac trunk is the first ventral branch of the abdominal aorta and it arises just below the aortic hiatus, at the level of the T 12-L 1 vertebra. It passes almost horizontally forwards and divides into the left gastric, the common hepatic and the splenic arteries [3].

Anatomical variations of the celiac trunk are not infrequent and have been described in many earlier studies. These vascular variations are due to unusual embryological development of the ventral splanchnic branches of aorta [4].

Anatomical variations of the hepatic arteries and celiac trunk are of considerable importance in liver transplants, laparoscopic surgery, radiological...
abdominal interventions and penetrating injuries to the abdomen [5].

Understanding and classifying the variations in CTA is imperative in view of its relevance in various clinical and surgical cases. Knowledge of the existence of variations in the hepatic arteries is useful for planning and conducting surgical or radiological procedures of the upper abdomen. It is important during biliary tract operations, liver transplants, chemo-embolization of a liver neoplasm [6,7].

With the recent advent of CT technology, multidetector-row CT (MDCT) has become a valuable tool for the visualization of the celiac trunk and its branches. Moreover, reformatted three-dimensional MDCT images allow detailed visualization of the complex vascular anatomy. Therefore, small vessel abnormalities may be detected with greater frequency in symptomatic and asymptomatic patients using these techniques [8].

The aim of the present study was to assess anatomical variations that occur in the celiac trunk and its branches using multidetector CT (MDCT) and dissecting cadavers as well as assess prevalence of the different variations in the Egyptian population.

**Material and Methods**

In the present work, two different samples have been analysed: Cadaveric and radiological.

**Cadaveric sample:**

We examined the celiac axis and its branches by dissection in 12 adult cadavers at the Department of Anatomy at Cairo University, (August 2013 and May 2015). There were 8 male and 4 female cadavers.

**Radiological sample:**

This study included one hundred and thirty one patients who were referred to the Radiology Department of Cairo University Hospital between August 2013 and May 2015 and underwent abdominal MDCT angiography. Data obtained during the arterial phase were used to evaluate the anatomy as well as the origin of the celiac axis and its major branches. Exclusion criteria applied were the presence of any condition likely to affect normal vascular anatomy.

**MDCT examinations:**

Abdominal CT was performed using two MDCT systems, a 64-row (GE Healthcare, Milwaukee, WI, USA), and a 256-slice system (Philips Healthcare, Cleveland, OH, USA).

MDCT coverage extended from the dome of the diaphragm to the inferior margin of the right kidney. The following imaging parameters were applied to 64-row and 256-slice MDCT systems: Detector configurations of 64x0.625 mm or 256x0.5 mm respectively; section thickness of 0.625 or 0.5mm, respectively; reconstruction intervals of 0.625 or 0.5mm, respectively; and table speeds of 64 or 256mm per rotation, respectively.

The following were applied to all examinations:

- Pitch 0.984, matrix 512x512, field of view 180-240mm, tube voltage 120kV and tube current 300mA.

Dynamic enhanced MDCT images were obtained in a craniocaudal direction during the hepatic arterial, portal venous and equilibrium phases. A dual-head power injector was used to administer a flush of Iopromide (Ultravist; Bayer Schering Pharma, Berlin, Germany) at 370mg iodine/ml and 30ml sterile saline (0.9 % NaCl).

The contrast medium and saline solution were injected at 4ml/s through an 18-gauge plastic intravenous catheter placed in an antecubital vein. Contrast medium volumes were delivered at 2ml/kg body weight, and the upper limit of dose was set to 120ml for every patient.

Hepatic arterial phase imaging delays were 11-20s after descending aorta enhancement to 150HU, as measured by an automatic bolus-tracking technique, and portal venous phase inter-imaging delays were 20-30s after the aortic enhancement. Equilibrium phase images were acquired 180s after completion of the contrast medium administration.

**Image analysis:**

For the purposes of this study, only the data obtained during the arterial phase were downloaded onto an off-line workstation (ADW 4.3; General Electric Healthcare, Milwaukee, WI, USA) for image post-processing and analysis. We used multiplanar reformation (MPR) in three spatial planes and 3-D reformation using volume rendering (VR) and maximum intensity projection (MIP). Images were reformatted, analysed and assessed with respect to origination sites and the anatomy of the celiac axis and their major branches. In cases with discrepancy, the images were reviewed again, with careful correlation among the radiologists. The anatomy was thereby determined by majority opinion.
We analysed patterns of aortic origin for the four major arteries the left gastric artery (LGA), common hepatic artery (CHA), splenic artery (SA) and superior mesenteric artery (SMA).

**Statistical methods:**

Data was analyzed using IBM SPSS advanced statistics version 22 (SPSS Inc., Chicago, IL). Qualitative data were expressed as frequency and percentage. Chi-square test was used to examine the relation between qualitative variables. All tests were two-tailed. A $p$-value <0.05 was considered significant.

**Results**

**Cadaveric study:**

Twelve cadavers were dissected eight were male cadavers while the other four were female cadavers to study the branches of the celiac trunk. The trifurcation of the celiac trunk into the usual three branches, the left gastric artery, the common hepatic artery and the splenic artery was observed in all the specimens (Fig. 1).

**CT study:**

*The classic trifurcation of the Celiac trunk:*

Eighty five out of 131 cases studied showed the classic trifurcation of the celiac trunk in their MDCT images which shows the usual three branches, the left gastric artery, the splenic artery arising and the common hepatic artery from the celiac trunk. The common hepatic artery bifurcates into the gastro duodenal artery and the proper hepatic artery that also bifurcates into right and left hepatic arteries. Fifty two of those cases were males while thirty three cases were females (Fig. 2).

*Anatomical variations of the branches celiac trunk:*

*Common hepatic artery from superior mesenteric and left hepatic from celiac:*

The celiac axis branches into the splenic artery, left hepatic artery and left gastric artery. The common hepatic artery bifurcates into the gastro duodenal artery and the proper hepatic artery. This variation was seen in two cases both were females.

*Common hepatic artery from superior mesenteric artery:*

The celiac axis trifurcates into the splenic artery, common hepatic artery and left gastric artery. The common hepatic artery bifurcates into the gastro duodenal artery and left hepatic artery. This variation was seen in four cases all were females.

*Common hepatic artery from aorta artery:*

The celiac axis trifurcates into the splenic artery, common hepatic artery and left gastric artery. The common hepatic artery arises directly from the aorta and bifurcates into the gastro duodenal artery and right hepatic artery. This variation was seen in two cases both were males.

*Absent celiac trunk:*

The splenic artery and left gastric artery arise directly from the aorta while the common hepatic artery arises from the superior mesenteric artery and bifurcates into the gastro duodenal artery and the right hepatic artery. This variation was seen in two cases which were both females.

*Right hepatic artery from superior mesenteric artery, left hepatic from left gastric artery and gastro duodenal artery from celiac trunk:*

The celiac axis branches into the splenic artery, left gastric artery and left hepatic artery. The common hepatic artery bifurcates into the right hepatic artery while the right hepatic artery arises from the superior mesenteric artery and the left hepatic artery arises from the left gastric artery. This variation was seen in four cases all were females.

*Right hepatic artery from aorta artery:*

The celiac axis trifurcates into the splenic artery, common hepatic artery and left gastric artery. The common hepatic artery bifurcates into the gastro duodenal artery and left hepatic artery. The right hepatic artery arises directly from the aorta. This variation was seen in two cases both were males.
Anatomical Variations of Celiac Trunk

Fig. (1): A classical trifurcation of the celiac trunk in an adult male cadaver. Splenic artery (SA), left gastric artery (LGA) and common hepatic artery (CHA).

Fig. (2): VR 3D CTA showing celiac trunk trifurcates into splenic artery (SA), common hepatic artery (CHA) and left gastric artery (LGA). Common hepatic artery bifurcates into gastro duodenal artery (GDA) and proper hepatic artery. Proper hepatic artery bifurcates into left (LHA) and right hepatic arteries (RHA).

Fig. (3): VR 3D CTA showing celiac trunk branching into splenic artery (SA), left gastric artery (LGA). Common hepatic artery (CHA) arises from the superior mesenteric artery (SMA) and bifurcates into gastro duodenal artery (GDA) and proper hepatic artery. The proper hepatic artery bifurcates into left (LHA) and right hepatic arteries (RHA).

Fig. (4): VR 3D CTA showing celiac trunk branching into splenic artery (SA), common hepatic artery (CHA) and left gastric artery (LGA). The common hepatic artery bifurcates into the gastro duodenal artery (GDA) and the left hepatic artery (LHA). The right hepatic artery (RHA) arises from the superior mesenteric artery (SMA).

Fig. (5): VR 3D CTA showing celiac trunk branching into splenic artery (SA), left gastric artery (LGA). The common hepatic artery (CHA) arises directly from the aorta and bifurcates into the gastro duodenal artery (GDA) and the proper hepatic artery. The proper hepatic artery bifurcates into the left (LHA) and right hepatic arteries (RHA).

Fig. (6): VR 3D CTA showing celiac trunk branching into splenic artery (SA), left gastric artery (LGA) and gastro duodenal artery (GDA) while the right hepatic artery (RHA) arises from the superior mesenteric artery (SMA) and the left hepatic artery (LHA) arises from the left gastric artery.
**Right hepatic artery from celiac artery:** The celiac axis trifurcates into the splenic artery, common hepatic artery and left gastric artery. The common hepatic artery bifurcates into the gastro duodenal artery and left hepatic artery. The right hepatic artery arises directly from the celiac axis. This variation was seen in two cases both were males.

**Statistical results:**

Twelve cadavers and one hundred and thirty one CT scans have been studied in the present work. They were distributed into ninety males and fifty three females.

**The classic trifurcation of the celiac trunk:**

Out of 143 cases, 97 cases (67.8%) showed the classic trifurcation of the celiac trunk without any anatomical variations; sixty males and thirty seven females (Tables 1,2,3 and Chart 1,2). Statistical analysis showed insignificant difference between both sexes (Table 4).

**Anatomical Variations of the branches celiac trunk:**

Variations encountered included the common hepatic artery from superior mesenteric artery (4.2%) and common hepatic artery from aorta artery (2.8%), left hepatic artery from left gastric artery (2.8%), right hepatic artery from superior mesenteric artery, left hepatic artery from left gastric artery and gastro-duodenal from celiac trunk (2.8%).

The most frequent variations of the branches of the celiac trunk observed in this study was right hepatic artery from superior mesenteric artery (12.6%), while the least common variations observed were the common hepatic artery from superior mesenteric artery and left hepatic artery from celiac trunk (1.4%), absent celiac trunk (1.4%), right hepatic artery from aorta artery (1.4%), right hepatic artery from celiac trunk (1.4%) and median arcuate ligament syndrome (1.4%).

**Sex difference:**

Statistical study shows statistically insignificant difference between both sexes for all of the anatomical variations of the celiac trunk ($p<0.05$) (Table 4).

<table>
<thead>
<tr>
<th>Branching</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classic trifurcation</td>
<td>97</td>
<td>67.8</td>
</tr>
<tr>
<td>Common hepatic artery from Superior mesenteric and left hepatic from celiac</td>
<td>2</td>
<td>1.4</td>
</tr>
<tr>
<td>Right hepatic from superior mesenteric artery</td>
<td>18</td>
<td>12.6</td>
</tr>
<tr>
<td>Common hepatic from superior mesenteric artery</td>
<td>6</td>
<td>4.2</td>
</tr>
<tr>
<td>Common hepatic from aorta</td>
<td>4</td>
<td>2.8</td>
</tr>
<tr>
<td>Left hepatic artery from left gastric artery</td>
<td>4</td>
<td>2.8</td>
</tr>
<tr>
<td>Median arcuate ligament syndrome</td>
<td>2</td>
<td>1.4</td>
</tr>
<tr>
<td>Absent celiac trunk</td>
<td>2</td>
<td>1.4</td>
</tr>
<tr>
<td>Right hepatic from superior mesenteric left hepatic from left gastric artery and gastro duodenal from celiac</td>
<td>4</td>
<td>2.8</td>
</tr>
<tr>
<td>Right hepatic artery from aorta</td>
<td>2</td>
<td>1.4</td>
</tr>
<tr>
<td>Right hepatic from celiac artery</td>
<td>2</td>
<td>1.4</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>143</strong></td>
<td><strong>100.0</strong></td>
</tr>
</tbody>
</table>

Chart (2): Bar chart showing the frequencies of different anatomical variations of the branches of the celiac trunk.

Chart (1): Pie chart showing comparison between the frequency of classic trifurcation to the frequency of the anatomical variations of the branches of the celiac trunk.

Table (1): The frequencies of different anatomical variations of the branches of the celiac trunk.
Table (2): Comparison between the frequency of classic trifurcation to the frequency of the anatomical variations of the branches of the celiac trunk.

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Percent</th>
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<tbody>
<tr>
<td>Classic</td>
<td>97</td>
</tr>
<tr>
<td>Variation</td>
<td>46</td>
</tr>
<tr>
<td>Total</td>
<td>143</td>
</tr>
</tbody>
</table>

Table (3): Comparison between the frequency of classic trifurcation to the frequency of the anatomical variations of the branches of the celiac trunk in relation to gender.

<table>
<thead>
<tr>
<th>Gender</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Classic:</td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>60</td>
</tr>
<tr>
<td>% within Gender</td>
<td>66.7%</td>
</tr>
<tr>
<td>Variation:</td>
<td></td>
</tr>
<tr>
<td>Count</td>
<td>30</td>
</tr>
<tr>
<td>% within Gender</td>
<td>33.3%</td>
</tr>
<tr>
<td>Total:</td>
<td>Count</td>
</tr>
<tr>
<td>% within Gender</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Table (4): Statistical analysis for the sex difference in cases with variations of the branches of the celiac trunk (Chi-Square Tests).

<table>
<thead>
<tr>
<th>Value</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>.151</td>
</tr>
</tbody>
</table>

*p-value is considered significant if ≤0.05.

Discussion

This study was designed to assess the different anatomical variations of the branches of the celiac trunk by studying one hundred and thirty one CT scans and twelve cadavers.

The most common classical type of celiac trunk is known as trifurcation and was first observed by Haller as tripus Halleri [9]. It was, and still is, considered to be the normal appearance of a celiac trunk. According to Haller, the celiac trunk is divided into the common hepatic artery, splenic artery and left gastric artery [9].

The present study detected the classic trifurcation of the celiac trunk in (67.8%) of the cases which is the most common pattern of branching of the celiac trunk. This comes in accordance with all of the studies which reported that the classic trifurcation of the celiac trunk is the most common anatomical variation [10] observed the celiac trunk in one forty three dissected cadavers found the classic trifurcation in (90.5%) of the cases he studied [11] investigated 5,002 MDCT angiographies found the classic trifurcation of the celiac trunk in (89.1%) of the cases he studied.

Anatomical variations of the celiac trunk were first classified by Adachi in 1928, based on 252 dissections of Japanese cadavers, where six types of divisions of the celiac trunk and superior mesenteric artery were described [12].

As revealed in the present work the most common variation was the right hepatic artery originating from the superior mesenteric artery as it represented (12.6%) of the studied cases. This supports the findings of [13] the right hepatic artery (RHA) branching off the superior mesenteric artery in (11.9%) of the cases that were studied on a total of 604 celiac angiographies. [14] found the RHA arising from SMA was detected in (10.13%) of the studied cases. On the other hand [15] found a low percentage of this variation in his study as he found only (3.1%). The replaced right hepatic artery or an accessory right hepatic artery run behind the portal vein and bile duct in the lesser omentum and can be identified at surgery by pulsation behind the portal vein. The accessory right hepatic artery may be injured during resections of the pancreatic head because the artery lies in close proximity to the portal vein [3].

Out of 143 cases studied from CT scans and cadavers in the present work, the common hepatic artery originating from superior mesenteric artery was detected in 6 cases (4.2%). These findings are consistent with that reported by [16] as he found that the common hepatic artery arising from the superior mesenteric artery were observed in (6.6%) of patients studied. On the other hand [17] mentioned that (0.86%) of the 701 cases he studied showed the common hepatic artery originating from the superior mesenteric artery.

In the present study the common hepatic artery originating directly from the aorta was detected in 4 cases (2.8%). This is consistent with the results achieved by [18] who found that (1.3%) show the common hepatic artery arising as a separate trunk from the aorta. However [19] mentioned that this variation was only in (0.33%) of the case he observed.

Regarding the variation where the left hepatic artery arises from the left gastric artery, the current study detected this variation in (2.8%) of the studied cases, the result of the present work is in agreement with the results of [13] who found an aberrant left
hepatic artery (LHA) arising from the left gastric artery in (3.0%) of his cases. On the other hand, [19] who carried his study on 600 MDCT angiographies found that the left hepatic artery originating from the left gastric artery represented (10.46%) of the cases studied. This vessel provides a source of collateral arterial circulation in cases of occlusion of the vessels in the porta hepatitis but may also be injured during mobilization of the stomach as it lies in the upper portion of the lesser omentum [3].

The present study revealed that the incidence of the absent celiac artery variation was (1.4%). This is consistent with the results achieved by [20] that reported the absence of the celiac trunk in (2.6%) of the 77 cadavers he dissected. Comparable result was reported by [21] who mentioned after studying 524 MDCT angiographies of the abdominal aorta that the celiac trunk was absent in (0.6%) of these cases. However [10] although he mentioned the absent celiac trunk variation the number of cases he found with this variation were (0%).

In the present study the right hepatic artery originating directly from the aorta was detected in two cases (1.4%). The result of the present work is in agreement with the results of [22] who found this variation in (1%) of the 100 MDCT angiographies he studied. However [21] mentioned this variation was present in (0.2%) after studying 524 MDCT angiographies of the abdominal aorta.

The current study detected that the right hepatic artery originating from the celiac trunk directly was in (1.4%) of the cases. This is consistent with the results achieved by [19] mentioned after studying 600 MDCT angiographies that the same variation was (1%) in his study. Comparable result was reported by [23] as he found this variation in (2.4%) of the cases studied.

Conclusion:

Anatomical variations of the celiac trunk are not infrequent and are of considerable importance in liver transplants, laparoscopic surgery, radiological abdominal interventions and penetrating injuries to the abdomen. Understanding and classifying the variations in CTA is imperative in view of its relevance in various clinical and surgical cases. MDCT has become a valuable tool for the visualization of the celiac trunk and its branches. Moreover, reformatted three-dimensional MDCT images allow detailed visualization of the complex vascular anatomy. Therefore, small vessel abnormalities may be detected with greater frequency in symptomatic and asymptomatic patients using these techniques.

References

الاختلافات التشريحية لشريان جذع البطن في المصريين: دراسة بالتصوير الوعائي

إن معرفة نوع التغيرات التشريحية والفرعية للأوعية الدموية له أمر أساسي لوضع خطة للتعامل مع الأوعية الدموية قبل إجراء أي تدخلات جراحية أو إشعاعية وفهم التشريح الوعائي باستخدام المتعدد الضوء متعدد الكشف معايا سهولة الجراحة ويسهم بإجراء تقييم دقيق للتشريح الطبيعي والاختلافات التشريحية لشريان جذع البطن.

وكان الهدف من هذه الدراسة تحديد وتقييم نسب حدوث الاختلافات التشريحية المختلفة لشريان جذع البطن وكذلك فروعه الثلاثة.

وقد أجريت هذه الدراسة على 131 حالة (26 ذكر و45 إناث) تم عمل مسح بالتصوير الوعائي متعدد الكشف وتم الحصول عليها من قسم الأشعة في مستشفى قصر العينى ومركز خاص للأشعة 12 جهالة باللغة العربية (8 ذكر و4 إناث) تم الحصول عليها من قسم التشريح بكلية الطب جامعة القاهرة.

وأظهرت الدراسة أن شريان الكبد المشترك نشأ من الشريان المسرقي العلوي في 2.7% من الحالات،ښ شريان الأوراء البطيني في 2.8% من الحالات.

كما أظهرت الدراسة أن شريان الكبد الأيسر نشأ من الشريان المعد في 2.8% من الحالات، شريان الكبد الأيسر نشأ من الشريان المعد في 2.8% من الحالات، الشريان المسرقي العلوي، والشريان الكبدي الأيسر في 2.8% من الحالات.

وكان الاختلاف الأكثر شيوعاً لفروع من شريان جذع البطن في هذه الدراسة هو نشأة الشريان الكبدى الأيمن من الشريان المسرقي العلوي والذي بلغ 3.4% من الحالات، في حين أن الاختلاف أقل شيوعاً كان في نشأة الشريان الكبدى المشترك من الشريان المسرقي العلوي والذي بلغ 1.4% من الحالات، وكذلك نشأة شريان الكبدى الأيسر من شريان جذع البطن والذي كانت 1.4% من الحالات.

كما أظهرت الدراسة عدم وجود شريان جذع البطن في 1% من الحالات، ونشأة الشريان الكبدى الأيمن من الشريان الأرtery البطيني في 1.4% من الحالات، والشريان الكبدى الأيمن من شريان جذع البطن في 1.4% من الحالات، وكشفت الدراسة أيضاً حدوث متلازمة الربط الأيسر في 1.4% من الحالات.

وبنهاية تتعلق بالفرق بين الجنسين من مختلف التغيرات التشريحية في هذه الدراسة فقد لوحظ وجود اختلافات إحصائية بين الذكور والإناث.