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RESEARCH ARTICLE

THE MEASUREMENT OF THE INFERIOR CELIAC ARTERY ANGLE ON COMPUTED TOMOGRAPHY ANGIOGRAPHY TECHNIQUE

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ABSTRACT

Introduction: The main purpose of this study is to measure the inferior angle between celiac artery and Abdominal Aorta (AA) in the Chinese population which underwent Multi-detector Computer Tomography (MDCT) or Computer Tomography Angiography (CTA) for various reasons.
Methods: A total of 520 patients were analyzed under CTA of the AA from January 1st 2015 to July 31st 2015. There were 306 males and 177 females cases, and 37 cases were not included in our study due to restrictions whom we labeled as not evaluate. The inferior celiac angle were measured from a constructed line at the posterior surface of celiac artery and anterior surface of AA. We marked the anterior side of the AA as the baseline, and the cranial and caudal sides of AA were designated as 180^o and 0^o, respectively.
Results: The mean inferior celiac angle was (mean ± SD) $50.5^o \pm 16.73^o$ and the median angle was $52.44^o \pm 16.73^o$. There were 306 male patients with a mean celiac angle of $53^o \pm 17.43^o$ and 177 female patients with a mean celiac angle of $51.5^o \pm 15.45^o$. It was found that 90.5% of the population's celiac artery angle falls in between 0^o and 90^o angle, and 3.3 % has deep acute celiac angle.
Conclusion: In conclusion, the CTA technique permits an accurate detail of the anatomical direction and angles of the celiac artery.

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INTRODUCTION

The inferior celiac angle is defined as the angle between the posterior surface of the celiac artery and the anterior surface of abdominal artery. The celiac artery is a wide and short ventral branch (Katz-Summercorn and Bridger, 2013; Lindner and Kemprud, 1971; Panagouli *et al*., 2013) that originates from the anterior AA, basically at the level of T_{12} –L_1 vertebra (Matusz *et al*., 2013; Mu *et al*., 2013). It trifurcates into the common hepatic artery, the left gastric artery and the splenic artery, supplying nutrients and oxygenated blood to most of the internal vital organs of the digestive tract such as liver, spleen, stomach and intestines (Panagouli *et al*., 2013). An anatomical background of this angle is important for the surgeon to undertake different surgeries of the abdominal region including liver transplantation (Prakash, *et al*., 2012). It is also helpful for the radiologist in evaluating the vessels prior to radiological catheter placement in procedures like implantation of an intra-arterial hepatic port system (Inaba, 2010), as well as to diagnose rare abdominal malformations such as MAL syndrome. Therefore, it is important to analyze individual information about the different anatomical variations and angles of celiac artery prior to performing each procedure. Historically, an intravascular catheterization on Digital Subtraction Angiography (DSA) had been the first choice diagnostic test regardless of vascular pathology. However, fast development of MDCT technology and helical scanning technique has changed the role of CT in vascular imaging. The modern CT scanner technology has brought the CTA technique into medical reality, relevant in the diagnostics of vascular evaluation (Peter and Liu, 2014). The advantages of the CTA technique include non-invasive, superior imaging speed, outstanding extra vascular anatomic depiction, single volumetric acquisition and low cost, this has provided the potential information over other diagnostic techniques (Inaba, 2010; Peter and Liu, 2014). DSA is regarded as the gold standard diagnostic test in the evaluation of vessel pathology, but several reasons such as sophisticated procedures, invasive technique, high cost and excessive radiation have limited its application (Peter and Liu, 2014; Sone *et al*., 2008). Magnetic

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resonance angiography imaging somehow has no physical radiation that seems to cause any harm, but it has poor imaging contrast regarding calcification and it also takes a relatively longer procedure time. Ultrasonography is a non-invasive and simple diagnostic procedure but there is limited visualization of internal organs in certain populations such as obese patient and patients with high gaseous content in the abdomen (Liu Jiangtao and Xiao Yueyong, 2006). In this study, our aim is to measure and analyze the inferior angle of celiac artery in patients who underwent MDCT scan of the AA for various reasons, and also to identify the main effects that can contribute in the reduction of the inferior celiac artery angle.

MATERIALS AND METHODS

Patients

A total of 520 patients who underwent CTA of AA in our hospital from Jan 1st 2015 to July 31st 2015 were randomly selected for various reasons. The study was conducted in 483 patients with ages between 5 to 85 years old (mean age: 53 years; S.D: 15.81), 306 of whom were males (mean age: 53 years) and 177 were females (mean age: 53 years). We were unable to include the remaining 37 patients in our study due to several difficulties and they were labelled as not evaluate (NE). The sampling population has satisfied the following inclusion criteria:

(a) Contrast agent should be infused intravenously.
(b) The origin and branches of the celiac artery was in the imaged region.
(c) No history of any port catheter system had been implanted.
(d) No history of abdominal operations.
(e) All were fully conscious and cooperated well during the scan.
(f) The institutional review board approved the review of medical records and also approved the informed consent of each of our patient prior to undergoing the investigation procedures.

CT technique

Procedure

The routine scanning started right after the patients were fully prepared and positioned well on the scanner. CTA scan was performed in all patients on a 256-slice MDCT scanner (Phillips Brilliance iCT 256-slice, Cleveland, Ohio, U.S.A) after mechanical injection through infusion pump (Ulrich Company) of 100-150 ml of non-ionic iodinated contrast medium (Ominpaque-350 or Visipaque-320) with a concentration of 300mg/ml. The medium was administered at a dose of 2ml/kg body weight to a maximum of 150 ml. The contrast materials were infused through a 20- or 22- gauge IV cannula that was placed through the dorsal metacarpal or antecubital fossa vein, running at a rate of 2-5ml/s. The scan was done from head-to-toe direction in a cephalo-caudal manner, starting from the top of the liver down to the pelvic region. To achieve optimal opacity of our study region, each examination has included non-enhance and contrast-enhance scanning in 3 phases: a hepatic-arterial phase, a portal venous phase and an equilibrium delay phase. The hepatic arterial phase was started at 35s after the start of injection, the portal phase at 70s, and the equilibrium phase at 140s respectively. Scanning was obtained during inhalation in all patients. The volume data gathered was then reconstructed by setting the slice thickness to collimation thickness (1- 2 mm),

Table 1. Classification of the celiac angle according to its respective groups (A-F)

Letter	A	B	C	D	E	F	NE
Angle (in degrees)	0-30	30-60	60-90	90-120	120-150	150-180	Not evaluate

Fig.1: Demonstrating how to measure the inferior celiac artery angle.

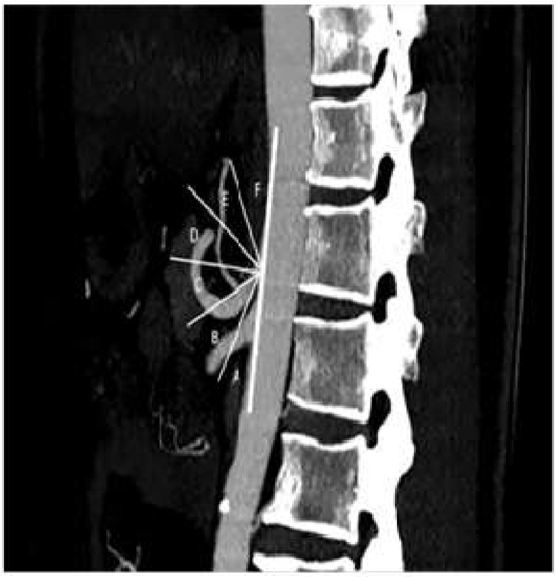

Fig. 2: Categorizing of the branching angle.

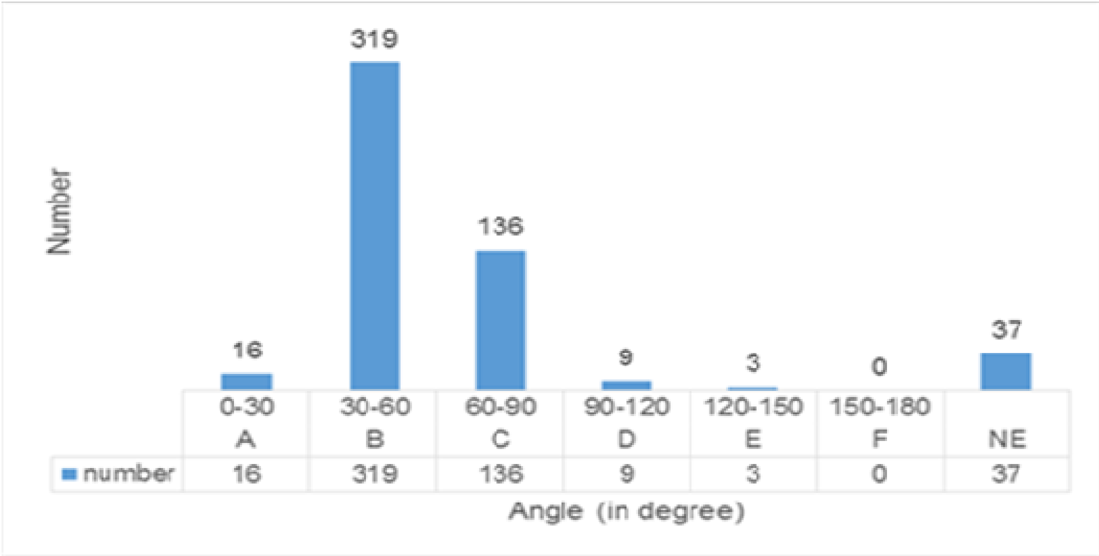

Fig.3: This graph illustrates the variation of celiac angle among our study population. NE: not evaluable

reconstruction field of view (FOV) to 150-300mm, and the reconstruction interval to ½ of the collimation thickness (0.5 or 1 mm). MIP reconstruction images were adjusted to 10 mm thickness. Scan parameters were as follow: 250mAs, 120 kV dose, detector collimation of 0.625×128 mm, pitch of 0.915, gantry rotation of 0.5s, slice thickness of 0.90 mm, and slice increment of 0.45 mm.

Image analysis

We located and measured the inferior celiac angle on reformatted MIP sagittal images between AA regions. The inferior celiac angle was defined from a constructed line on the posterior surface of celiac artery and the anterior surface of AA (Fig.1). In definition of the branching angle, the anterior surface of the AA was labelled as the baseline, and the cranial and caudal sides were designated as 180^o to 0^o. The angles between 0^o and 90^o was regarded as downward branching and the angle between 90^o and 180^o from the caudal side was regarded as upward branching. The branching angle of the celiac artery were categorizing in every 30^o (Fig.2), all labelled angle were designated into their respective groups (Group A to F) as shown in Table 1. The branching angles of the celiac artery were investigated based on this classification method (Figure 2).

RESULTS

The total population of this study was 520 patients: 483 of them are my raw data and 37 patients were not evaluated (NE) as they faced difficulties in image analysis and data gathering. Analysis of the branching angle was difficult in 37 patients (7 %) who were excluded and presented as NE. The details of these cases met the following: a) poor enhancement of the image in patients with an allergic reaction to contrast medium (3 patients). (b) Severe narrowing of the origin of the celiac artery (9 patients), and (c) Severe calcification of the origin of the celiac artery (25 patients). The medianceliac angle was $50.5^o \pm 16.73^o$ (range: 23.3^o–113.1^o) and mean angle was 52.44^o $\pm16.73^o$ in our sampling population. There were 306 male patients, with a mean celiac angle of $53^o \pm 17.43^o$ and 177 female patients with a mean celiac angle of $51.5^o \pm 15.45^o$. We divided these patients into 6 main groups, each group had 30^o interval, and were labeled accordingly (Table 1). No patients were included in Group F or cases with sharp upward branching angle of more than 150^o. The majority of our population (97.5 %: 471/483 patients) have celiac angle below 90^o or downward branching angle, and about 3% (16/483 patients) has an angle below 30^o ora sharp downward angle (Fig.3).

DISCUSSION

In this research we have found out that the mean inferior angle was 52.44^o $\pm16.73^o$ (angle range: 25.3^o-113.1^o), and celiac artery branched downward in 90.5 % of our study population. Similar finding presented by Mu *et al*. In his study with a mean angle of 63.5^o (14^o -159^o) (Mu *et al*., 2013). Tokue *et al*. did measure the celiac artery angle but followed a different method and reported that the median inferior angle was $135^o \pm 23^o$: (range: 51^o-174^o), and celiac artery branched downward sharply (150^o or more) in 177 patients, which is 16.03 % of the overall population (Tokue *et al*., 2012). Tokue *et al*. measurements labelled the cranial side of AA as 0^o and the caudal sideas 180^o. These afore-mentioned studiessh are similar features and have shown that the majority of the population have celiac artery branched downward or a celiac angle between 0^o and $90^o$from the caudal side of AA. No case was discovered with an upward branching angle between 150^o and 180^o in our study as well as other reported studies, however we have found that 3% of our study population have celiac artery below 30^o angle. The angle and direction of celiac artery affects the technique of catheter placement (Inaba, 2010). The approaching sides for catheterization based on the direction of celiac artery (downward or upward), caudal course of celiac axis is regarded as more difficult than cranial course because of multiple inflection points results in reduction in torque of catheter and guide wire (Sone *et al*., 2008). The rate of downward direction of the celiac artery was high in various population including 90.5% of our study population, and compression by MAL is one of the primary reasons (Chou *et al*., 2012; Kopecky *et al*., 1997; Randall *et al*., 1991). This ligament is formed by fusion of the diaphragmatic crura on either side of the aortic hiatus (Lindner and Kemprud, 1971; Kokotsakis *et al*., 2000; Lee *et al*., 2003; Vivian *et al*., 2003), usually passes posterior and inferior in relation to the position of the celiac artery (Randall *et al*., 1991). Lindner and Kemprud described that the celiac artery branched right below the median arcuate ligament in 25 of 75 autopsy cases (33%) (Lindner and Kemprud, 1971). Gumus *et al*. agreed as stated in their study that 2.8% of the 744 patients were shown that they have celiac artery compression by MAL, which resulted in a narrowed inferior celiac angle (Gumus *et al*., 2012). Compressing of celiac artery by MAL is known as MAL syndrome, a condition presenting with several symptoms such as postprandial pain, nausea/vomiting, diarrhea, weight loss, and epigastric bruit, however some patients reported to be asymptomatic (Lee *et al*., 2003). The incidence of this condition is predominantly on female population than in male patients with a 4:1 ratio (Chou *et al*., 2012; Gumus *et al*., 2012 Horton *et al*., 2005). This is in correspondence with our study, that female patients have a narrow celiac angle of 51.5^{o} in comparison to male patients who have a celiac angle of 53^{o}, the differences in angles maybe related to MAL compression effect. A hooked like presentation of the origin of celiac artery revealed on CTA sagittal images help to distinguish this condition from other celiac artery narrowing, such as atherosclerosis (Randall *et al*., 1991; Gumus *et al*., 2012; Horton *et al*., 2005). In addition, breathing movement also affect the degree of celiac artery angle. CT scans were obtained during deep inspiration and showed minimal changes in celiac artery angle. During deep inspiration the diaphragm contracts and draws downwards as it creates space for the inflation of the lungs. However, the celiac artery and the aorta moves simulatneously caudally and MAL moves ventrally (Vaziri *et al*., 2009). It is shown that during this time MAL relaxed providing less pressure on the celiac artery, hence minimizing it effects in compressing and narrowing of the celiac angle (Kokotsakis *et al*., 2000). Lee *et al*. agree that there is a slight compression of the inferior angle at the end of expiration as MAL contracts, stated in their finding that at the end of expiration mean angle was decreased to $41^{o}\pm19^{o}$ as in comparison to no change at the end of inspiration ($50^{o}\pm19^{o}$c; P<0.03) (Vivian *et al*., 2003). Furthermore, depletion of the retroperitoneal fat tissue between celiac artery and AA causes narrowing of the inferior angle of celiac artery resulting in a deep downward branching angle (Horton *et al*., 2005; Bedogni *et al*., 2001; Bhagirath Desai *et al*., 2013; Ozkurt *et al*., 2007). The body mass index (BMI) provides an accurate standard of an individual's fat mass (Bedogni *et al*., 2001; Ozkurt *et al*., 2007). Recent researches have shown specific relationships between BMI values and celiac artery angles or superior mesenteric artery (Liu Jiangtao *et al*., 2006; Chou *et al*., 2012; Bhagirath Desai *et al*., 2013) and have stated that the higher the BMI as in overweight or obese patients (BMI>25), the wider the inter-vascular angle, and the lower the value of BMI as in underweight patients (BMI<18.5), the narrower the angle (Bhagirath Desai *et al*., 2013). Chou *et al*. agreed by stating in their study that the mean BMI score in 14 patients with celiac artery compression syndrome were measured to be 18.2 ±1.9 kg/m^2, which is underweight by standard (Chou *et al*., 2012). Superior mesenteric artery forms a normal angle of 45^{o} (normal angle ranging from 25^{o} to 60^{o}) from AA (Bhagirath Desai *et al*., 2013; Ahmed and Taylor, 1997), conditions resulting in rapid weight loss reduces inter-arterial fat pad causes more acute angle ($<22^{o}$) (Ahmed and Taylor, 1997). Such conditions like underweight individuals with a history of rapid weight loss (Vulliamy *et al*., 2013), thin body build, exaggerated lumbar lordosis, catabolic states such as cancer, trauma, surgery, burns, or psychiatric problems like anorexia nervosa and malabsorption (Bhagirath Desai *et al*., 2013) have known to cause more acute angle ($<22^{o}$). It is also reported that compression of celiac angles also resulted from other etiologies, such as neoplasms of pancreatic head, vascular aneurysms, adjacent duodenal carcinoma, aortic dissection, or sarcoidosis (Chou *et al*., 2012). There has been no recent literature on celiac axis angle. MDCT has proved to be the most accurate diagnostic test in detection of abdominal arterial anatomy, variations and abnormalities (Gumus *et al*., 2012). It has been used in evaluation of a wide variety of splanchnic artery pathology like stenosis and occlusion (MAL syndrome, superior mesenteric artery syndrome, renal artery stenosis), hemorrhage and ischemia, mesenteric aneurysm and dissection (abdominal artery aneurysm and dissection), and venous pathology (Grierson *et al*., 2007; Smith *et al*., 2006; Chow and Rubin, 2002). The combination of VRT, MIP and MPR display in 3D imaging helps identify the branches of celiac trunk and superior mesenteric artery (Smith *et al*., 2006) which were used in this study. The limitations of our study include: (a) No comparison between normal and abnormal cases. (b) No comparison with other techniques, such as ultrasound and no comparisons with an abnormal findings of the celiac angle. (c) Limited literature about celiac artery angle.

Conclusion

In conclusion, MDCT has become a fairly comprehensive, minimally invasive and accurate technique for evaluation of the abdominal vasculature pathology, replacing DSA and other diagnostic investigations. MDCT scan prior to interventional therapy would help maximize anatomical understanding by creating a broad background among individual patients and help minimize catastrophic complications.

Conflict of Interests: The authors declare that they have no conflict of interests.

Author's contribution: The concept, data collection, analysis and drafting of the manuscript was done by UaiseleMafi. All authors contributed to writing the manuscript, and all authors read and approved the manuscript prior to submission.

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