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Superior mesenteric artery clinical classification and morphometrical analysis

Radosław Chmiel et al., SMA clinical classification

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Abstract

Background: The superior mesenteric artery is one of the most important arteries in the abdominal cavity, which is of great clinical importance, especially in surgical procedures and fatal ischemic complications. The aim of this study was to develop a clinical classification of the superior mesenteric artery.

Materials and methods: Postmortem contrast-enhanced computed tomography of 104 (29.8% female, age 50.7±18.7) human bodies were analyzed. Based on anatomic predisposition to ischemic and iatrogenic complications, a three-tiered clinical classification of the superior mesenteric artery was developed. Type 0 was defined as standard risk for ischemic and iatrogenic complications. Type 1 was defined as increased thromboembolic risk with decreased risk of iatrogenic bleeding, and type 2 was defined as decreased ischemic risk with increased risk of iatrogenic bleeding. The supply area of the superior mesenteric artery was divided into 4 regions: pancreas, caecum, ascending colon, and transverse colon.

Results: Type 0 (standard risk) was found in 62.5% of cases. Type 1 was most frequently observed in the ascending colon region (15.4%). Type 2 was most frequently observed in the pancreatic region (17.3%). Regarding type, most abnormalities were found in the region of the ascending colon (18.3%), pancreas region (17.3%), and transverse colon (16.3%).

Conclusions: The proposed clinical classification of SMA links anatomic variations in morphology with their clinical significance. A simple, three-level classification can be easily applied in daily practice and serve as a great support for preoperative evaluation and recognition of patients at risk of iatrogenic or thromboembolic complications.

Keywords: superior mesenteric artery, intestinal vasculature, mesenteric ischemia, iatrogenic abdominal bleeding, classification

INTRODUCTION

The superior mesenteric artery anatomy

The superior mesenteric artery (SMA) arises from the abdominal aorta, usually as the second major branch after the celiac trunk. The supply area of the SMA includes the head of the pancreas, the lower part of the duodenum, the jejunum, the ileum, the caecum, the appendix, the ascending colon, and the transverse colon [15] In some cases, it may supply the liver [4]. Classic anatomical descriptions of the SMA branches include the inferior pancreaticoduodenal, middle colic, right colic, ileocolic, and jejunal arteries [15]. Rare anatomic variants have also been described previously [3, 5, 16]. A five-level SMA classification has been described previously based on the prevalence of specific SMA branches [3]

The superior mesenteric artery thromboembolism

Thromboembolism of the superior mesenteric artery is a rare clinical situation (0.09-0.2% of all acute admissions to emergency departments) that results in mesenteric ischemia and is associated with a very high risk of death (50–70%) [2, 11]. The method of treatment depends on the patient's condition and ranges from laparotomy in hemodynamically unstable patients to percutaneous revascularization [2]. Mesenteric ischemia is most commonly caused by SMA emboli (40–50% of cases) [11].

The Superior Mesenteric Artery supply region surgical procedures

The most common surgical procedures performed in the SMA service area are related to oncologic treatment of colon cancer, particularly in the ascending and transverse colon. The number of colectomies performed is expected to increase by over 60% by 2030 [1]. Surgical treatment of appendicitis, carcinoma of the head or uncinate process of the pancreas, small bowel resection, and hernia surgery may also involve ligation of SMA branches [13]. Collateral circulation provides additional blood supply to the operated regions, which can lead to severe bleeding during surgery [17]. However, this factor plays a crucial role in preventing ischemic complications [9].

The Arc of Riolan is a strategic vessel that provides collateral mesenteric circulation in 10% of people [18]. Preoperative examination of the bowel may play an important role in both preventing iatrogenic complications and diagnosing thromboembolic events.

The aim of the study

The aim of this study was to evaluate the anatomy and morphometry of SMA to establish a clinical classification of SMA types based on the anatomical favoring of ischemic complications related to iatrogenic damage and thromboembolic events.

MATERIAL AND METHODS

Study Population

Postmortem contrast-enhanced computed tomography angiography (CTA) scans of 104 (29.8% female, age 50.7±18.7) human bodies acquired between 2012 and 2017 were retrospectively evaluated. Detailed imaging and contrast injection were described in previous study [7]. Results were obtained using RadiAnt DICOM Viewer three-dimensional reconstruction software (Medixant. RadiAnt DICOM Viewer [Software]. Version 2022.1. Feb 10, 2022. URL: https://www.radiantviewer.com). Arterial phase acquisition results were reconstructed and further analyzed by two different investigators. If measurements > differed 5% between researchers, both measurements were repeated. If no consensus was found for quantitative assessment, the decision of the lead author was reported.

The superior mesenteric artery analysis

The diameter and angle of origin of the SMA, inferior pancreaticoduodenal, ileocolic, right, and middle colic arteries were measured. The distances between the origin of the SMA and each of the above branches were measured. The distance between the origin of the SMA and the origin of the abdominal aorta and aortic bifurcation was measured. The number of jejunal arteries, arterial anastomosis, and presence of additional arteries were determined. Three classes were formed:

— Type 0 — normal risk of thrombosis and additional iatrogenic bleeding, characterized by a common trunk for one large and one small vessel, a common trunk for two large vessels, or the absence of a large vessel in the presence of an additional artery supplying the area of interest.

— Type 1 — high risk of thrombosis and low risk of additional iatrogenic bleeding, characterized by the presence of common trunks for large branches of the SMA or the absence of a large vessel originating from the SMA in the presence of additional arteries supplying the same region.

— Type 2 — low risk of thrombosis and high risk of additional iatrogenic bleeding, characterized by the presence of all major vessels of the SMA, the presence of additional arteries and arterial anastomoses.

In addition, a letter code was used to code the vascular regions: p — pancreatic region, c — caecum, a — ascending colon, t — transverse colon. See Figure 1 for a flowchart to determine the SMA type.

Statistical analysis

Data were analyzed using IMB SPSS Statistics 28.0 (Predictive Solutions, Pittsburgh, PA, USA). Categorical variables are presented as number (n) or percentages. Normal distribution was examined using the Shapiro-Wilk test. Quantitative variables are presented as means with standard deviation. Sex comparisons between quantitative variables were performed using the U-Mann Whitney test. Categorical variables were compared using Chi square test with Fisher exact test when group number was lower than 5. Quantitative variables comparisons between SMA clinical types were performed with Kruskal-Wallis's test with post-hoc Dunn test and applied Bonferroni correction. Pearson and rho-Spearman correlations were performed. R = 0.277 ($p < 0.05$ for 104 patients) was considered significant. The p value < 0.05 was considered significant.

RESULTS

SMA classification

Type 0 (standard risk) was found in 62.5% of cases. Type 1 was most commonly observed in the ascending colon region (15.4%). Type 2 was most frequently observed in the pancreatic region (17.3%). Regarding type, most abnormalities were found in the region of the ascending colon (18.3%), pancreas region (17.3%), and transverse colon (16.3%). A summary of the prevalence of all types is provided in Table 1, and all anatomic abnormalities are provided in Table 1A in the Appendix. A statistically significant difference between the SMA types was found in the ileocolic artery diameter of origin ($p = 0.009$). The most common representatives for each SMA clinical type can be found in Figure 2. SMA and its branches origin diameter comparison between the presented types can be found in Table 2.

DISCUSSION

The SMA runs along the superior mesenteric vein posterior to the pancreas. It courses in a convex line to the left side. The classic description of SMA shows the presence of four branches originating from the right margin, namely the inferior pancreaticoduodenal artery, which originates as the first branch of SMA, gives off an anterior and a posterior branch, which subsequently anastomose with the anterior and posterior branches, respectively, of the superior pancreaticoduodenal artery. Together, they supply the head of the pancreas and the lower part of the descending, transverse, and ascending portions of the duodenum. The middle colic artery, which gives off two branches, consists of a right branch supplying 2/3 of the right part of the transverse colon. It forms an anastomosis with the ascending branch of the right colic artery and nourishes the ascending part of the colon. The left branch of the middle colic artery supplies 1/3 of the left part of the transverse colon [8]. Together with the ascending branch of the left colic artery, it forms the Riolan arch (also known as the meandering mesenteric artery) [12]. It can serve as a vital conduit when one or more of these other arteries are occluded, the dilation of which is common in patients with isolated mesenteric artery dissection (ISMAD). The prevalence and diameter of the Riolan arch were significantly increased in the ISMAD group compared with the control group (83.16% vs. 35.79%, $P < 0.001$; 2.63 ± 0.56 mm vs. 2.12 ± 0.39 mm, $P < 0.001$) [14].

The peripheral arterial arch on the right side of the colon, which also forms the main collateral network between SMA and IMA, is called the artery of Drummond (also known as the marginal artery), which vascularizes the transverse and descending colon and makes an important contribution to the collateral circulation of the left colic structures [12]. The right colic artery, which divides into an ascending branch that joins the ascending right branch of the middle colic artery and together supplies the ascending portion of the colon. It also gives off a descending branch of the right colic artery, which anastomoses with the colic branch of the ileocolic artery [6]. The ileocolic artery supplying the ascending colon, appendix, cecum, and ileum. It is traditionally described as the terminal branch; however, in our study, it served as the terminal branch [16]. From the left margin: the jejunal and ileal arteries forming anastomotic arcades. From these arcades, small straight arteries called vasa recta supply the intestinal wall [16].

The former classification of SMA distinguishes five morphological types based on the presence of certain branches:

Type I, classic (53.33% of cases). Type II, defined by the absence of the inferior pancreaticoduodenal artery (26.67% of cases). Type III characterized by the absence of the right collicular artery (3.33% of cases). Type IV characterized by the presence of a common truncus for the inferior panreaticoduoneal artery and the middle collicular artery (3.33% of cases). Type V, characterized by an abnormal hepatic artery and the absence of the inferior pancreaticoduodenal artery (13.33% of cases) [3].

Based on our results, we found the following distribution of SMA morphological types in the previously presented classification: type 1 — 74.0%, type 2 — 13.5%, type 3 — 5.8%, type 4 and type 5 2.9% each. In 1.0% of cases, the anatomy of SMA corresponded to more than one classification (absence of the right colic artery and absence of the inferior pancreaticoduodenal artery). The above classification allows characterization of most anatomic variants of SMA in a simple and rapid manner. However, it omits the following variants that may be relevant and were detected in our study: an additional common hepatic artery independent of the presence of the inferior pancreaticoduodenal artery (18.3%), a common trunk of the pancreaticoduodenal artery and the jejunal artery (27.9%), a common trunk for the middle and right colic arteries (7.7%), colic branches from the common hepatic artery (1.0%), additional branches to the liver, with normal common hepatic morphology (1.0%), and the inferior pancreaticoduodenal artery branches from the common hepatic artery originating from SMA (1.9%) [10].

In our study, we described three clinical types of SMA.

Type 0 — Figure 2A — normal risk of thrombosis and additional iatrogenic bleeding, characterized by a common trunk for one large and one small vessel, a common trunk for two large vessels, or the absence of one large vessel in the presence of an additional artery supplying the affected area.

Type 1 — Figure 2B — high risk of thrombosis and low risk of additional iatrogenic bleeding, characterized by the presence of common trunks for large branches of the SMA or the absence of a large vessel originating from the SMA in the presence of additional arteries supplying the same region.

Type 2 — Figure 2C — low risk of thrombosis and high risk of additional iatrogenic bleeding, characterized by the presence of all major vessels of the SMA, the presence of additional arteries and arterial anastomoses.

The use of a letter-based code facilitates communication between radiologists and surgeons and allows information to be communicated in a simplified and systematic manner. Emphasis on the functionality of the scale allows its direct application in daily clinical practice and ultimately leads to increased intraoperative patient safety. It is recommended that only the types associated with abnormalities (types 1 and 2) be indicated with a letter code assigned to the region and that type 0 not be indicated to allow clear communication.

Significant differences between postmortem and normal low dose CT should be mentioned. In postmortem CT, higher doses of radiation and hydrophobic paraffin-based contrast agent is used, as opposed to the hydrophilic iodine contrast agent used in low-dose radiation CT patients. These features provide more detailed anatomical images compared to steady-state visualization methods.

Limitations

There are several important limitations that should be noted with this study. First, this study was performed at a single center and involved the analysis of retrospective computed tomography scans. The study involved only individuals belonging to a specific ethnic group (Caucasians). In addition, the male population was overrepresented in the study (70.2%). In addition, we did not analyze the population with confirmed mesenteric thromboembolism or iatrogenic intraoperative bleeding.

CONCLUSIONS

The proposed clinical classification of SMA links anatomic variations in morphology with their clinical significance. A simple, three-step classification can be easily applied in daily practice and can serve as a great support for preoperative assessment and recognition of patients at risk of iatrogenic or thromboembolic complications. The proposed assessment can be easily performed by a radiologist or surgeon based on a simple three-dimensional reconstruction with cheap available tools.

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Ethical statement

This study was approved by the Bioethical Committee of the Jagiellonian University, Cracow, Poland (No. 1072.6120.241.2021 approved in 2021). The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki.

Conflict of interest: None declared

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Table 1. The superior mesenteric artery types prevalence categorized.

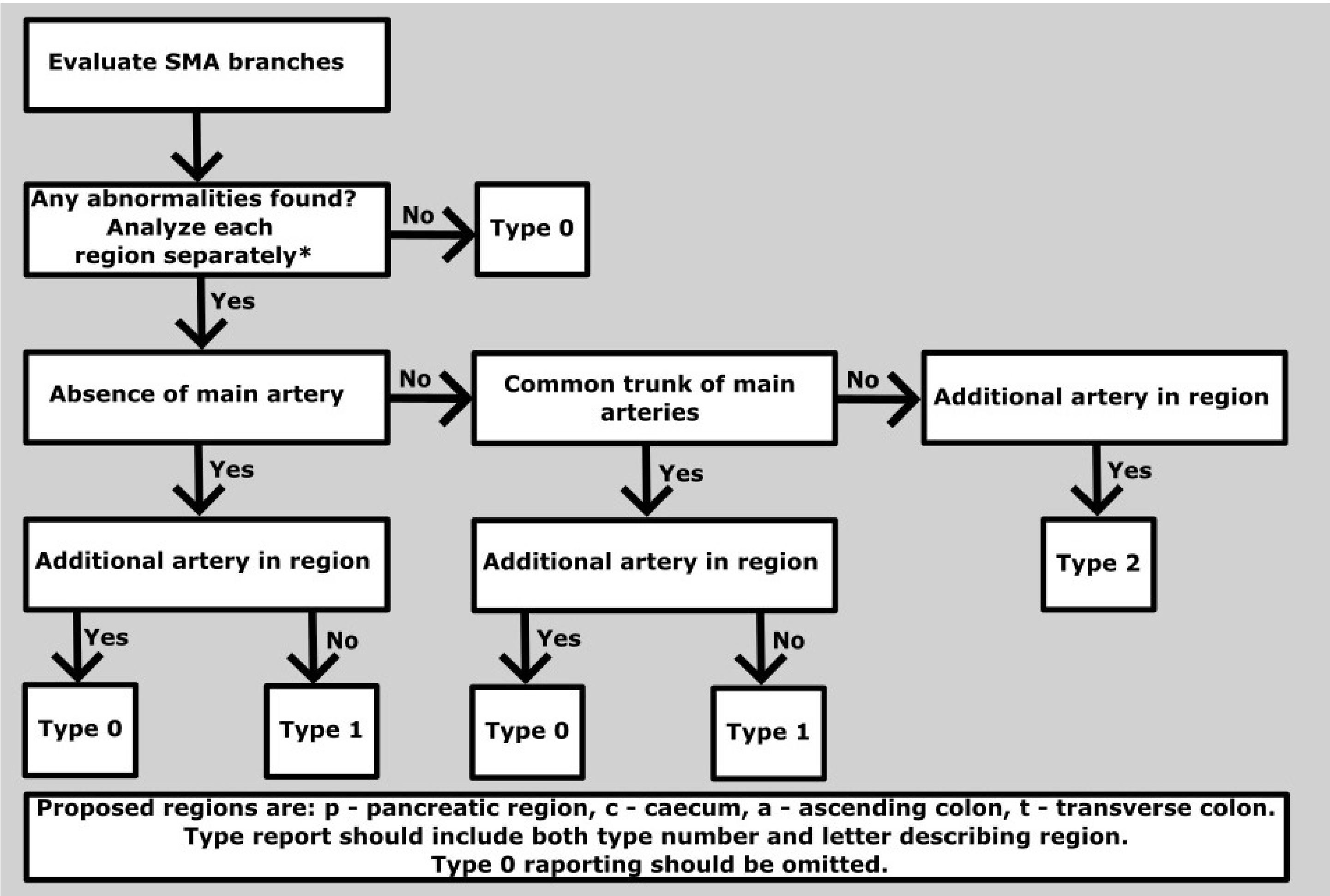
Category	type	n (%)
general patients' prevalence	type 0	65 (62.5%)
	type 1	12 (11.5%)
	type 2	21 (20.2%)
	Type 1 and 2	6 (5.8%)
Number of types per patient	0	65 (62.5%)
	1	22 (21.2%)
	2	15 (14.4%)
	3	2 (1.9%)
Types prevalence in pancreatic region	type 0	86 (82.7%)
	type 1	0 (0.0%)
	type 2	18 (17.3%)
Types prevalence in cecum region	type 0	100 (96.2%)
	type 1	4 (3.8%)
	type 2	0 (0.0%)
Types prevalence in ascending colon region	type 0	85 (81.7%)
	type 1	16 (15.4%)
	type 2	3 (2.9%)
Types prevalence in transverse colon region	type 0	87 (83.7%)
	type 1	7 (6.7%)
	type 2	10 (9.6%)

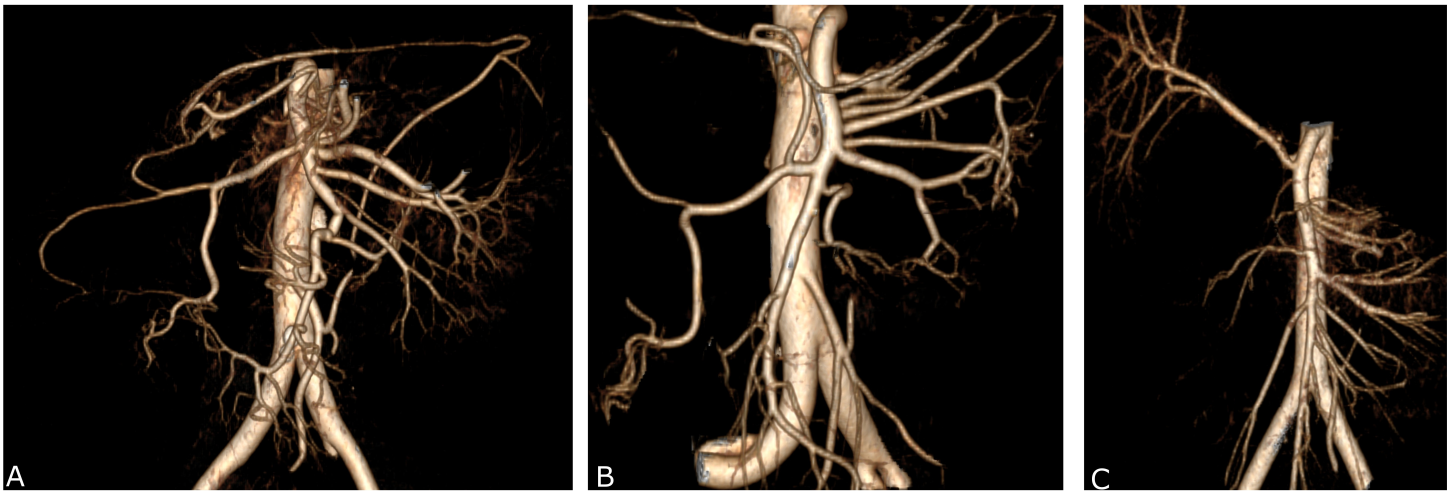
Table 2. Artery diameter comparison between superior mesenteric artery types. IC – ileocolic artery; IPD – inferior pancreaticoduodenal artery; MC – middle colic artery; RC – right colic artery; SMA – superior mesenteric artery

Artery diameter	**Type 0** mean ± SD	**Type 1a** mean ± SD	**Type 1c** mean ± SD	**Type 1t** mean ± SD	**Type 2a** mean ± SD	**Type 2p** mean ± SD	**Type 2t** mean ± SD	**p**
IC diameter	3.7 ± 0.8	4.4 ± 0.9	4.5 ± 1.1	4.8 ± 0.8	4.3 ± 1.2	4.3 ± 0.9	4.3 ± 0.7	0.009
MC diameter	3.6 ± 0.9	3.7 ± 0.5	3.5 ± 1.1	3.7 ± 0.5	2.8 ± 0.4	3.7 ± 1.3	3.6 ± 1.6	0.389
IPD diameter	2.7 ± 0.7	3 ± 0.8	2.3 ± 1	3.3 ± 0.8	2.5 ± 0.2	2.9 ± 0.7	2.8 ± 0.6	0.230
RC diameter	3.8 ± 0.9	3.9 ± 0.7	3.7 ± 0.7	3.7 ± 1	4 ± 0.8	3.6 ± 1	3.8 ± 1	0.962
SMA diameter	8.7 ± 1.4	8.5 ± 1.3	8.5 ± 1.5	8.8 ± 1.5	7.2 ± 0.5	8.8 ± 1.4	9 ± 1.3	0.457

Figure 1. Flow diagram for determining type of superior mesenteric artery.

Figure 2. Representatives for each superior mesenteric artery type; **A.** Superior mesenteric artery type 0 with visualized arch of Riolan; **B.** Superior mesenteric artery type 1, with single trunk for ileocolic, right colic, and middle colic artery; **C.** Superior mesenteric artery type 2, with common hepatic artery originating from superior mesenteric artery.


Evaluate SMA branches
Any abnormalities found? Analyze each region separately*
No
Type 0
Yes
Absence of main artery
No
Common trunk of main arteries
No
Additional artery in region
Yes
Yes
Yes
Additional artery in region
Additional artery in region
Type 2
Yes
No
Yes
No
Type 0
Type 1
Type 0
Type 1
Proposed regions are: p - pancreatic region, c - caecum, a - ascending colon, t - transverse colon.
Type report should include both type number and letter describing region.
Type 0 raporting should be omitted.


A
B
C