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ORIGINAL ARTICLE

Magnetic resonance imaging investigation of age-related morphological changes in the pancreases of 226 Chinese

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Abstract

Objective: To investigate the morphological changes with age in the pancreases of healthy individuals undergoing magnetic resonance imaging (MRI).

Methods: The participants were selected from adults who were undergoing physical examinations from January 2017 to September 2020 at Huadong Hospital. They were divided according to age, as broken down by decades into seven groups ranging from 20 to 29 years to ≥80 years of age. There were 30 to 35 cases for each decade. They were then divided into a young and middle-aged group (<60 years of age) and an elderly group (≥60 years of age). The morphological characteristics of the pancreases of each participant in the group were measured on magnetic resonance images. The characteristics included the pancreatic anteroposterior diameters and volumes. The relationships between the anteroposterior diameters of the pancreatic head, body, and tail and pancreatic volume and age were analyzed.

Results: A total of 226 magnetic resonance images from 112 (49.56%) men and 114 (50.44%) women, aged 22–93 (54.68 ± 19.52) years. The age ranges of the seven groups consisted of the following: 20–29 years (n = 33), 30–39 years (n = 32), 40–49 years (n = 32), 50–59 years (n = 31), 60–69 years (n = 35), 70–79 years (n = 33) and ≥80 years (n = 30). The age range and numbers of patients in the young and middle-aged group was 22–59 (40.09 ± 10.88) years (n = 128) and in the elderly group was 60–93 (73.74 ± 8.99) years (n = 98). The MRI findings characteristic of aging included pancreatic atrophy (especially of the pancreatic tail), pancreatic lobulation, uneven signal intensity, fatty degeneration, and widening of the main pancreatic duct. The respective anteroposterior diameters of the pancreatic head, body, and tail and the pancreatic volumes peaked at 30 to 39 years as follows: 28.03 ± 4.45 mm, 24.10 ± 4.27 mm, 24.57 ± 4.94 mm, 98.54 ± 26.56 cm^3; and then gradually decreased to 19.05 ± 3.59 mm, 16.00 ± 3.81 mm, 13.83 ± 3.39 mm, 45.02 ± 9.15 cm^3 at ≥80 years, for respective decreases of 32.03%, 33.60%, 43.71%, and 54.31%. The respective anteroposterior diameters of the pancreatic head, body, tail, and pancreatic volume in the elderly patients were 21.45 ± 4.15 mm, 18.14 ± 4.09 mm, 16.81 ± 4.37 mm, and 59.02 ± 21.44 cm^3, which were significantly smaller than the respective corresponding measurements in the young and middle-aged patients (26.09 ± 4.40 mm, 22.30 ± 4.42 mm, 22.08 ± 4.53 mm, and 88.32 ± 23.92 cm^3). The differences were statistically significant (t = 8.06, 7.24, 8.79, 9.54, respectively, $p < 0.0001$). The anteroposterior diameters of the pancreatic head, body, tail, and pancreatic volume were negatively correlated with age ($r = -0.53, -0.47, -0.56, -0.57$, respectively, $p < 0.0001$).

Conclusion: The anteroposterior diameters of the pancreatic head, body, tail, and the pancreatic volume all peaked at the age range of 30–39 years and then gradually decreased with increasing age. After the age of 60 years, pancreatic atrophy became increasingly obvious, with changes in shape and widening with age of the main pancreatic duct.

KEYWORDS
aging, magnetic resonance imaging, pancreas

1 | INTRODUCTION

The morphology of organs is based on function. The deterioration of organ function associated with aging can be understood by exploring age-related morphological and structural changes.

The pancreas is an essential organ that has both internal and external secretory functions. Understanding the patterns of aged-related changes in the morphological features and functions of the pancreas can clarify the pathogenesis of pancreatic diseases in the elderly and enable their prevention. This study analyzed the MRI images of the pancreases of 226 normal Chinese participants to reveal the age-related morphological changes of the pancreas.

2 | METHODS

2.1 | Inclusion criteria

We retrospectively examined the records of 226 adults who underwent upper abdominal MRI between 2017 and 2020. Participants who satisfied the following criteria were included: (1) good general condition and without active systemic diseases; (2) no history of pancreatic diseases (acute pancreatitis, chronic pancreatitis, and pancreatic tumor) or diabetes; (3) no history of systemic diseases involving the pancreas; (4) normal blood biochemical indicators (such as alanine aminotransferase, aspartate aminotransferase, blood glucose, and amylase); (5) normal body mass index (BMI); (6) normal pancreatic MRI scans.

2.2 | Distribution of participants and research contents

The participants were divided according to age broken down by decades into the seven following groups: 20–29 years (n = 33), 30–39 years (n = 32), 40–49 years (n = 32), 50–59 years (n = 31), 60–69 years (n = 35), 70–79 years (n = 33), and ≥80 years (n = 30). They were further divided into a young and middle-aged group (<60 years of age) and an elderly group (≥ 60 years of age). The general morphological characteristics of the pancreas in the pancreatic MRI of the participants in each group were observed. The differences between the pancreatic volumes and anteroposterior diameters of the pancreatic head, body, and tail of each group and their relationships with age were analyzed. This study was approved by Ethics Committee of Huadong Hospital (Ethics Committee Number: 2020K091).

2.3 | MRI technique

MRI was performed by the Siemens Magnetom Trio 3.0T system. Each participant was in the supine position during the routine MRI examination of the upper abdomen and was scanned from head to foot. The MRI protocol included in-phase and opposed-phase T1-weighted fast spoiled gradient-echo imaging (FSPGRI) and fat-saturated T2-weighted fast spin echo imaging (FSEI); (T1WI:repetition/echo time (TR/TE)) = 220–350/5.1–7 ms; T2WI:TR/TE = 1600/70 ms; slice thickness, 6 mm; interslice gap, 1.0 mm; matrix, 256×256, field of view (FOV), 300–380 mm). Magnetic resonance cholangiopancreatographic (MRCP) used 3D fast spin echo sequence, TR 3529.00 ms, TE 558.96 ms. Opposed-phase T1 weighted sequence images and MRCP images were selected for analysis and processing in this study.

2.4 | Image analysis

Clinical Mimics 20.0 software was used retrospectively to observe and analyze the collected MRI images. The anteroposterior diameters of the head, body, and tail of the pancreas were measured and recorded. The three-dimensional reconstruction function was used to reconstruct the pancreas in order to calculate the pancreatic volume. Two radiologists with 20 years and 5 years of experience in abdominal MRI performed the qualitative and quantitative analyses and obtained decisions by consensus.

2.5 | Measurement of anteroposterior pancreatic diameters

The anteroposterior diameters of the head, body, and pancreatic tail were measured on the opposed-phase T1-weighted image by the technique of Heuck et al.[1] The measurement of the pancreatic head was performed on the right side of the mesenteric vessels, the head was measured with a line drawn from the left border of the vertebral body, and the tail was measured with a line drawn from the internal border of the left kidney (Figure 1). Then the maximal anteroposterior diameter that was perpendicular to the pancreas was measured.

2.6 | Measurement of pancreatic volumes

Clinical Mimics 20.0 software was used to reconstruct the pancreas. The edge of pancreatic parenchyma was drawn on each cross-sectional image with the brush tool in this software (Figure 1). The software then automatically created a three-dimensional model of the pancreas and calculated the pancreatic volume.

2.7 | Statistical analysis

SPSS 23.0 statistical software was used for analysis. Kolmogorov-Smirnov test was used to verify whether the data conformed to the normal distribution. All measurements conformed to the normality were described as $\bar{x} \pm s$. Multiple groups were compared by one-way ANOVA with comparison by LSD method. The t-test was used to assess the difference between quantitative variables of the groups. The Spearman correlation coefficient was determined to assess the association between two quantitative variables. Statistical significance was established at the $p < 0.05$ level.

3 | RESULTS

3.1 | Patient characteristics

A total of 226 eligible participants were enrolled, including 112 men (49.56%) and 114 women (50.44%) aged 22–93 (54.68 ± 19.52) years. The age distribution of each group was as follows: 20–29 years (n = 33, male: 16 (48.48%), female: 17 (51.52%)), 30–39 years (n = 32, male: 16 (50.00%), female: 16 (50.00%)), 40–49 years old (n = 32, male: 16 (50.00%), female: 16 (50.00%)), 50–59 years (n = 31, male: 16 (51.61%), female: 15 (48.39%)), 60–69 years (n = 35, male: 17 (48.57%), female: 18 (51.43%)), 70–79 years (n = 33, male: 16 (48.48%), female: 17 (51.52%)) and ≥80 years (n = 30, male: 15 (50.00%), female: 15 (50.00%)). The age range and numbers of patients in the young and middle-aged group was 22–59 (40.09 ± 10.88) years (n = 128) and in the elderly group was 60–93 (73.74 ± 8.99) years (n = 98).

3.2 | Manifestations of the aging pancreas on MRI

The pancreas is a retroperitoneal organ located in the posterior abdominal wall and shows marked morphological differences between individuals. In young individuals, the pancreas tends to show a regular shape, with homogeneous signal, flat edges, clear boundaries distinct from surrounding tissues, and invisible main pancreatic duct on opposed-phase T1-weighted images (Figure 2). MR pancreatic

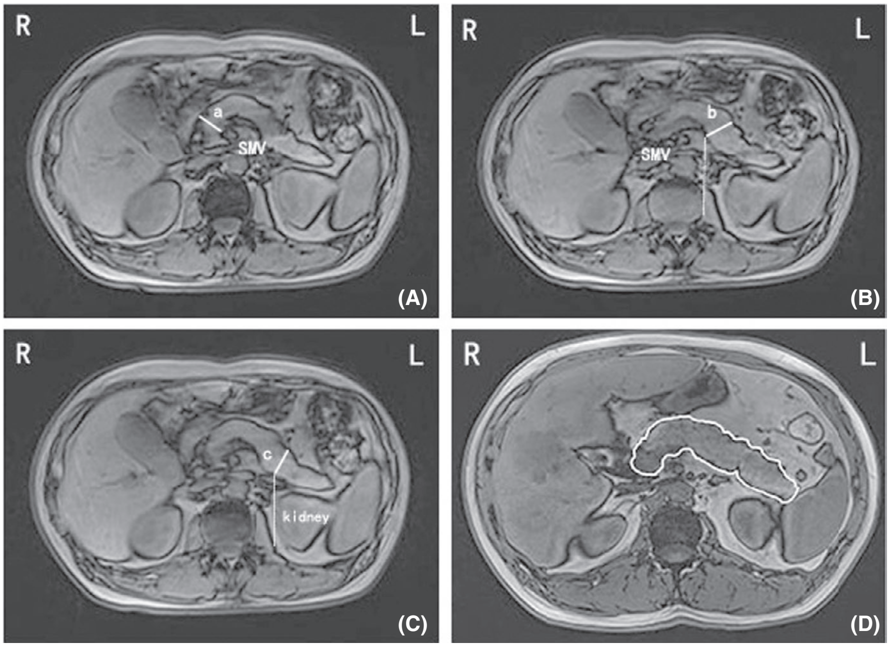

FIGURE 1 Methods used to measure anteroposterior pancreatic diameters and pancreatic volumes. Note: SMV in A and B = superior mesenteric vein. White solid lines ‘a,’ ‘b,’ and ‘c’ in figures A, B, and C = anteroposterior diameters of the pancreatic head, body and tail. The white solid line in D delineates the pancreas on the T1-weighted opposed-phased image

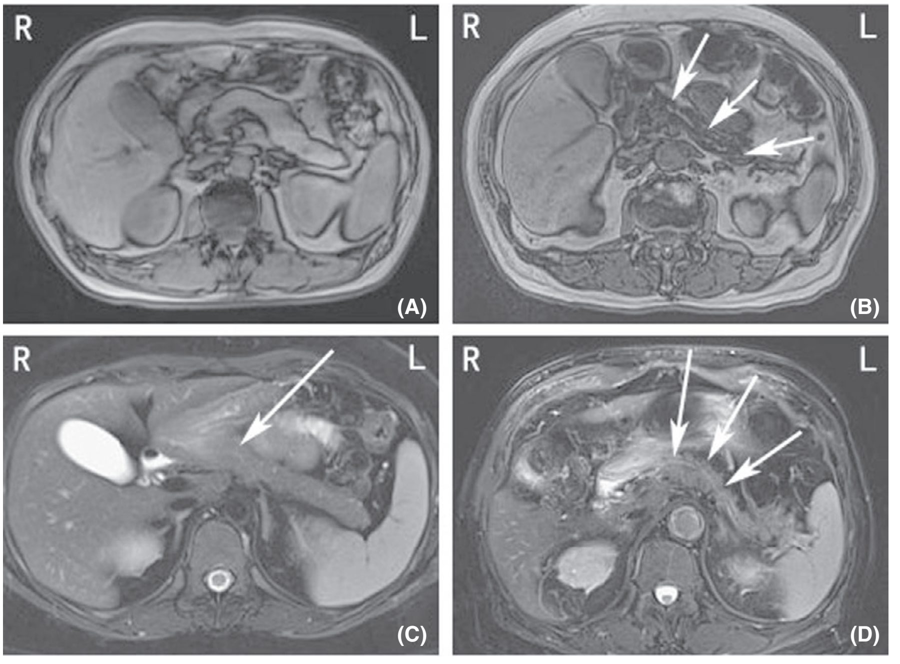

FIGURE 2 Pancreatic magnetic resonance images of a young versus an elderly individual. A, an opposed-phase T1-weighted image of a 27-year-old man. B, an opposed-phase T1-weighted image of an 83-year-old man (arrows indicate atrophy of the pancreas). C, a MRCP image of a 35-year-old man (arrow indicates that the normal main pancreatic duct is invisible). D, an MRCP image of an 85-year-old man (arrows show apparent main pancreatic duct, which is markedly wider than the young)

images of older individual show scattered and diffuse lobulation, fatty degeneration, uneven signal intensity, and a widened main pancreatic duct (Figure 2).

3.3 | Anteroposterior pancreatic diameters

The anteroposterior diameters of the head, body, and tail were 13.50–36.80 (24.08 ± 4.87) mm, 8.30 ~ 35.20 (20.50 ± 4.74) mm, and 8.00~ 34.70 (19.80 ± 5.16) mm, respectively (Table 1). The variations and trends in the anteroposterior diameters of the pancreatic head, body, and tail in relation to aging are shown in Figure 3. The anteroposterior diameters of pancreatic head, body, and tail manifested the same trends, obtaining maximum values at 30–39 years, with subsequent gradual decreases, especially for the pancreatic tail. Pancreatic anteroposterior diameters of the head, body, and tail of the pancreas in the young and middle-aged and the elderly groups are shown in Table 2. The anteroposterior diameters of the pancreatic head, body, and tail were significantly decreased in the elderly compared with the young and middle-aged group (t = 8.06, 7.24, 8.79, 9.54, $p < 0.0001$).

3.4 | Pancreatic volumes

The pancreatic volumes of 226 participants ranged from 24.22 to 161.36 (75.62 ± 27.08) cm^3. The volumes of each group are shown in Table 1, and the graph showing changes in pancreatic volumes with age is shown in Figure 3. The pancreatic volumes gradually increased to peak during the ages ranging from 20–39 years, gradually decreased after 40 years of age and then decreased faster after 60 years of age. The pancreatic volumes of the two groups of patients are shown in Table 2. The mean pancreatic volume of the elderly patients was significantly reduced compared with the volume of the young and middle-aged patients, $p < 0.0001$.

3.5 | Correlation analysis

Table 3 shows the results of the correlation of pancreatic anteroposterior diameters and pancreatic volumes of 226 participants with age. The pancreatic anteroposterior diameters of the pancreatic head, body, and tail and the pancreatic volume were negatively correlated with age ($r = -0.53, -0.47, -0.56, -0.57$, respectively; $p < 0.0001$).

4 | DISCUSSION

The pattern of aging in vital organs along with the characteristics of the aged organ is an important field of gerontological research. The morphology of the pancreas determines its functional status, especially its reserve function. There have only been a few studies on age-related changes of pancreatic morphology. Autopsies,[2] computerized tomographic scan[3] and MRI technology,[4] endoscopic ultrasound elastography,[5] and endoscopic retrocholangiography (ERCP)[6,7] have been used to study the age-related morphological changes of the human pancreas. The main conclusion of these studies was that the weights, anteroposterior diameters, and volumes of the pancreas peaked before the age of 40 years and gradually decreased thereafter. The main pancreatic duct became slightly dilated.[8] It could be found that when observing human organs in the Opposed-Phase T1 weighted sequence images, the tissue edges could be better displayed, which was convenient for description and measurement. MR technology was more sensitive in diagnosis of pancreatic cysts than computerized tomographic scan. Those with

TABLE 1 Measurements of pancreatic AP head, AP body, AP tail, and pancreatic volumes ($\bar{x} \pm s$)

Age group (years)	Number of patients	AP head (mm)	AP body (mm)	AP tail (mm)	Pancreatic volume (cm^3)
20–29	33	25.55 ± 3.24	21.59 ± 4.37	21.39 ± 4.06	86.60 ± 21.97
30–39	32	28.03 ± 4.45*	24.10 ± 4.27*	24.57 ± 4.94*	98.54 ± 26.56*
40–49	32	27.29 ± 4.84	22.96 ± 4.69	22.25 ± 4.76	89.30 ± 22.55
50–59	31	23.45 ± 3.62*	20.52 ± 3.58	20.07 ± 3.05	78.60 ± 20.98
60–69	35	23.37 ± 4.19*	20.11 ± 3.56	19.96 ± 3.99	70.11 ± 25.34*
70–79	33	21.59 ± 3.49*	18.00 ± 3.96*	16.19 ± 3.26*	59.98 ± 17.80*
≥80	30	19.05 ± 3.59*	16.00 ± 3.81*	13.83 ± 3.39*	45.02 ± 9.15*
F value		20.12	14.88	26.17	23.30
p value		<0.001	<0.001	<0.001	<0.001

Note: AP head, anteroposterior diameter of pancreatic head; AP body, anteroposterior diameter of pancreatic body; AP tail, anteroposterior diameter of pancreatic tail. *$p < 0.05$ compared with the 20–29-year-old group.

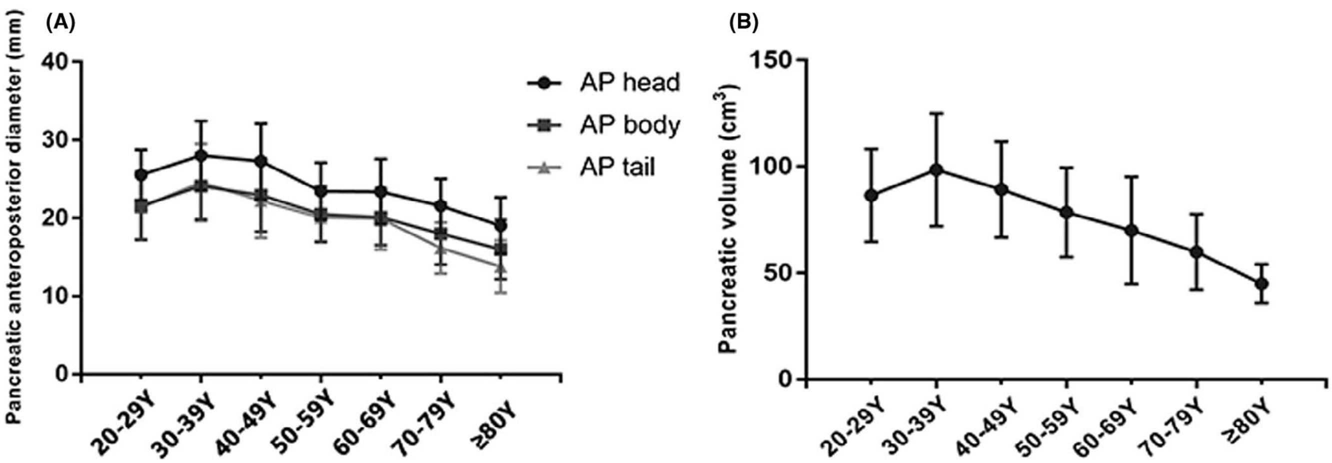

FIGURE 3 A, Pancreatic anteroposterior diameters and B, pancreatic volumes with age of patients. Note: AP head (anteroposterior diameter of pancreatic head), AP body (anteroposterior diameter of pancreatic body), AP tail (anteroposterior diameter of pancreatic tail)

TABLE 2 Pancreatic anteroposterior diameters and volumes in the young and middle-aged and the elderly groups ($\bar{x} \pm s$)

Variables	Young and middle-aged patients ($n = 128$)	Elderly patients ($n = 98$)	*T* value	*p* value
AP head (mm)	26.09 ± 4.40	21.45 ± 4.15	8.06	<0.001
AP body (mm)	22.30 ± 4.42	18.14 ± 4.09	7.24	<0.001
AP tail (mm)	22.08 ± 4.53	16.81 ± 4.37	8.79	<0.001
Pancreatic volume (cm^3)	88.32 ± 23.92	59.02 ± 21.44	9.54	<0.001

Note: AP head, anteroposterior diameter of pancreatic head; AP body, anteroposterior diameter of pancreatic body; AP tail, anteroposterior diameter of pancreatic tail.

pancreatic cysts needed to be excluded in this study. Thus far, to our best knowledge, few reports on the morphological changes in MR images of the human pancreas in Chinese population have been published.

In this study, the method of measurement established by Heuck et al.[1] was adopted to explore the trends with increasing age of anteroposterior pancreatic diameters and volumes. The morphological characteristics of the pancreas in healthy Chinese participants were vividly illustrated. The main conclusions of this study are basically consistent with the conclusions of other reports and include the following: (1) senescent pancreases manifested atrophy, serrated edges, and a widened main pancreatic duct. The atrophy was especially obvious in the tail of the pancreas. Glaser and Stienecker concluded that the main pancreatic duct widened with age; however, if the maximum diameter of the duct in a patient was found to be >3 mm, the patient should be evaluated for pancreatic diseases.[9] (2) The anteroposterior diameters of the pancreatic head, body and tail and pancreatic volume reached the maximum

TABLE 3 Correlation analysis of pancreatic anteroposterior diameters and volume and age

	AP head (mm)	AP body (mm)	AP tail (mm)	Pancreatic volume (cm^3)
r value	−0.528	−0.472	−0.562	−0.574
p value	<0.001	<0.001	<0.001	<0.001

Note: AP head, anteroposterior diameter of pancreatic head; AP body, anteroposterior diameter of pancreatic body; AP tail, anteroposterior diameter of pancreatic tail.

at the age range of 30–40 years, which were 28.03 ± 4.45 mm, 24.10 ± 4.27 mm, 24.57 ± 4.94 mm, 98.54 ± 26.56 cm^3 respectively. The minimum values were seen in patients ≥80 years of age, as follows: 19.05 ± 3.59 mm, 16.00 ± 3.81 mm, 13.83 ± 3.39 mm, 45.02 ± 9.15 cm^3, respectively. The pancreatic anteroposterior diameters and pancreatic volume gradually decreased in patients older than 40 years and the decrease accelerated after 60 years, the decline percentage of which were 32.03%, 33.60%, 43.71%, and 54.31%, respectively. The results indicate that there were two turning points, namely at 40 years and at 60 years of age. Since the measurement of anterior and posterior diameters of pancreas is easily affected by pancreatic morphology, the change of pancreatic volume with age can more directly reflect the change of pancreatic parenchyma with aging. Anteroposterior diameters of pancreas can respectively reflect the severity of pancreatic atrophy with senescence in pancreatic head, body, and tail.

This study described the morphological characteristics of the pancreas as seen on MR scans of healthy elderly participants. Although chronic pancreatitis and diabetes can cause pancreatic atrophy, under no circumstances should the manifestations of the physiologically aging pancreas be attributed to these conditions. Clinicians should increase their understanding of the morphological characteristics of the aging pancreas in order to differentiate physiological changes due to aging from pathological changes.[10,11]

Studies of histological preparations of human and animal pancreases have revealed that stromal hyperplasia, fibrillation, acinar atrophy, decreased numbers of acinar cells, fatty infiltration, and papillary hyperplasia in the epithelium of the pancreatic duct were common in aging pancreases. The results of ultrastructural studies have indicated that the amount of lipids gradually increases in the matrix of ductal epithelial cells, and mitochondrial vacuoles become increasingly obvious in acinar cells.[12,13] These changes should be taken into account as the histological basis of the morphological changes of the pancreas seen in MR scans.

Does physical aging or atrophy of the pancreas lead to deterioration in the exocrine function of the pancreas? Torigoe et al. used noninvasive dynamic magnetic resonance cholangiopancreatography to evaluate the relationship between pancreatic exocrine function and aging and found that pancreatic exocrine function decreased physiologically with aging.[14] Laugier et al. collected duodenal fluid to evaluate pancreatic exocrine function after a single intravenous injection of secretin and cholecystokinin in 180 participants without pancreatic diseases aged 16–83 years. They found that the secretion volumes of duodenal fluid and bicarbonate increased linearly until 43 and 34 years old, respectively, and then began to decline gradually. The concentrations and secretion volumes of lipase, phospholipase, and chymotrypsin all showed a gradual decrease in participants after 30 years of age ($p < 0.02$), indicating that the pancreatic reserve exocrine function decreases with age.[15] It can be found that the rate of hyposecretion of the pancreas was increasing after the tests of the pancreatic exocrine function of 914 subjects without pancreatic diseases, the percent of which was 15.5% in those who were older than 65 years old.[16] The results of these studies show that the general morphology, histology, and ultrastructure of the aged pancreas are consistent with a decline in the exocrine function. These findings provide a powerful theoretical basis for using clinical supplements of pancreatic enzymes in the elderly to treat patients with severe dyspepsia due to pancreatic exocrine insufficiency.[17]

Follow-up studies should increasingly focus on the mechanisms involved in pancreatic senescence and explore targets of intervention that might delay pancreatic senescence.

5 | CONCLUSION

The anteroposterior diameters of the pancreatic head, body, tail, and the pancreatic volume all peaked at the age range of 30–39 years and then gradually decreased with increasing age. After the age of 60 years, pancreatic atrophy became increasingly obvious, with changes in shape and widening with age of the main pancreatic duct.

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CONFLICT OF INTEREST

None to disclose.

AUTHOR CONTRIBUTIONS

All authors wrote the paper. Lu Wang: design, data collection, and statistical analysis. Songbai Zheng: design, literature review, coordination, and modifications. Huihui Jia: Observation and analysis of the images. Guangwu Lin: Observation and analysis of the images.

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