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Novel morphological classification of the normal pancreatic uncinate process based on computed tomography

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Abstract

Objectives: This study aimed to assess computed tomographic (CT) features of the normal pancreatic uncinate process (UP) and to classify UP types on the basis of morphological characteristics.

Methods: From November 2017 to December 2018, consecutive Han Chinese adults were enrolled in this retrospective study. Morphometric evaluation of the UP was performed using CT imaging, including assessment of the maximal transverse diameter of the UP (MTDUP) and pancreas head, and assessment of the relationship between the UP and superior mesenteric vessels.

Results: A total of 318 participants were studied. The mean MTDUP and maximal transverse diameter of the pancreas head were 15.89 ± 4.82 mm and 46.47 ± 7.18 mm, respectively. The mean MTDUP was 10.83 ± 2.59 mm for type I UP (21.70% of participants), 13.87 ± 2.35 mm for type II (13.21%), 17.08 ± 3.43 mm for type III (56.29%), and 23.74 ± 5.02 mm for type IV (8.81%). There was a significant difference among the UP types.

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Conclusions: Four types of normal UP can be defined on the basis of morphological CT features. The length of the UP significantly increases from types I to IV, and type III accounts for $> 50\%$.

Keywords
Uncinate process, pancreas, morphology, computed tomography, superior mesenteric vessel, radical pancreaticoduodenectomy, mesopancreas

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Introduction

The uncinate process (UP) is the caudal segment of the pancreatic head that hooks posteriorly to the superior mesenteric vessels.[1] However, precisely delineating the UP is difficult because of a lack of anatomical and surgical landmarks.[2,3] For research purposes, the UP is usually defined as the leftward projection from the right lateral margin of the superior mesenteric vein (SMV) (Figure 1).[4]

As part of the pancreatic head, the UP plays an important role in cases of radical pancreaticoduodenectomy (RPD). Resection of the UP during RPD is difficult because of the location of this process deep behind the mesenterico-portal confluence. However, resection of the UP is a major factor in surgical margin outcomes with RPD. The UP margin has been reported as the most common site of margin positivity, which is an important negative indicator of postoperative survival.[5] Recently, as understanding of pancreatic anatomy has increased, a new concept of the "mesopancreas" has emerged, although this theory has not been universally accepted.[6] According to this mesopancreas theory, RPD should involve complete clearance of the peripancreatic retroperitoneal tissue, particularly clearance of the entire UP.

Resection of the UP can be challenging because the normal UP can vary from patient to patient in terms of shape, transverse diameter, antero-posterior diameter, and relationship with the superior mesenteric vessels.[1] UPs with different morphologies should be resected with different surgical procedures; there is no standard surgical procedure that is suitable for all cases. Classifying UPs on the basis of morphological characteristics would allow for procedures to be chosen by taking into account the type of UP involved. However, no morphological classification of normal UPs has been described to date.

In this retrospective study, we aimed to analyze computed tomographic (CT) imaging features of normal pancreatic UPs in Han Chinese adults. On the basis of this information, we then created a classification system for normal UPs.

Methods

Study population

This study was approved by the Ethics Study Committee of Changzhou No. 2 People's Hospital (No. 2018KY024-01). Informed consent was obtained from all individual participants included in the study.

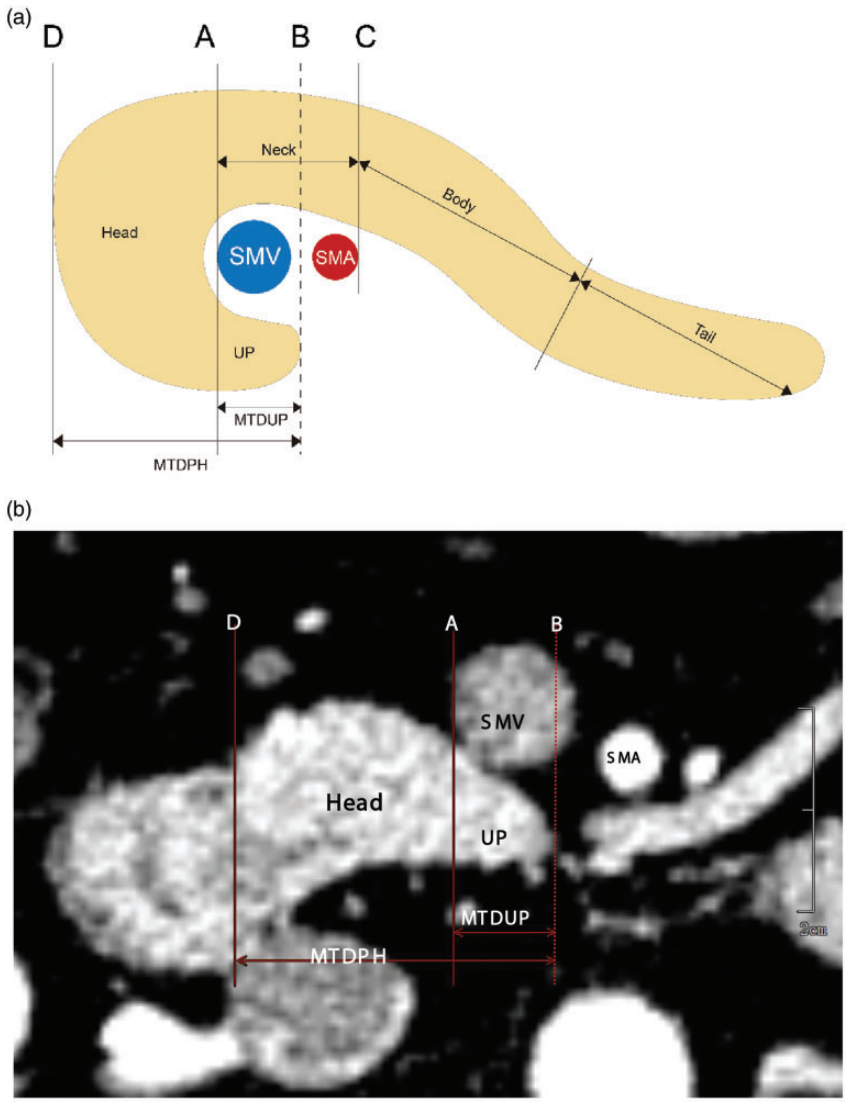

Figure 1. Definitions and measurement methods of the UP and pancreatic head. (a) Schematic diagram showing the boundaries of various segments of the pancreas and how these segments are measured. (b) Boundaries of the UP and pancreatic head and their measurements as shown on computed tomography. Line A indicates the right border of the SMV, line B indicates the left border of the UP, line C indicates the left border of the SMA, and line D indicates the right border of the pancreatic head.
UP, uncinate process; SMV, superior mesenteric vein; SMA, superior mesenteric artery; MTDUP, maximal transverse diameter of the UP; MTDPH, maximal transverse diameter of the pancreatic head.

From November 2017 to December 2018, consecutive Han Chinese adults who received a health checkup at our hospital were enrolled in the study. All participants underwent initial ultrasonic testing, and if one or more conditions were suspected, further CT scans were suggested by doctors. The inclusion criteria included the

following: 1) aged 18 to 60 years; 2) body mass index (BMI) between 18.5 and 24.9 kg/m^2[27]; 3) no history of hepatobiliary or pancreatic diseases; 4) no diabetes mellitus; 5) no autoimmune disease; 6) no history of abdominal tumors, trauma, or surgery; 7) no dysplasia; 8) no organ dysfunction (e.g., heart failure, liver function failure); and 9) the conditions diagnosed via a CT examination did not affect morphological study of the UP. Participants were excluded from the study if they met any of the following criteria: 1) CT images were unsuitable for analysis; 2) CT images indicated the presence of pancreatic disease, such as tumors or chronic pancreatitis; 3) CT images indicated the presence of other abdominal conditions that affect analysis of the UP; 4) allergy to CT contrast agents; 5) presence of situs inversus[8]; and 6) presence of pancreatic aberrance, such as pancreatic divisum or annular pancreas.

CT scans

Participants were imaged on a 64-slice dual-source CT scanner (Siemens Somatom Definition DS, Erlangen, Germany) after allergy testing of the contrast agent and fasting for 12 hours. After a plain scan was completed, a 2-mL/kg dose of nonionic iodinated contrast medium (Iodixanol; Yangtze River Pharmaceutical, Taizhou, China) was injected through a 16- or 18-gauge catheter into an antecubital vein at a flow rate of 5 mL/s. This was followed by a chaser bolus of 40 mL of saline solution. Images were obtained separately in the arterial phase (the delay time was determined by bolus-tracking software, generally at 20 to 25 s after injection, according to the time of abdominal aortic enhancement), portal venous phase (45 s after the first acquisition), and delayed phase (120 s after the first acquisition). The scanning parameters were as follows: collimation, 128 rows $\times$ 0.6 mm; section thickness, 5 mm; 120 kVp; and effective tube current-time charge, 200 mA. Coronal reconstructions were performed with a section thickness of 2 mm. Additionally, thin sections measuring 1 mm were obtained, and the acquired images were transferred to a workstation (Syngo Multimodality Workplace software; Siemens) to create high-resolution curved planar reformatted images of the pancreas.

Image analysis and definition of the UP

Images were evaluated using ONIS Viewer 2.5 (Digital Core, Co. Ltd., Tokyo, Japan). Both arterial and venous phases were used in this study for morphological analysis and measurement of the pancreas. For most cases, we used the arterial phase, especially the late arterial phase, because of clear imaging of the pancreas. For some cases, we used the early venous phase when the imaging was clearer than that in the arterial phase. The whole pancreas was traced from the cephalic beginning to the caudal end throughout the serial CT images on all scanning phases. Each segment of the pancreas was defined as shown in Figure 1.[4,8] Specifically, the UP was defined as the segment dorsal to the SMV and the superior mesenteric artery (SMA).[4,8] As such, the right border of the UP was defined as the right border of the SMV in the vertical plane[4] and the left border of the UP was defined as the ultimate left edge of the UP in the same vertical plane. All analyses were performed using CT sections that showed the maximal transverse diameter (MTD) of the UP (MTDUP). The MTDUP was measured from the right border to the left border of the UP (Figure 1). Using the same sections, the MTD of the pancreatic head (MTDPH) was measured from the utmost right border of the pancreas to the left border of the UP (Figure 1). The ratio of MTDUP/MTDPH was also calculated to

determine the length of the UP relative to the pancreatic head.

Morphological analysis was performed by two surgeons specializing in pancreatic surgery and two abdominal radiologists, all with more than 15 years of experience in their respective fields. Consensus on all of the cases was reached by all four readers.

Morphological classification of the UP

On the basis of the morphology, we identified four types of UP (Figure 2). The type I UP appeared behind the SMV and did not extend beyond the left lateral margin of the SMV. The type II UP projected leftward beyond the left lateral margin of the SMV, but did not reach the SMA. The type III UP appeared behind the SMA, but did not extend beyond the left lateral margin of the SMA. The type IV UP lay dorsal to the SMV and SMA and extended beyond the left lateral margin of the SMA.

Statistical analysis

All data were input into a computer-based database using IBM SPSS Statistics for Windows, version 19.0 (IBM Corp., Armonk, NY, USA). Quantitative data are expressed as mean ± standard deviation. One-way analysis of variance was used to compare the means of three or more independent groups. Levene's test was used to assess homogeneity of variance. For data with homogeneity of variance, the least significance difference test was used to compare the means of two groups. For data without homogeneity of variance, Welch analysis of variance and the Games–Howell test were used to compare the means of two groups. The Wilcoxon rank-sum test was used when certain conditions could not be met. The chi-square test was used to analyze count data. A P value < 0.05 was considered to be statistically significant.

Results

A total of 345 Han Chinese adults were initially enrolled in this study on the basis of the inclusion and exclusion criteria. Twenty-seven of these adults were excluded from the original sample on the basis of the exclusion criteria. Nineteen adults were excluded for poor image quality. One case was identified as annular pancreas. Six adults were diagnosed with liver cirrhosis and one was identified as having gastric carcinoma. Therefore, 318 participants were included in the final analysis (Table 1). No cases of congenital dysplasia of the UP (e.g., agenesis or hypertrophy) were observed among the participants. Morphological analysis showed that type I UP occurred in 21.70% of participants, type II in 13.21%; type III in 56.29%, and type IV in 8.81%. The mean MTDUP was found to account for approximately one third of the mean MTDPH.

Types of UP and related variables

When participants were classified on the basis of the type of UP, no significant difference was observed in sex, age, or BMI among the groups (Table 2). However, the MTDUP and MTDUP/MTDPH significantly increased with the type of UP from type I to types II, III, and IV ($P < 0.001$). The same results were found for the MTDPH ($P < 0.001$) with the exception of comparison between types I and II.

Associations of sex and related variables

When participants were classified by sex, no significant difference was observed in age, BMI, or type of UP between men and women (Table 3). However, the MTDUP, MTDPH, and MTDUP/MTDPH were significantly higher in men than in women (all $P < 0.001$), which suggested that men had a longer UP.

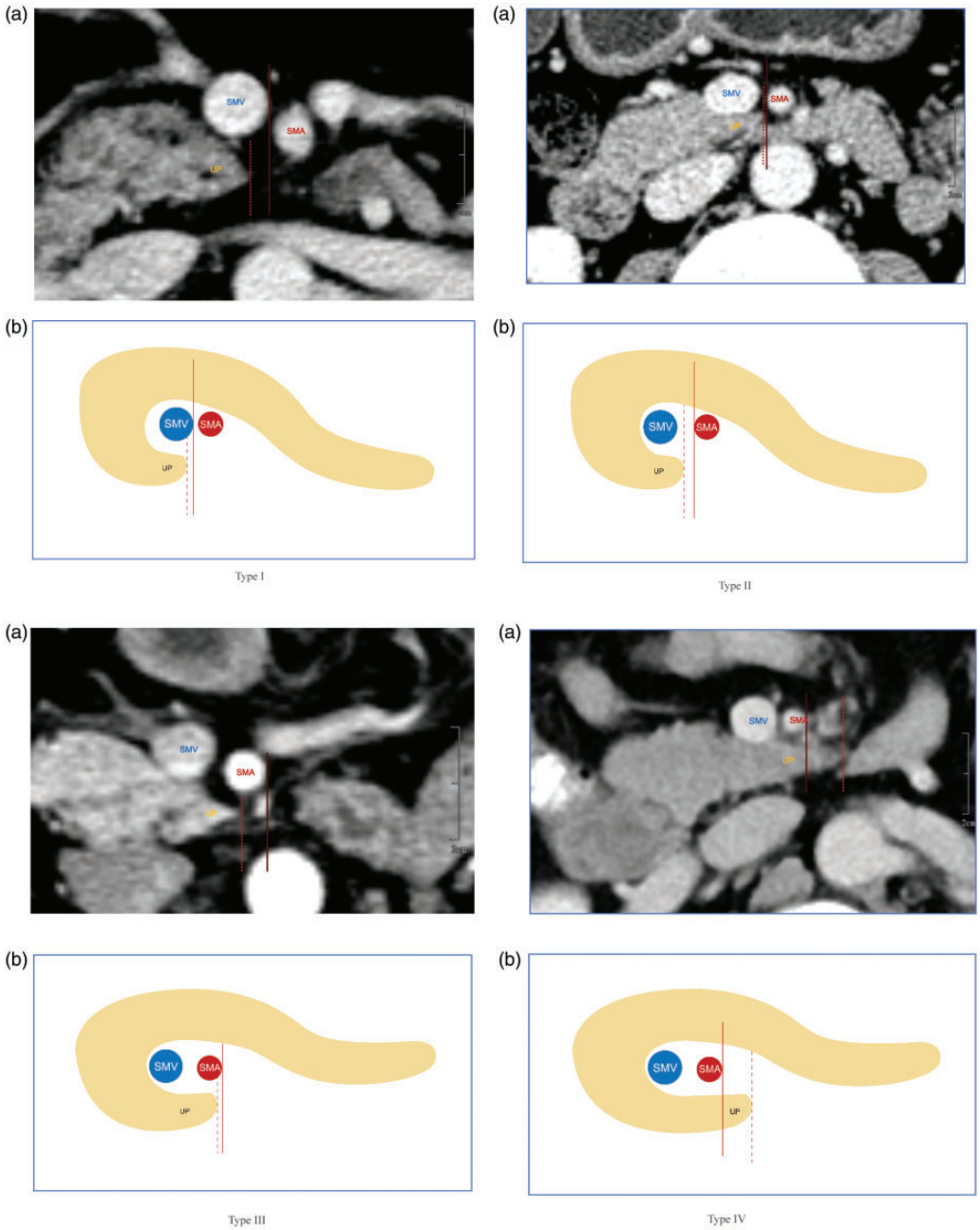

Figure 2. Morphological classification of the UP. UP types I to IV are shown. The vertical solid line indicates the border of the superior mesenteric vessel (SMV or SMA) and the dotted line indicates the ultimate edge of the UP. (a) Computed tomographic section of the UP and (b) schematic diagram of the UP.
SMA, superior mesenteric artery; SMV, superior mesenteric vein; UP, uncinate process.

Table 1. Characteristics of participants and UP morphology (n = 318).

Variable	Value
Sex, n (%)	
Male	163 (51.26)
Female	155 (48.74)
Mean age ± SD, years (range)	40.84 ± 8.42 (18–51)
Mean body mass index ± SD, kg/m^2 (range)	22.47 ± 3.62 (18.55–24.90)
Type of UP, n (%)	
I	69 (21.70)
II	42 (13.21)
III	179 (56.29)
IV	28 (8.81)
Mean MTDUP ± SD, mm (range)	15.89 ± 4.82 (2.84–35.05)
Mean MTDPH ± SD, mm (range)	46.47 ± 7.18 (29.50–74.60)
Mean MTDUP/MTDPH ± SD (range)	0.34 ± 0.09 (0.07–0.78)

SD, standard deviation; UP, uncinate process; MTDUP, maximal transverse diameter of the UP; MTDPH, maximal transverse diameter of the pancreatic head.

Associations of age and related variables

When participants were classified based on age, there was no significant difference in sex, BMI, type of UP, the MTDUP, the MTDPH, or the MTDUP/MTDPH among the age groups (Table 4).

Discussion

In this study, we analyzed the morphological characteristics of the normal UP in healthy adults. In this analysis, we created a novel classification system for UPs in which four UP types were defined according to the relationship of the UP to the SMA and SMV.

Our study showed no association between types of UP and sex, age, or BMI. However, there were associations between types of UP and the MTDUP, MTDUP/MTDPH, and MTDPH. We found that as the level of classification increased, the MTDUP, MTDUP/MTDPH, and MTDPH (except for types 1 and 2) increased. Therefore, a higher level of UP classification, which indicates a longer UP, suggests more difficulty for resection of the UP in clinical practice.

Resection of the UP is typically considered the most critical step in RPD because improper UP resection is associated with a high rate of positive margins (R1 resection).[5,9–12] For classic RPD, the standard technique of UP resection involves separating the UP from the right lateral wall of the SMA via serial ligation and then dividing the soft tissue attaching the UP to the SMA. In this situation, a linear stapler is sometimes used for rapid resection.[13] According to our classification system, this standard technique can be used to resect types I and II UPs because the left border of the UP does not extend to the SMA in these cases. However, this technique would not be effective for type III UPs, which project leftward behind the SMA, or for type IV UPs, which extend beyond the left lateral margin of the SMA. If the standard technique of UP resection is used in cases with type III or IV UP, incomplete resection of the UP will occur, potentially leading to a positive UP margin. Therefore, other strategies must be considered for complete resection of types III and IV UPs. These strategies might include the UP-first approach[14] or the artery-first

Table 2. Associations of types of UP and related variables (n = 318).

Variable	Type of UP				*P*
	I	II	III	IV	
n (%)	69 (21.70)	42 (13.21)	179 (56.29)	28 (8.81)	–
Sex, n (%)					
Male	33 (47.83)	20 (47.62)	90 (50.28)	20 (71.43)	0.159
Female	36 (52.17)	22 (52.38)	89 (49.72)	8 (28.57)	
Mean age ± SD, years (range)	42.48 ± 7.41 (19–50)	41.17 ± 8.21 (20–50)	40.26 ± 8.90 (18–50)	40.71 ± 6.67 (19–51)	0.304
Mean body mass index ± SD, kg/m^2 (range)	22.35 ± 4.85 (18.93–24.61)	21.19 ± 3.87 (18.90–24.90)	22.52 ± 5.77 (18.55–24.61)	21.89 ± 4.19 (19.05–24.38)	0.299
Mean MTDUP ± SD, mm (range)	10.83 ± 2.59 (2.84–16.81)	13.87 ± 2.35 (8.52–19.16)	17.08 ± 3.43 (6.00–27.48)	23.74 ± 5.02 (13.19–35.05)	<0.001
Mean MTDPH ± SD, mm (range)	43.76 ± 6.21 (29.50–56.19)	44.48 ± 6.97[§](30.03–59.46)	46.96 ± 6.69 (30.58–62.99)	53.00 ± 8.26 (33.74–74.60)	<0.001
Mean MTDUP/MTDPH ± SD (range)	0.25 ± 0.06 (0.07–0.39)	0.32 ± 0.07 (0.17–0.48)	0.37 ± 0.07 (0.18–0.78)	0.45 ± 0.10 (0.22–0.75)	<0.001

Significant *P* values are shown for comparison between two variables, except for §*P* = 0.584 for comparison between types I and II.
UP, uncinate process; MTDUP, maximal transverse diameter of the UP; MTDPH, maximal transverse diameter of the pancreatic head.

Table 3. Associations of sex and related variables (n = 318).

Variable	Sex		*P*
	Male	Female	
n (%)	163 (51.26)	155 (48.74)	–
Mean age ± SD, years (range)	40.55 ± 8.14 (18–50)	41.14 ± 8.71 (18–51)	0.288
Mean body mass index ± SD, kg/m^2 (range)	22.92 ± 3.92 (18.59–24.90)	22.05 ± 4.15 (18.55–24.80)	0.799
Type of UP, n (%)			
I	33 (20.25)	36 (23.23)	0.159
II	20 (12.27)	22 (14.19)	
III	90 (55.21)	89 (57.42)	
IV	20 (12.27)	8 (5.16)	
Mean MTDUP ± SD, mm (range)	17.48 ± 5.28 (5.38–35.05)	14.20 ± 3.60 (2.84–22.84)	<0.001
Mean MTDPH ± SD, mm (range)	48.22 ± 7.22 (30.03–74.60)	44.64 ± 6.68 (29.50–62.99)	<0.001
Mean MTDUP/MTDPH ± SD (range)	0.36 ± 0.10 (0.11–0.78)	0.32 ± 0.07 (0.07–0.52)	<0.001

SD, standard deviation; UP, uncinate process; MTDUP, maximal transverse diameter of the UP; MTDPH, maximal transverse diameter of the pancreatic head.

approach,[15] both of which differ from the classical resection technique. For the UP-first approach, the main procedure begins with dissection of the UP, allowing the operator to completely lateralize the UP to the right side and dissect the UP from the retroperitoneum with the superior mesenteric vessels under visual control.[14] This technique is considered suitable for any special anatomical situations.[14] For the artery-first approach, the operation begins with dissection of the SMA and the posterior pancreatic capsule, which is considered the most difficult area of dissection.[15,16] This approach is associated with an improved rate of R0 resection.[17,18] Both of these procedures may facilitate dissection and complete resection of types II and IV UPs.

The classification system that we have proposed might also be applied to research addressing the mesopancreas. The mesopancreas, which was first defined by Gockel et al. in 2007,[6] is considered a firm and well-vascularized structure extending from the posterior surface of the pancreatic head to behind the mesenteric vessels (SMA and SMV). The mesopancreas is regarded as the "holy plane" of RPD.[6] Surgical dissections along this plane ensure radical resection of the UP and the retropancreatic tissues, including the regional lymphatic tissues and neural plexuses.[6,19] For UPs that are classified as type I, II, or III in our system, the anatomical structure of the mesopancreas can be easily understood, and resection of the mesopancreas can be easily achieved. However, for type IV UPs, the anatomical structure of the mesopancreas is unclear, and how to best radically resect the UP and the mesopancreas is unknown. Further study on this issue is required.

In 44 of the 318 participants in this study, the SMA and SMV were closely adjacent or overlapping (data not shown). As a result, there was no space between the SMA and SMV, and therefore, no type II UPs were identified in these participants. This might partially explain why the proportion of type II UPs (13.21%) was lower than that of type I (21.70%) and type III (56.29%) UPs.

Table 4. Associations of age and related variables (n = 318).

Variable	Age, years			*P*
	18–30	31–40	41–51	
n (%)	53 (16.67)	66 (20.75)	199 (62.58)	–
Sex, n (%)				
Male	24 (45.28)	42 (63.64)	97 (48.74)	
Female	29 (54.72)	24 (36.36)	102 (51.26)	0.070
Mean body mass index ± SD, kg/m^2 (range)	22.13 ± 5.17 (18.55–24.87)	21.81 ± 4.02 (19.01–24.90)	22.66 ± 4.72 (18.73–24.90)	0.663
Type of UP, n (%)				
I	7 (13.21)	13 (19.70)	49 (24.62)	0.114
II	6 (11.32)	10 (15.15)	26 (13.07)	
III	39 (73.58)	37 (56.06)	103 (51.76)	
IV	1 (1.89)	6 (9.09)	21 (10.55)	
Mean MTDUP ± SD, mm (range)	15.84 ± 4.20 (2.84–26.55)	16.25 ± 4.90 (7.10–23.88)	15.78 ± 4.96 (4.47–35.05)	0.790
Mean MTDPH ± SD, mm (range)	46.55 ± 6.51 (31.09–59.91)	47.40 ± 6.55 (30.58–60.98)	46.14 ± 7.54 (29.50–74.60)	0.467
Mean MTDUP/MTDPH ± SD (range)	0.34 ± 0.09 (0.07–0.53)	0.34 ± 0.10 (0.16–0.78)	0.34 ± 0.09 (0.11–0.75)	0.972

SD, standard deviation; UP, uncinate process; MTDUP, maximal transverse diameter of the UP; MTDPH, maximal transverse diameter of the pancreatic head.

Only Han Chinese adults were included in this study. Therefore, our results may not be applicable to adults of other ethnicities. Further studies involving participants of different ethnicities should lead to improvement in the accuracy and applicability of this UP classification. Additionally, we did not perform a sample size calculation and only estimated the sample size before starting this study. Therefore, the limited number of samples may have affected the statistical significance of our results.

In conclusion, we propose a novel morphological classification system for the normal UP based on CT imaging features. This classification system can be used to guide RPD and may also be of use in future studies assessing the mesopancreas. Although further studies are required to evaluate this proposed system, we believe that this classification of UP types may prove useful in a variety of clinical and research applications.

Declaration of conflicting interest

The authors declare that there is no conflict of interest.

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