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Hexafurcated celiac trunks, trifurcated common hepatic artery, and a new variant of the arc of Bühler

Authors: B. A. Manta, M. C. Rusu, A. M. Jianu, A. C. Ilie

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Hexafurcated celiac trunks, trifurcated common hepatic artery, and a new variant of the arc of Bühler

B.A. Manta et al., Rare variants of celiac trunk, hepatic artery and Bühler's arc

B.A. Manta[1], M.C. Rusu[1], A.M. Jianu[2], A. C. Ilie[3]

[1]Division of Anatomy, Department 1, Faculty of Dental Medicine, "Carol Davila" University of Medicine and Pharmacy, Bucharest, Romania

[2]Department of Anatomy and Embryology, Faculty of Medicine, "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania

[3]Department of Functional Sciences, Discipline of Public Health, Faculty of Medicine, "Victor Babeş" University of Medicine and Pharmacy, Timisoara, Romania

Address for correspondence: Adelina Maria Jianu, MD, PhD, Associate Professor „Victor Babeş" University of Medicine and Pharmacy, Department of Anatomy and Embryology, 2 Eftimie Murgu Square, 300041, Timisoara, Romania, tel: 0040/0256204250, e-mail: adelina.jianu@gmail.com, adelina.jianu@umft.ro

Abstract

The celiac trunk (CT) is well-known as trifurcated into the left gastric (LGA), common hepatic (CHA) and splenic (SA) arteries. Scarce reports indicate that the CT could appear cvadri-, penta-, hexa-, or even heptafurcated. Reports of CTs with six branches (hexafurcated CT) are few, less than ten. The hexafurcated CT variant was documented by a retrospective study of 93 computed tomography angiograms. Two hexafurcated CTs were found. In one case an arc of Bühler was added to the inferior phrenic arteries, LGA, CHA and SA. In the second case the dorsal pancreatic artery was added to the other five branches. That arc of Bühler descended in front of the aorta to connect with the origin of the third jejunal artery. The CHA in that second case was trifurcated into the left and right hepatic arteries, and the gastroduodenal artery; the proper hepatic artery was absent. Although the hexafurcated CT, as well as the trifurcated CHA, are rarely occurring and reported anatomic variants, this doesn't mean they could not be encountered during surgical or interventional procedures, which they would complicate if not recognized. Moreover, the arc of Bühler, the embryonic remnant, was not reported previously to insert into the CT as an additional branch of it.

Key words: aorta, computed tomography, hepatic artery, splenic artery, superior mesenteric artery, arc of Bühler, portal vein

INTRODUCTION

The celiac trunk (CT) is the first ventral branch of the abdominal aorta, commonly emerging at the level of the 12th thoracic vertebra, beneath the aortic hiatus of the diaphragm.[20] The CT usually trifurcates to form the *tripus Halleri*, sending off the left gastric artery (LGA), common hepatic artery (CHA) and splenic artery (SA) [21]. Panagouli et al (2013) defined the Type III of CT variation in which additional branches of the CT occur [17]. These authors documented a prevalence of 1.06% of this type of anatomic variations of the CT [17]. Different patterns of such additional branches include the inferior phrenic arteries, left (LIPA) and right (RIPA), or the dorsal pancreatic artery (DPA) [4].

To the authors' knowledge, eight hexafurcated patterns of the CT were previously reported [1,2,5,6,8,18,19]. A different study reported a prevalence of 4% for the hexafurcated CT, but this results just from a meeting abstract [25]. In these reports different arteries with specific patterns of distribution were added to the three normal branches of the CT to increase their number to six.

We hereby report a new pattern of hexafurcated CT in which one of the additional branches was not an artery with a specific target tissue, but it was a previously unreported variant of the arc of Bühler. The Bühler's arc is a rare direct retropancreatic anastomosis between the CT and the superior mesenteric artery (SMA) or their branches [15]. Different other celiacomesenteric anastomotic paths are more distanced from the aorta than the arc of Bühler, being either anastomoses of the superior and inferior pancreaticoduodenal arteries, or anastomoses of the dorsal pancreatic artery

(DPA) and the SMA, or one of its branches (middle colic artery, inferior pancreaticoduodenal arteries) [14,15]. To the authors' knowledge, an insertion of the arc of Bühler into a jejunal artery was not reported previously.

MATERIALS AND METHODS

The anatomic variants of CT hexafurcation reported here were found during a targeted retrospective study of 93 computed tomography angiograms of 44 male and 49 female cases, with ages from 48 to 72 y.o.. The computed tomographic exams consisted in injecting an iodine radiocontrast agent in the left brachial vein (100 ml, with 6 ml/sec flow), followed by 50 ml iodine radiocontrast agent (Ultravist 370 mg/ml) in the brachial vein, and by 20 ml saline medium. The computed tomography was performed with a 32-slice scanner (Siemens Multislice Perspective Scanner), using a 0.6 mm collimation and reconstruction of 0.75 mm thickness with 50% overlap for multiplanar, MIP, and 3D volume rendering technique [22]. The specific arterial anatomy was documented using the Horos software and its 3D Volume Rendering application.

RESULTS

In the 93 computed tomography angiograms that were studied were found two cases ((#1 male 60 y.o. and #2 male 50 y.o.) (2.15%) with hexafurcated CTs. In both cases, five of the CT branches were the inferior phrenic arteries, LGA, CHA and SA. The sixth branch of the CT was in Case #1 an arc of Bühler and in Case #2 – the DPA.

Case #1

The CT origin was on the anterior side of the abdominal aorta at the level of the upper third of the 1st lumbar vertebra. The SMA origin was 1.37 cm below, at the level of the middle third of the 1st lumbar vertebra. The calibre of the CT at its origin was 5.46 mm, while the calibre of the SMA was 6.63 mm.

There were found six branches emerging from the CT, three of these being collateral (LIPA, RIPA, LGA), and the other three, terminal branches (CHA, SA, arc of Bühler) (fig.1).

At 2.07 mm from the aortic insertion of the CT the two inferior phrenic arteries (LIPA, RIPA) emerged independently from the superior side of the CT, being separated between by a distance of 2.28 mm. The inferior phrenic arteries further ascended and diverged, to enter each within the pillar of the diaphragm on that side (fig.2).

The LGA emerged from the superior side of the CT at 1.36 cm distally to the origin of the inferior phrenic arteries. The LGA had an initial calibre of 4.37 mm. It sent off esophageal branches and further continued to distribute on the lesser gastric curvature.

The CT further arched anterior and to the right and trifurcated terminally at 1.84 cm in front of the abdominal aorta, still at the level of the upper third of the 1st lumbar vertebra. It sent off the CHA, directed superiorly to the right, the SA, directed inferiorly to the left, and a posterior branch which further proved being an arc of Bühler. The CHA further trifurcated in front of the portal vein into the RHA, LHA and GDA (fig.3). Thus, the proper hepatic artery (PHA) lacked in this case (absent PHA). The SA continued towards the spleen, crossing in front of the SMA and coiling superior to the pancreas and posterior to the stomach.

The sixth branch of the CT was an arc of Bühler which descended from the terminal trifurcation of the CT (fig.1). The diameter of the arc of Bühler was 3.65 mm. It descended initially applied on the posterior side of the portal vein, antero-medial to the inferior vena cava, and crossing anteriorly over the left renal vein (fig.4). Then it continued posterior to the superior mesenteric vein. In its course, that arc of Bühler was paralleling the SMA on its right posterior side. Inferiorly, the arc of Bühler crossed the posterior side of the SMA below the level of origin of the first jejunal artery (distributed to the duodenojejunal flexure) and ended into the segment of origin of the third jejunal artery (fig.1). The 2nd and the 3rd jejunal arteries left the SMA by a common trunk of origin.

Case #2

In this second case the CT origin was on the anterior side of the abdominal aorta at the level of the lower third of the 12th thoracic vertebra. The SMA origin was 1.58 cm below, at the level of the upper third of the 1st lumbar vertebra. The calibre of the CT at its origin was 4.51 mm, while the calibre of the SMA was 6.34 mm.

There were found six branches emerging from the CT, three of these being collateral (LIPA, RIPA, LGA), and the other three, terminal branches (CHA, SA, DPA) (fig.5).

The LGA emerged from the superior side of the CT at 2.38 distally to the origin of the CT.

The CT further trifurcated terminally at 3.19 cm in front of the abdominal aorta, at the level of the middle third of the 1st lumbar vertebra. It sent off the CHA, directed to the right, the SA, directed to the left, and the descending DPA. The CHA further divided into the GDA and PHA in front of the portal vein.

DISCUSSION

Hexafurcated celiac trunks

Few authors previously reported, or described, hexafurcations of the CT [1,2,5,6,8,18,19,25]. Moreover, there are certain flaws of these reports, as documented in Table 1. A single previous study used computed tomography angiograms, but that meeting abstract did not indicate the arterial pattern of those hexafurcations but reported a 4% prevalence of the variant [25]. There were six previous reports of hexafurcated CTs resulted after [1,2,5,6,18,19], but only one [1] came with an accurate proof of the evidence of all those six branches of the CT. To these poor previous evidences of hexafurcated CTs was added a review paper in which the variant was depicted just by a drawing [8]. It is therefore considered that the evidence presented here is the second convincing one.

The hereby reported variants of hexafurcation of the CT could be regarded as resulted from a LIPA+RIPA+LGA+CHA+SA pentafurcation pattern to which was added either the DPA, or an arc of Bühler. Such pentafurcated patterns were reported only twice previously [13,19].

The arc of Bühler and novelty of the present variant

Anatomic variations of the CT and SMA are explained by the Mac Kay arc theory and by the longitudinal ventral anastomosis described by Julius Tandler in 1904 [15,26]. According to Mac Kay's theory, the distribution of the embryonic aorta branches is metameric [15]. Each metamere gives rise to three pairs of branches which unite in an arch, posterior, lateral and anterior or visceral [15]. Further, the visceral arches evolve to metameric single median digestive arteries [15]. The 10th metameric artery will form the LGA, the 11th metameric artery will form the SA, the 12th one forms the CHA and the 13th one – the SMA [14,15]. These embryonic arteries are united by Tandler's longitudinal anastomosis located in front of the aorta [15,26]. However, although the arc of Bühler is regarded as a vestige of Tandler's anastomosis between the CT and the SMA, its embryogenesis closely relates to the DPA [15]. This because the DPA could emerge either the SA, or the SMA, and if both origins are maintained, the arc of Bühler is configured [15]. In the variant reported here (Case #1) the upper origin of the DPA was translated to the CT itself, the lower origin – to the third jejunal artery, but both were maintained to configure a retropancreatic arc of Bühler. In Case #2, the origin of the DPA was translated from the SA to the CT itself, but an inferior insertion onto the SMA lacked.

In a recent review of the literature, Michalinos et al concluded that "Despite its importance, knowledge on the Buhler's arc is still incomplete" [15]. Indeed, the report presented here adds such knowledge, by demonstrating that the arc of Bühler could insert in the CT as one of the six branches of a hexafurcation.

Michalinos et al (2019) documented that Grabbe and Bücheler (1980) determined the diameter of the arc of Bühler being 2-7 mm. The respective authors found the arc of Bühler with a prevalence of 4,11% (14/340 cases) [9]. Later, Saad et al (2005), also documented by Michalinos et al (2019), found the diameter of the arc of Bühler being 1.5-2.5 mm. But those later authors found the respective anastomosis in

4/120 angiograms, thus with a prevalence of 3.3% [23]. In the case reported here the diameter of the arc of Bühler was of 3.65 mm, which corresponds to the measurements of Grabbe and Bücheler, but is larger than the values of Saad et al. The arc of Bühler could use as collateral path of blood flow between the CT and SMA, if one of these two main arteries is obstructed [15]. A direct CT insertion of the arc of Bühler would equally supply the branches of the CT from the SMA, if the CT is obstructed. However, a jejunal insertion of the arc of Bühler could not ensure a good hemodynamic support of the SMA, if this later artery is obstructed. It should also be emphasized that when the arc of Bühler acts as a shunt, either it could steal blood from different collateral branches of the CT and SMA, or it could facilitate the development of aneurysms by local increase of the arterial pressure.[15]

Trifurcated common hepatic artery – absent proper hepatic artery

Song et al (2010) evaluated the arterial anatomy on CT angiograms of 5002 patients [24]. From what was observed, the variant of the RHA and LHA originating directly from the CHA which is reported here (absent PHA, Case #1) was not found among that large lot of cases, although those authors got evidence to present and discuss the absent CHA variants [24]. A recent study by Ekingen et al on the specific variation of the PHA was performed on 671 MDCT angiography images [7]. The authors classified as Type 2 the RHA + LHA + GDA originated from the CHA, with absent PHA (trifurcation of CHA) morphology [7], which is similar to the findings reported here in Case #1. Ekingen et al (2020) found this Type 2 morphology in 8.94% of cases, while the normal anatomy of the PHA was encountered in just 43.52% of their cases. They quoted Gurgacz et al. (2011) for reporting a trifurcated CHA[10], but that trifurcated CHA had not a RHA + LHA + GDA pattern, it had instead the LHA + GDA + right gastric a. pattern, which is different equally from the variant reported here, and from Ekingen's Type 2. Moreover, while Ekingen et al (2020) did not indicate whether, or not, the cases with trifurcated CHA added multiple branching patterns of the CT, hereby is reported a hexafurcated CT with a trifurcated CHA. At the opposite end of the spectrum of such variations, Badagabettu et al (2016) reported an absent CT with a trifurcated CHA with a RHA + LHA + GDA pattern [3]. Hiatt et al (1994) documented the previous reports of Kemeny et al (1986) and, respectively, Niederhuber and Ensminger (1983), who reported the RHA + LHA + GDA pattern of the CHA trifurcation [12,16], but regarded that pattern as “a subtype of the normal scheme” [11]. As quoted by Hiatt et al, the respective authors documented a prevalence of 9%, and, respectively, 14%, of the trifurcated CHA [11].

CONCLUSIONS

In conclusion, additional branches of the celiac trunk are exposed at risk during surgical and interventional procedures, if not accurately documented. Available literature resources in such cases are still poor and in various instances insufficiently documented. Nevertheless, finding a rare arterial variant does not mandatory imply it is the only variant which occurred in that territory.

List of Abbreviations: CHA – common hepatic artery; CT – celiac trunk; DPA – dorsal pancreatic artery; GDA – gastroduodenal artery; LGA – left gastric artery; LHA – left hepatic artery; LIPA – left inferior phrenic artery; PHA – proper hepatic artery; RHA – right hepatic artery; RIPA – right inferior phrenic artery; SA – splenic artery; SMA – superior mesenteric artery.

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Conflicts of interests: None.

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Table 1. Previously reported or described hexafurcations of the celiac trunk

Author(s), year	Method	Anatomical pattern	Observations
Çiçekcibaşi et al. (2005)	Dissection	LIPA, RIPA, LGA, CHA, SA, LGEA	Case report of a CMT; in the figures it is not clear whether, or not, the LGEA has indeed a gastric distribution
Gielecki et al. (2005)	Review paper	LIPA, RIPA, LGA, CHA, SA, ASRHA	A schema depicts the variant
Chitra (2010)	Dissection	LIPA, RIPA, LGA, CHA, SA, duodenal branch	1/50 cadavers (2%) was reported with hexafurcated CT but there is no figure to support the finding
Paraskevas and Raikos (2011)	Dissection	LIPA, ALSA, LGA, CHA, SA, AJA	Case report, the CHA is not depicted in the figures, nor is the target loop of the AJA
Srivastava (2012)	Computed tomography	-	Meeting abstract only, a prevalence of 4% of the hexafurcation of the CT is reported but the pattern is obscure
Alashkham (2012)	Dissection	LIPA, RIPA, LGA, CHA, SA, aberrant branch for pancreas and duodenum	The inferior phrenic arteries emerging the CT do not appear in the image presented by the author
Agarwal et al. (2016)	Dissection	LIPA, RIPA, LGA, CHA, SA, DPA	The hexafurcation of the CT is accurately demonstrated in the figure
Pinal-Garcia et al. (2018)	Dissection	(a) LIPA, RIPA, LGA, CHA, SA, DPA (b) LIPA, LMSA, RIPA, LGA, CHA, SA	Hexafurcation of the CT was found in 1.4% (2 from 140 cases) but it was not proofed by any figure

AJA: accessory jejunal a.; ALSA: accessory left suprarenal a.; ASRHA: accessory superior right hepatic a.; CHA: common hepatic a.; CMT: celiacomesenteric trunk; CT: celiac trunk; DPA: dorsal pancreatic a.; LGA: left gastric a; LGEA: left gastroepiploic a.; LIPA: left inferior phrenic a.; LMSA: left middle suprarenal a.; RIPA: right inferior phrenic a.; SA: splenic a.

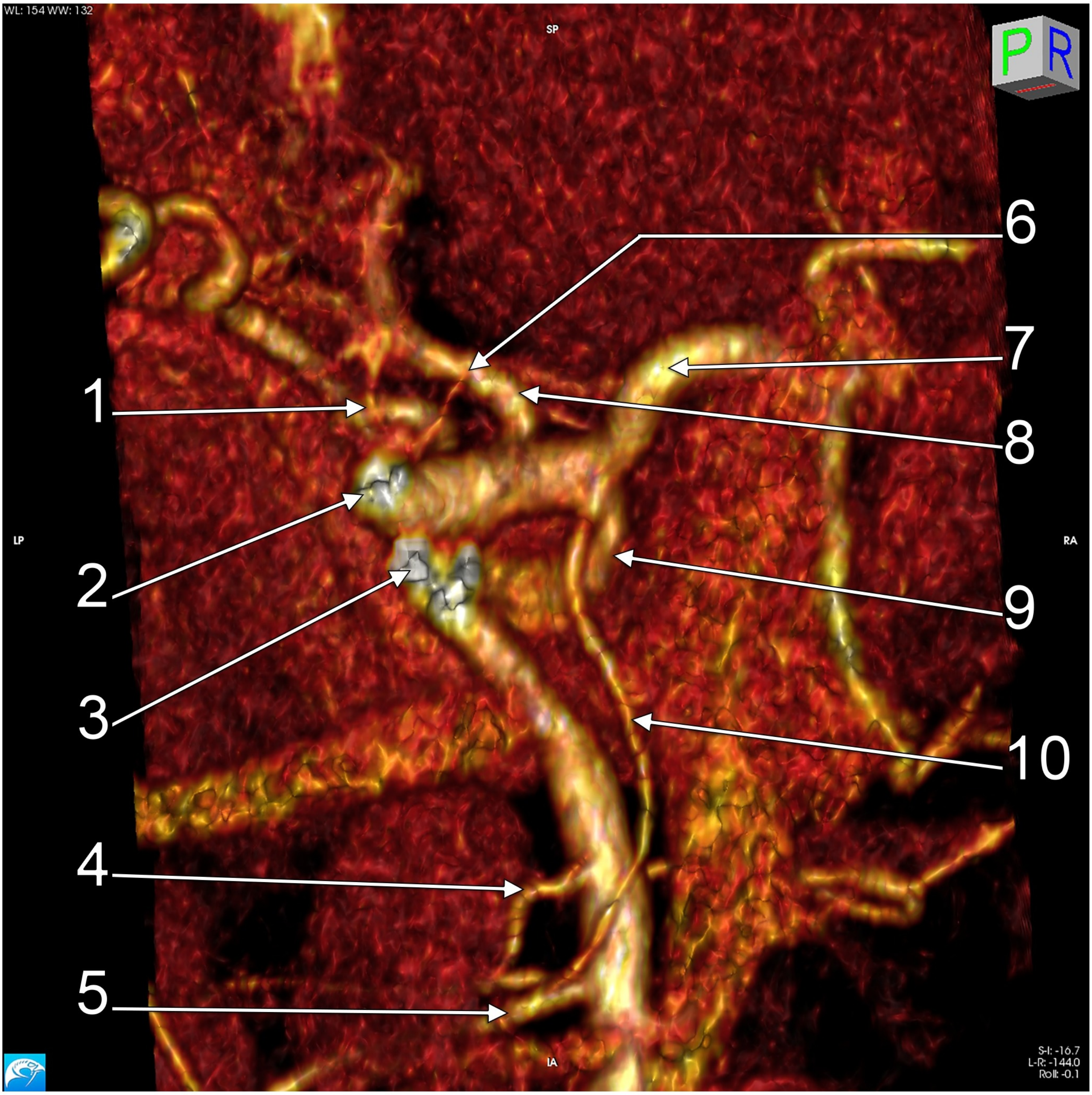
Figure 1. Case #1. Hexafurcated celiac trunk. Left posterior view of the celiac trunk and superior mesenteric artery. Three-dimensional volume renderization. 1.left inferior phrenic a.; 2.celiac trunk origin; 3.superior mesenteric a.; 4.first jejunal a.; 5.third jejunal a.; 6.right inferior phrenic a.; 7.common hepatic a.; 8.left gastric a.; 9.splenic a.; 10.arc of Bühler.

Figure 2. Case #1. Hexafurcated celiac trunk. Coronal MIP slice demonstrating the independent celiac origins of the inferior phrenic arteries. 1.left gastric a.; 2.right inferior phrenic a.; 3.celiac trunk; 4.aorta; 5.left inferior phrenic a.

Figure 3. Case #1. Hexafurcated celiac trunk. Right antero-inferior view of the trifurcated common hepatic artery. Three-dimensional volume renderization. 1.right inferior phrenic a.; 2.aorta; 3.left hepatic a.; 4.right hepatic a.; 5.trifurcation of the common hepatic a.; 6.right renal a.; 7.gastroduodenal a.; 8.left gastric a.; 9.coiled splenic a.; 10.celiac trunk; 11.superior mesenteric a.

Figure 4. Case #1. Hexafurcated celiac trunk. Axial MIP slice through the lower third of the 1st lumbar vertebra. 1.arc of Bühler; 2.portal vein; 3.inferior vena cava; 4.right kidney; 5.right renal a.; 6.aorta; 7.left renal v.; 8.superior mesenteric a.; 9.pancreas.

Figure 5. Case #2. Hexafurcated celiac trunk. A. Three-dimensional volume rendering, anterior view; **B.** Sagittal MIP slice through the celiac trunk; **C.** Coronal MIP slice through the terminal end of the celiac trunk. 1.12th thoracic vertebra; 2.right inferior phrenic a.; 3.left gastric a.; 4.celiac trunk; 5.common hepatic a.; 6.proper hepatic a.; 7.gastroduodenal a.; 8.left inferior phrenic a.; 9.splenic a.; 10.superior mesenteric a.; 11.dorsal pancreatic a.



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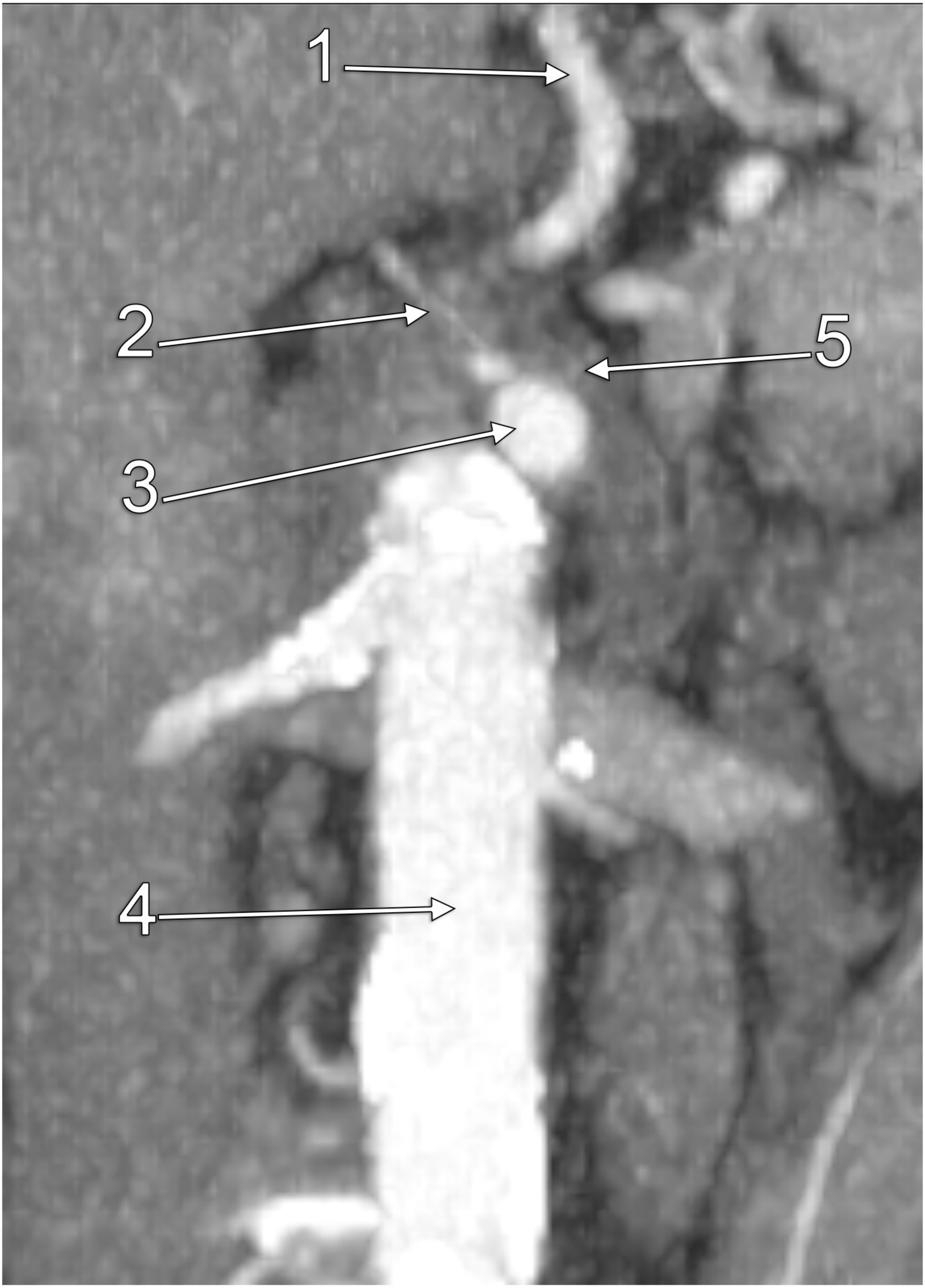
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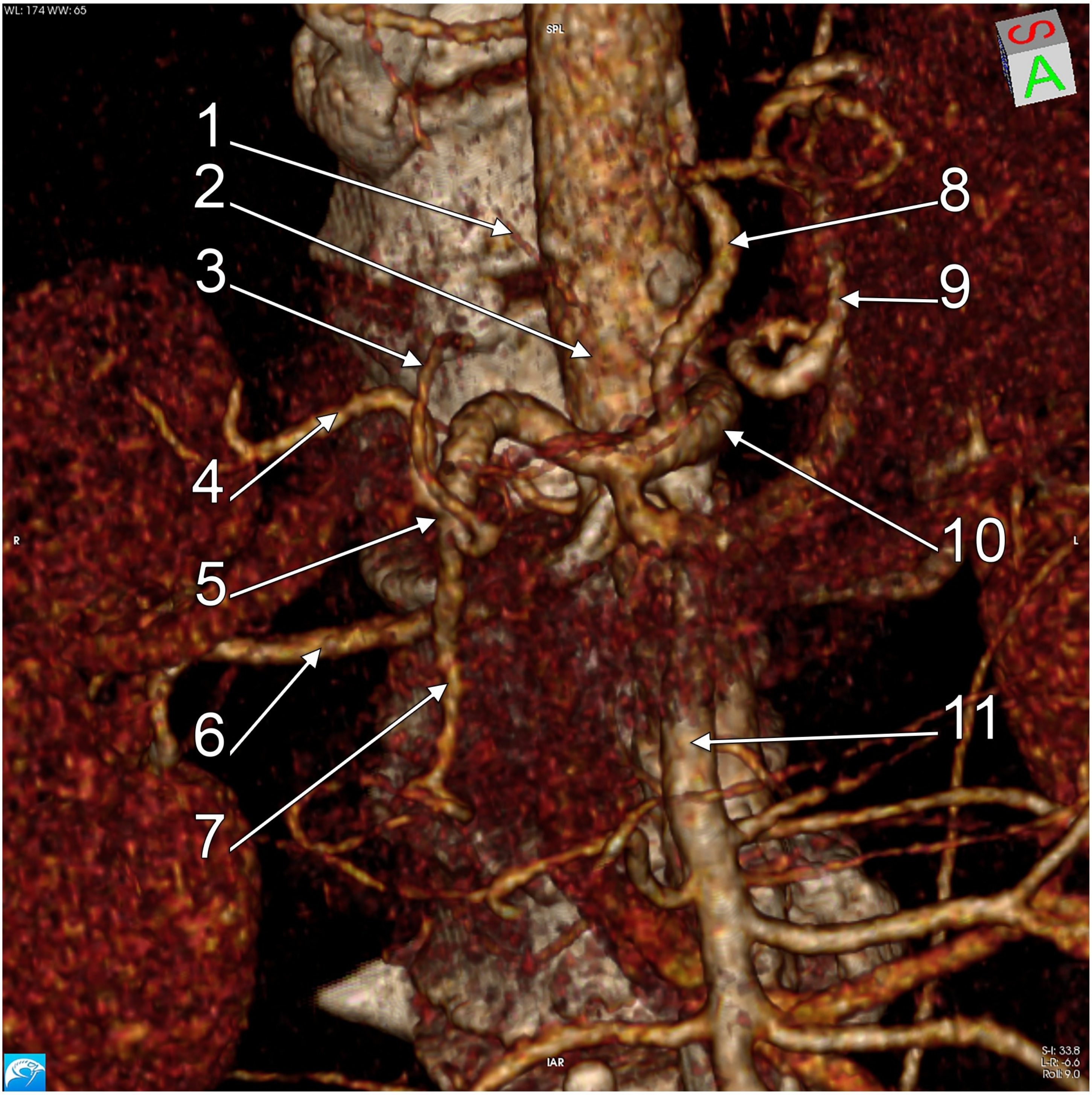

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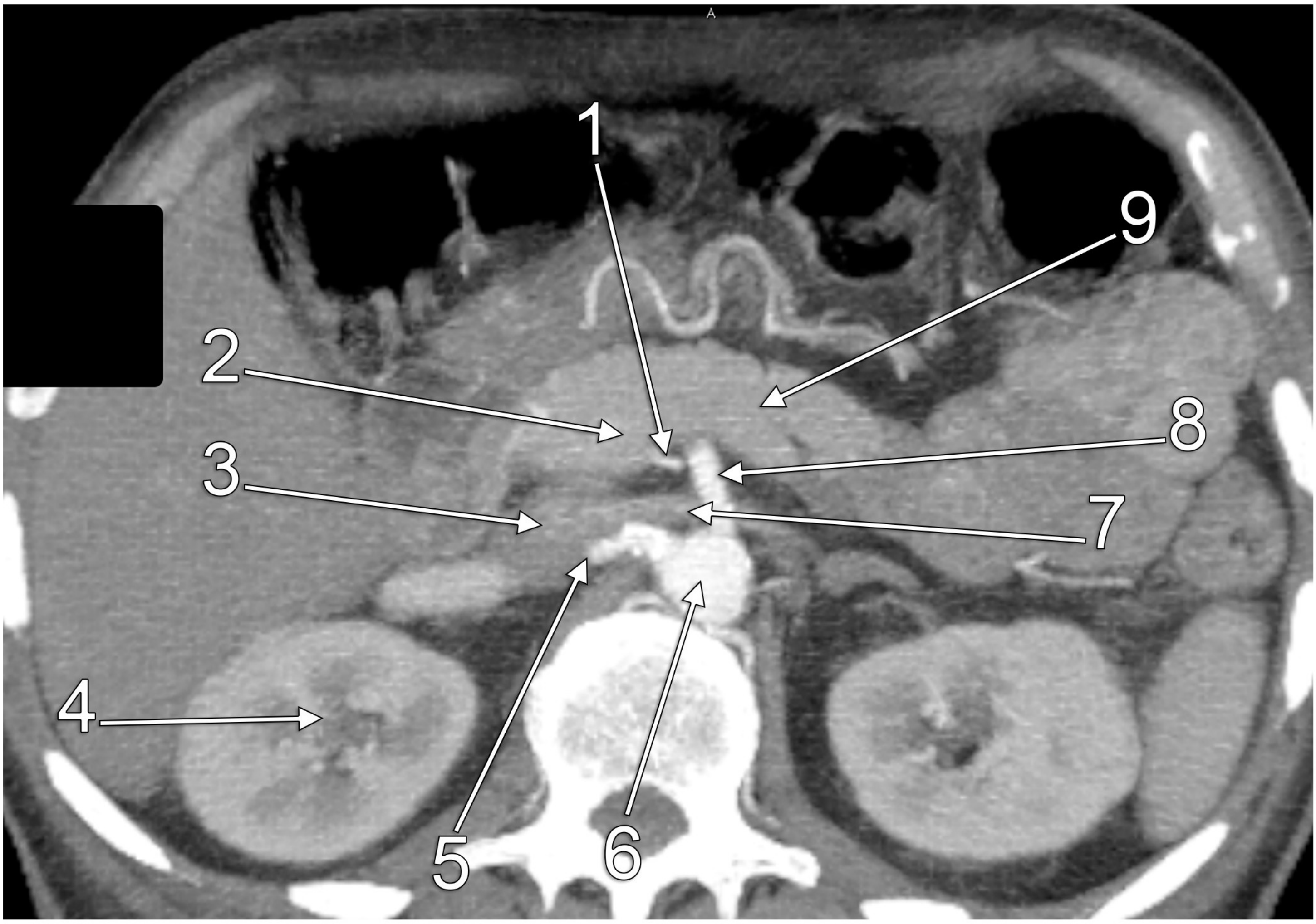

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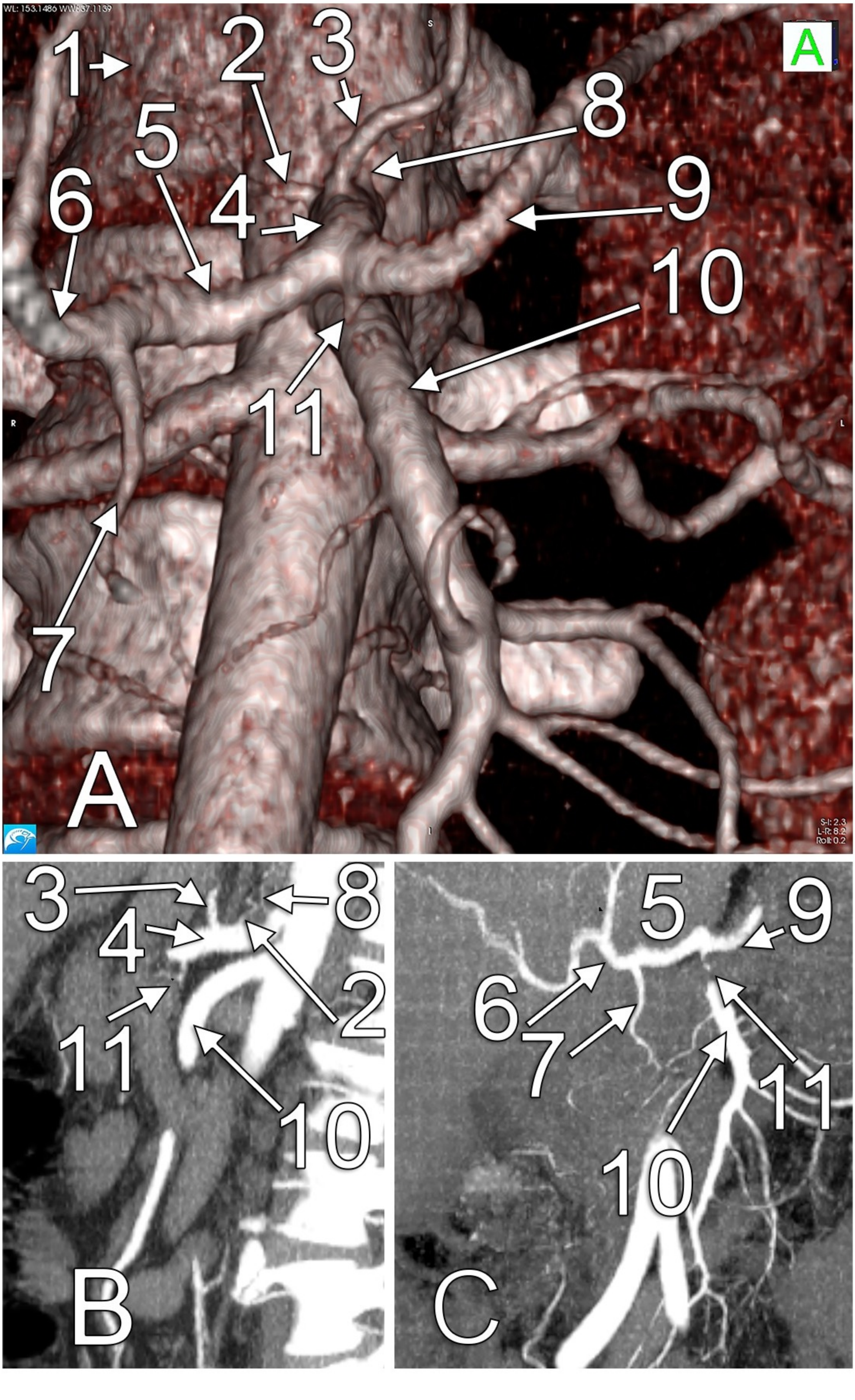

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L-R: 8.2
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