VIA MEDICA

ORIGINAL ARTICLE

Folia Morphol.
Vol. 69, No. 4, pp. 216–224

ISSN 0015–5659
www.fm.viamedica.pl

Foetal development of the pancreas

K. Desdicioglu, M.A. Malas, E.H. Evcil

Department of Anatomy, Medical Faculty, Suleyman Demirel University, Isparta, Turkey

[Received 29 June 2010; Accepted 30 July 2010]

In the present study, we aimed to gather morphometric data on the localisation and development of the pancreas during the foetal period. The study was carried out on 222 human foetuses aged 9–40 weeks of gestation with no external pathology or anomaly. The abdominal wall was dissected after general external measurements of the foetuses were carried out. Data on the localisation of the pancreas in the abdominal cavity and its localisation relative to the median plane, xiphoid process, and umbilicus were acquired and various morphometric parameters including the length of the pancreas and heights of the head and body of the pancreas were measured. It was found that, in the foetal period, the foetal pancreas was primarily accumulated on the transverse plane passing through the umbilicus, and on the other quadrants. Means and standard deviations of all morphometric parameters were calculated for each gestational week, month, and trimester. There were significant relations between the parameters and gestational age ($p < 0.001$). There were no differences in any of the parameters between sexes ($p > 0.05$). In conclusion, morphometric and location data on foetal pancreases acquired in the present study will contribute to other studies carried out in obstetrics, perinatology, forensic medicine, and foetal pathology departments, aimed at identifying anomalies, pathologies, and variations of the pancreas and treatment of such cases. (Folia Morphol 2010; 69, 4: 216–224)

Key words: pancreas, morphometry, developmental anatomy, foetal period, human foetus

INTRODUCTION

The pancreas is an important alveolar gland with endo- and exocrine functions. It consists of four parts: the head, neck, body, and tail of the pancreas [5]. Embryologically, the pancreas develops from two separate buds: the dorsal and ventral buds. The dorsal and ventral buds fuse in the seventh week of gestation [9, 12, 13].

During the foetal period that spans the ninth week of gestation and the parturition, the development of the pancreas is critical since abnormal shapes of the pancreas may be related to congenital malformations [9]. Furthermore, it has been argued that pancreatic pathologies observed in adults may be related to foetal development, and that certain pathologies started during the foetal life. Therefore, prenatal diagnosis of these pathologies is claimed to be quite important [8, 11, 14, 15].

Studies on prenatal development of the pancreas have focused primarily on pancreatic pathologies [11, 14, 15]. These studies are usually conducted using obstetric ultrasound [2, 4, 6, 10]. However, these radiological studies have reported that visualisation of the foetal pancreas is better in the later stages of the second trimester. This, in turn, hinders and delays diagnosis of pancreatic pathologies

Address for correspondence: Dr. K. Desdicioglu, Department of Anatomy, Medical Faculty, Suleyman Demirel University, 32260 Isparta, Turkey, tel: +90 246 211 33 01, fax: +90 246 237 11 65, e-mail: kdesdici@yahoo.com

[2, 4, 6, 10]. Krakowiak-Sarnowska et al. [7] carried out a study on the prenatal development of the pancreas using 60 foetuses aged 17–40 weeks of gestation in which they measured the length of the pancreas, the widths of the head and body of the pancreas, and determined the localisation of the pancreas relative to the vertebral column [7]. Callen [1] and Fleischer et al. [3] reported the difficulties of visualising the embryonic and foetal pancreas with ultrasound. Hill et al. [6] argued that gestational age and position of the foetus was important in finding the localisation of the foetal pancreas. They also claimed that the reliability of the data on the foetal pancreas was insufficient before the 14th week of gestation [6]. In a study by Hata et al. [4], the researchers reported that the foetal pancreas was best depicted between weeks 20 and 23 of gestation. Data obtained in previous studies on the foetal pancreas are related to certain periods of the foetal period [4, 6, 10]. Furthermore, measurements on the foetal pancreas are possible only after a certain gestational age and lack detailed information [4, 6, 10].

In contrast to previous studies, we aimed to gather detailed morphometric data on the foetal pancreas and its localisation through anatomical dissections in a large series of human foetuses.

MATERIAL AND METHODS

The present study was carried out on 222 human foetuses (114 males, 108 females) aged between 9 and 40 weeks of gestation and with no external pathology or anomaly. All were medical or spontaneous abortions (unknown causes) or stillbirths and neonatal deaths (from premature and prenatal asphyxia) obtained from Isparta Maternity and Paediatric Hospital from 1996 to 2005. The foetuses were fixed by immersion in 10% formalin. Written consent from the families and approval from the Ethics Board of the Faculty of Medicine, Süleyman Demirel University were obtained prior to the commencement of the study. The gestational ages of the foetuses were determined using crown--rump length (CRL), bi-parietal diameter (BPD), head circumference (HC), femur length (FL), and foot length (9). The foetuses were assigned to one of four groups according to their gestational age: Group I (1st trimester, 9–12 weeks), Group 2 (2nd trimester, 13–25 weeks), Group 3 (3rd trimester, 26––37 weeks), and Group 4 (term, 38–40 weeks).

Foetuses were also divided into eight groups according to their gestational age in months; foetuses aged 9–12, 13–16, 17–20, 21–24, 25–28, 29–32, 33–36, and 37–40 weeks were assigned to 3-, 4-, 5-, 6-, 7-, 8-, 9-, and 10-month groups, respectively.

Initially, general parameters, namely CRL, HC, BPD, FL, and foot length, were measured for each foetus. This was followed by measuring the thoraco-abdominal parameters including thorax circumference, thoracic width, bi-crest width, and the distance between the xiphoid process and umbilicus. All measurements were performed as described below using a measuring tape, plastic and metal rulers, silk suture thread, and thin metal rods.

During anatomical dissections, we examined the relationships between the pancreas and the liver, stomach, duodenum, transverse colon, kidneys, and adrenal glands. By dissecting the neighbouring structures we exposed the pancreas. In this way, the boundaries of the superior, inferior, and lateral surfaces of the pancreas and its relation to the neighbouring structures were established. When the dissections were completed, pancreatic parameters were measured.

Localisation of the pancreas: Regarding the localisation of the pancreas, the abdomen was divided into four quadrants (A — right upper quadrant, B — left upper quadrant, C — right lower quadrant, D — left lower quadrant) by horizontal and vertical lines passing through the umbilicus, and the localisation of the pancreas was determined with respect to these quadrants (Fig. 1).

The methods described in previous studies were used to measure the pancreatic parameters (Fig. 2) [4, 7, 10].

Length of pancreas (L): The transverse distance between the vertical axes passing through the lateral-most points of the pancreas.

Height of the head of pancreas (Hhp): The vertical distance between the transverse axes passing through the superior-most and inferior-most points of the head of the pancreas.

Height of the body of the pancreas (Hbp): The vertical distance between the transverse axes passing through the superior-most and inferior-most points of the body of the pancreas.

Distance between the upper pancreas (Hp) and xiphoid process (Xp): The vertical distance between the transverse axes passing through the superior-most point of the head of the pancreas and the xiphoid process.

Distance between the upper pancreas (Hp) and umbilicus (U): The vertical distance between the transverse axes passing through the superior-most point of the head of the pancreas and the umbilicus.

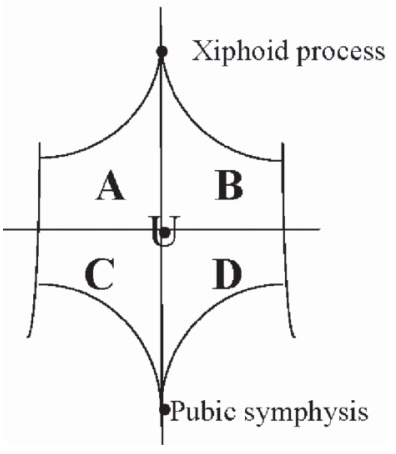

Figure 1. The abdomen was divided into four quadrants: A — the right upper quadrant; B — the left upper quadrant; C — the right lower quadrant; D — the left lower quadrant by planes which passed through the umbilicus horizontally and vertically. The location of the pancreas mass in the abdominal cavity was determined according to these quadrants; U — umbilicus.

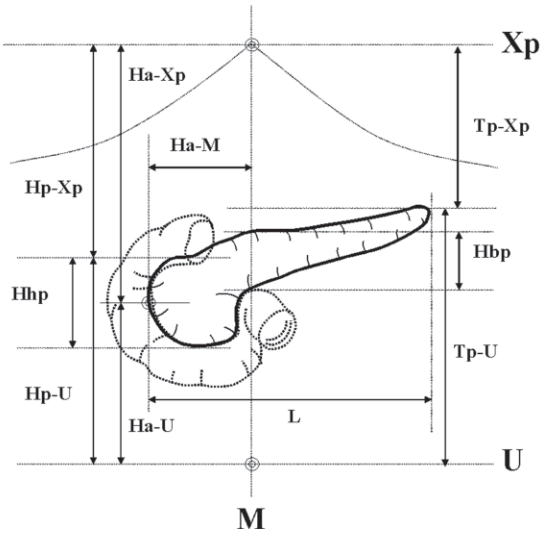

Figure 2. Measurement parameters on the pancreas; Xp — transverse axis through the xiphoid process, U — transverse axis through the umbilicus; M — vertical axis through the median plane; L — length of pancreas; transverse distance between vertical axes passing through the outermost points of the pancreas; Hhp — height of the head of the pancreas; vertical distance between transverse axes passing through the upper- and lower--most points of the head of pancreas; Hbp — height of the body of pancreas; vertical distance between transverse axes passing through the upper- and lower-most points of the body of the pancreas; Hp–Xp — vertical distance between transverse axes passing through the upper-most point of the head of the pancreas and the xiphoid process; Hp–U — vertical distance between transverse axes passing through the upper-most point of the head of the pancreas and the umbilicus, Tp–Xp — vertical distance between transverse axes passing through the tip of the tail of the pancreas and the xiphoid process; Tp–U — vertical distance between transverse axes passing through the tip of the tail of the pancreas and the umbilicus; Ha–M — transverse distance between the vertical axis passing through the hepatopancreatic ampulla and the median plane; Ha–Xp — vertical distance between transverse axes passing through the hepatopancreatic ampulla and the xiphoid process; Ha–U — vertical distance between transverse axes passing through the hepatopancreatic ampulla and the umbilicus.

Distance between the tail of the pancreas (Tp) and umbilicus (U): The vertical distance between the transverse axes passing through the tip of the tail of the pancreas and the umbilicus.

Distance between the tail of the pancreas (Tp) and xiphoid process (Xp): The vertical distance between the transverse axes passing through the tip of the tail of the pancreas and the xiphoid process.

Distance between the papilla of Vater (Ha) and the median plane (M): The transverse distance between the vertical axis passing through the papilla of Vater and the median plane.

Distance between papilla of Vater (Ha) and the xiphoid process (Xp): The vertical distance between the transverse axes passing through the papilla of Vater and the xiphoid process.

Distance between papilla of Vater (Ha) and the umbilicus (U): The vertical distance between the transverse axes passing through the papilla of Vater and the umbilicus.

Statistical analysis

Means of each parameter and standard deviations were computed with respect to sex, gestational age, and group using the SPSS statistical package (SPSS Inc, Chicago, Illinois, USA). The level of statistical significance was set at 0.05. Non-parametric tests were used to compare groups due to insufficient data in some groups. First, Kruskall Wallis ana-lysis of variance was performed, and significant groups according to Kruskall Wallis analysis of variance were compared pair-wise using Mann-Whitney U test. Levels of significance were assessed with Bonferroni correction. Relationships between para-meters and gestational age (weeks) were tested using Pearson's correlation. Comparisons of parame-tric variables between sexes were performed by Student-t test (for all cases) and by Mann-Whitney U test (within each group, for separate comparisons). With respect to non-parametric data, the χ^2 test was used for comparisons of percentage distributions among groups (p and χ^2

Table 1. General and thoraco-abdominal parameters (shown as means [mm]) with respect to foetal age

Age (weeks)	N	Crown--rump length	Head circumfe-	Bi-parietal diameter	Femur length	Foot length	Thorax circumfe-	Thorax width	Bi-crest width	Xiphoid process--umbilicus rence distance
9	9	68	61	13	14	7	59	18	11	16
10	5	71	63	15	16	9	61	22	14	18
11	3	73	66	18	19	11	66	25	16	19
12	4	76	68	21	20	12	70	26	17	20
13	7	80	71	24	21	13	75	28	19	22
14	16	86	75	27	24	15	80	29	20	24
15	5	93	80	31	26	17	85	33	23	25
16	15	100	90	35	29	20	92	36	26	27
17	14	109	102	38	31	21	100	39	30	28
18	10	117	115	41	33	25	116	41	32	29
19	10	127	129	45	36	29	130	45	33	31
20	10	138	143	48	38	30	143	50	37	33
21	6	147	160	51	40	33	156	54	38	35
22	6	160	178	55	44	36	160	55	40	37
23	7	175	193	57	47	39	174	57	44	39
24	10	188	206	60	50	43	190	60	47	40
25	10	200	220	63	52	44	200	64	51	44
26	6	210	241	66	56	46	210	68	53	45
27	7	218	260	70	60	50	218	70	57	47
28	5	228	284	73	64	53	229	72	61	50
29	3	240	300	75	67	55	242	78	65	52
30	7	248	316	77	71	56	249	80	67	55
31	4	260	330	80	74	58	260	81	70	57
32	5	272	340	84	78	61	270	85	74	59
33	4	280	348	87	79	62	274	90	77	60
34	3	290	356	89	82	64	283	91	81	63
35	2	298	365	90	85	67	290	94	85	65
36	7	305	370	92	87	70	298	97	88	67
37	2	310	376	93	90	73	306	100	90	70
38	7	316	380	96	93	74	314	103	92	72
39	3	320	386	98	96	75	318	105	93	73
40	10	326	390	99	97	77	320	106	95	74

values are presented in the results section and in relevant table captions).

RESULTS

Means of general (CRL, HC, BPD, FL, and foot length) and thoraco-abdominal para-meters (thoracic width, bi-crest width, and xiphoid process-umbilicus distance) in each gestational week were calculated (Table 1). There were no sex differences in any of the parameters measured in 222 foetuses ($p > 0.05$).

By anatomical dissection, the pancreas and neighbouring structures were exposed in all foetal material. Initially, the relation of the pancreas with

Table 2. Location of the pancreas in the abdominal cavity quadrants

Group (trimester)	N	AB quadrants	ABCD quadrants	B quadrant
Group 1 (9–12 wk)	21	100 (21%)	–	–
Group 2 (13–25 wk)	126	97 (122%)	2 (3%)	1 (1%)
Group 3 (26–37 wk)	55	100 (55%)	–	–
Group 4 (38–40 wk)	20	90 (18%)	–	10 (2%)
Total (9–40 wk)	222	97 (216%)	1.5 (3%)	1.5 (3%)

Percentage distribution was calculated along the rows; $p < 0.0001$ — differences between groups χ^2: 32,417; AB — in upper left and right quadrants; ABCD — in all quadrants; B — in upper-left quadrant

the stomach, duodenum, transverse colon, spleen, kidneys, and adrenal glands was explored. All relations of the pancreas with neighbouring structures were normal and no abnormality was identified. It was observed that the pancreas was stuck to the back of the abdominal wall and the frontal section was covered with peritoneum.

With regard to the localisation of the pancreas during the foetal period relative to the quadrants, we found that the pancreas was located in the left-upper and right-upper quadrants, i.e. above the transverse axis passing through the umbilicus, in 97% of cases (A–B) (Table 2). In 1.5% of cases it was located solely in the left-upper (B) whereas it was located in all four quadrants in 1.5% of cases (Table 2). Significant differences were observed in the locations of the pancreas throughout the foetal period between trimester groups (Table 2, $p < 0.0001$, χ^2 32.417).

Means of the length of the pancreas, height of the head, and body of the pancreas in each gestational week are given in Table 3. Comparisons of the mean length of the pancreas and means of the heights of the head and body of the pancreas between trimester groups revealed significant differences between groups ($p < 0.05$, Table 4). When we compared the groups by month we found significant differences in the pancreas length ($p < 0.05$, Table 5). The mean height of the head of the pancreas was significantly different between groups except between 7^{th} and 8^{th} and between 9^{th} and 10^{th} months. The mean height of the body of the pancreas was significantly different between groups except between the 6^{th} and 7^{th}, between the 7^{th} and 8^{th}, and between the 8^{th} and 9^{th} months ($p < 0.05$, Table 5).

In the present study, in addition to morphometric measurements, we also calculated the means of the distances between the pancreas and the xiphoid process and the umbilicus (Hp–Xp distance, Hp–U distance, Tp–Xp distance, and Tp–U distance) to determine the localisation of the pancreas and its relationship with the neighbouring structures in all gestational weeks (Table 3). Means and standard deviations of the same parameters for each trimester and month are presented in Tables 4 and 5. When the parameters taken from the pancreas were compared between trimester groups, we found significant differences in Hp–Xp and Tp–Xp distances between groups ($p < 0.05$, Table 4). There were significant differences in Hp–U and Tp–U distances between all groups except groups 3 and 4 ($p < < 0.05$, Table 4). When we compared the months, significant differences in Hp–Xp (except between 6 and 7 months and between 7 and 8 months), Hp–U (except between 8 and 9 months and between 9 and 10 months), Tp–U (except between 8 and 9 months and between 9 and 10 months), and Tp–Xp distances (except between 6 and 7 months, between 7 and 8 months, and between 8 and 9 months) ($p < 0.05$, Table 5).

With regard to the localisation of the papilla of Vater, where the pancreatic duct opens into the duodenum, Table 3 shows the means of distances between the papilla of Vater and the median plane, xiphoid process, and the umbilicus with respect to the number of weeks. The means and standard deviations of the parameters for trimesters and months are presented in Tables 4 and 5. Comparison of the parameters between trimesters revealed significant differences in Ha–Xp distance between all groups ($p < 0.05$, Table 4). Ha–M distance and Ha–U distance were different between all groups except Groups 3 and 4 ($p < 0.05$, Table 4). When we compared the parameters between groups by month, we found significant differences in Ha–M distance between the groups except between 4–5, 6–7, 7–8, and 8–9 month groups, in Ha–Xp distance except between 6–7

Table 3. Pancreatic parameters (shown as means [mm]) with respect to foetal age

Age (weeks)	N	Pancreas dimensions			Pancreas Xp–U relation				Localisation of the papilla of Vater		
		L	Hhp	Hbp	Hp–Xp	Hp–U	Tp–Xp	Tp–U	Ha–M	Ha–Xp	Ha–U
9	9	7.3	2.7	1.1	4.2	5.6	8.7	7.3	0.7	5.6	4.6
10	5	9.4	3.3	1.8	4.4	6.4	9.1	8.2	0.8	6.0	5.1
11	3	10.5	4.0	2.0	4.6	7.0	9.5	8.4	1.3	6.6	5.8
12	4	11.1	4.2	2.1	4.7	7.8	10.0	10.5	1.5	7.0	6.0
13	7	11.8	4.5	2.3	5.0	8.4	10.6	11.2	1.6	7.1	6.9
14	16	12.5	4.6	2.5	6.0	9.5	11.4	12.0	1.8	8.3	7.4
15	5	14.2	4.8	2.6	6.1	11.0	11.8	12.6	1.9	8.5	7.5
16	15	15.1	5.4	2.8	6.9	11.2	12.2	13.8	2.0	9.8	8.9
17	14	16.2	5.9	3.2	7.2	12.1	12.8	16.6	2.4	9.9	10.3
18	10	18.3	6.9	3.5	8.3	13.0	13.6	18.0	2.5	10.4	11.0
19	10	20.4	7.2	4.0	9.0	13.4	13.8	18.4	2.6	11.3	11.7
20	10	21.7	7.7	4.2	9.7	14.1	14.0	20.2	3.1	12.4	12.7
21	6	23.6	8.0	4.5	10.6	15.3	14.3	20.7	3.5	13.1	13.5
22	6	24.2	8.5	4.8	11.9	16.1	15.0	21.1	3.6	14.3	14.3
23	7	26.0	9.4	5.0	12.3	17.0	15.2	23.7	3.7	15.6	15.4
24	10	27.8	9.8	5.1	12.7	18.1	15.8	26.6	4.0	16.9	16.2
25	10	29.0	11.3	5.6	13.3	18.8	16.5	27.5	4.1	17.8	17.5
26	6	29.6	11.9	5.8	13.6	19.6	16.8	28.6	4.4	18.7	18.8
27	7	30.4	12.0	6.2	14.4	20.3	18.5	29.0	4.6	19.2	19.5
28	5	31.4	12.2	6.4	15.6	21.5	20.7	29.3	5.0	20.2	20.6
29	3	33.5	12.4	6.7	16.0	22.8	22.2	29.8	5.3	21.5	21.1
30	7	34.7	12.5	7.0	16.5	23.8	24.0	31.0	5.5	22.1	21.9
31	4	35.5	13.0	7.5	17.6	25.0	25.8	31.2	5.7	23.3	23.2
32	5	36.6	13.2	8.0	18.1	26.3	26.5	32.5	6.3	24.0	24.2
33	4	37.3	13.5	8.6	19.0	27.2	27.3	32.7	6.6	24.8	25.7
34	3	39.5	14.0	8.7	19.6	28.0	29.5	33.5	7.1	25.7	26.1
35	2	40.6	14.2	9.1	20.4	29.3	30.5	34.5	7.5	26.1	27.2
36	8	41.7	14.6	9.5	21.1	30.0	32.0	35.0	8.1	27.5	28.0
37	1	42.4	15.0	9.8	22.0	31.0	33.9	36.1	8.6	28.1	28.7
38	7	42.7	16.1	10.3	23.2	32.4	34.1	37.9	9.1	28.5	29.1
39	3	43.3	16.3	10.8	24.0	34.5	34.7	38.3	9.3	29.1	30.0
40	10	44.5	16.8	11.3	24.9	36.3	35.0	40.0	9.8	30.1	30.9

L — pancreas length, Hhp — height of the head of pancreas, Hbp — height of the body of pancreas, Hp–Xp — vertical distance between transverse axes passing through the upper-most point of the head of pancreas and the xiphoid process, Hp–U — vertical distance between transverse axes passing through the upper-most point of the head of pancreas and the umbilicus, Tp–Xp — vertical distance between transverse axes passing through the tip of the tail of pancreas and the xiphoid process, Tp–U — vertical distance between transverse axes passing through the tip of the tail of pancreas and the umbilicus, Ha–M — transverse distance between the vertical axis passing through the hepatopancreatic ampulla and the median plane, Ha–Xp — vertical distance between transverse axes passing through the hepatopancreatic ampulla and the xiphoid process, Ha–U — vertical distance between transverse axes passing through the hepatopancreatic ampulla and the umbilicus

Table 4. Means and standard deviations of pancreatic parameters [mm] with respect to groups (trimester)

Age (trimester)	N	Pancreas dimensions			Pancreas Xp–U relation				Localisation of the papilla of Vater		
		L*	Hhp*	Hbp*	Hp–Xp*	Hp–U**	Tp–Xp*	Tp–U**	Ha–M**	Ha–Xp*	Ha–U**
1. group (9–12 wk)	21	8.9±2.0	3.4±1.0	1.5±0.5	4.4±0.5	8.2±2.1	8.7±3.7	8.6±2.0	1.1±0.8	6.1±0.9	5.7±1.6
2. group (13–25 wk)	126	19.4±6.1	7.1±2.8	3.6±1.3	8.9±3.6	17.7±6.1	13.4±7.6	18.1±6.4	2.5±1.4	12.5±4.6	11.8±5.2
3. group (26–37 wk)	55	32.7±6.1	12.0±2.9	6.2±1.5	14.2±5.7	29.3±7.8	21.6±10.5	30.7±7.1	4.2±1.9	20.2±6.3	20.9±7.2
4. group (38–40 wk)	20	42.3±7.1	15.4±3.1	10.0±5.5	19.3±7.2	33.5±9.7	29.8±1.9	34.0±10.4	6.7±3.7	27.0±7.8	22.2±7.6
Total (9–40 wk)	222	23.7±10.8	8.7±4.2	4.6±3.0	10.7±5.9	21.1±9.9	16.5±10.3	21.8±10.1	3.2±2.3	15.1±7.6	14.4±7.7

L — pancreas length, Hhp — height of the head of pancreas, Hbp — height of the body of pancreas, Hp–Xp — vertical distance between transverse axes passing through the upper–most point of the head of pancreas and the xiphoid process, Hp–U — vertical distance between transverse axes passing through the upper–most point of the head of pancreas and the umbilicus, Tp–Xp — vertical distance between transverse axes passing through the tip of the tail of pancreas and the xiphoid process, Tp–U — vertical distance between transverse axes passing through the tip of the tail of pancreas and the umbilicus, Ha–M — transverse distance between the vertical axis passing through the hepatopancreatic ampulla and the median plane, Ha–Xp — vertical distance between transverse axes passing through the hepatopancreatic ampulla and the xiphoid process, Ha–U — vertical distance between transverse axes passing through the hepatopancreatic ampulla and the umbilicus;
*$p < 0.05$ — difference between all groups; **$p < 0.05$ — difference between all groups (except between groups 3 and 4)

Table 5. Means and standard deviations of pancreatic parameters (mm) with respect to groups (months)

Age (months)	N	Pancreas dimensions			Pancreas Xp–U relation				Localisation of the papilla of Vater		
		L[a]	Hhp[b]	Hbp[c]	Hp–Xp[d]	Hp–U[e]	Tp–Xp[c]	Tp–U[e]	Ha–M[f]	Ha–X[d]	Ha–U[g]
3. months (9–12 wk)	21	8.9 ± 2.0	3.4 ± 1.0	1.5 ± 0.5	4.4 ± 0.5	8.2 ± 2.1	8.7 ± 3.7	8.6 ± 2.0	1.1 ± 0.8	6.1 ± 0.9	5.7 ± 1.6
4. months (13–16 wk)	43	13.8 ± 2.7	4.8 ± 0.9	2.3 ± 0.5	6.3 ± 2.2	12.3 ± 3.2	10.5 ± 6.0	12.4 ± 3.2	1.7 ± 0.9	8.7 ± 2.4	7.9 ± 2.9
5. months (17–20 wk)	44	18.8 ± 4.0	6.8 ± 1.5	3.6 ± 0.8	8.5 ± 2.7	18.0 ± 4.2	12.5 ± 5.1	18.1 ± 4.4	2.3 ± 1.6	11.9 ± 3.2	11.9 ± 4.5
6. months (21–24 wk)	29	25.6 ± 3.9	9.5 ± 2.2	5.1 ± 1.0	12.4 ± 2.9	22.3 ± 5.2	17.6 ± 10.4	23.4 ± 5.0	3.5 ± 1.1	17.2 ± 3.2	15.2 ± 4.9
7. months (25–28 wk)	28	28.2 ± 3.6	11.2 ± 2.5	5.6 ± 1.2	12.9 ± 4.1	25.4 ±5.4	19.8 ± 9.2	26.8 ± 5.3	4.2 ± 1.8	18.5 ± 4.2	17.5 ± 4.4
8. months (29–32 wk)	19	32.1 ± 4.3	12.3 ± 2.4	5.9 ± 1.6	13.4 ± 5.0	30.6 ± 7.7	22.4 ± 9.6	31.0 ± 7.7	4.7 ± 1.7	20.6 ± 5.4	22.6 ± 8.1
9. months (33–36 wk)	17	37.4 ± 6.2	12.9 ± 3.5	6.7 ± 1.6	16.8 ± 7.1	32.5 ± 8.0	23.3 ± 12.2	34.1 ± 4.7	5.4 ± 1.9	23.3 ± 8.2	23.0 ± 6.8
10. months (37–40 wk)	21	42.2 ± 6.9	15.1 ± 3.1	9.9 ± 5.4	19.0 ± 7.1	33.3 ± 9.5	29.7 ± 11.6	34.4 ± 10.3	6.6 ± 3.6	26.6 ± 7.8	24.2 ± 7.4

L — pancreas length, Hhp — height of the head of pancreas, Hbp — height of the body of pancreas, Hp–Xp — vertical distance between transverse axes passing through the upper-most point of the head of pancreas and the xiphoid process, Hp–U — vertical distance between transverse axes passing through the upper-most point of the head of pancreas and the umbilicus, Tp–Xp — vertical distance between transverse axes passing through the tip of the tail of pancreas and the xiphoid process, Tp–U — vertical distance between transverse axes passing through the tip of the tail of pancreas and the umbilicus, Ha–M — transverse distance between the vertical axis passing through the hepatopancreatic ampulla and the median plane, Ha–Xp — vertical distance between transverse axes passing through the hepatopancreatic ampulla and the xiphoid process, Ha–U — vertical distance between transverse axes passing through the hepatopancreatic ampulla and the umbilicus.
[a]$p < 0.05$ — difference between all groups; [b]$p < 0.05$ — difference between all groups (except between 7–8 months and 9–10 months); [c]$p < 0.05$ — difference between all groups (except between 6–7 months, 7–8 months, and 8–9 months); [d]$p < 0.05$ — difference between all groups (except between 6–7 months and 7–8 months); [e]$p < 0.05$ — difference between all groups (except between 8–9 months and 9–10 months); [f]$p < 0.05$ — difference between all groups (except between 4–5 months, 6–7 months, 7–8 months, and 8–9 months); [g]$p < 0.05$ — difference between all groups (except between 6–7 months, 8–9 months, and 9–10 months)

and 7–8 month groups, and in Ha–U distance except between 6–7, 8–9, and 9–10 month groups ($p < 0.05$, Table 5).

Correlation analyses between all parameters showed that all pancreatic parameters increased with gestational age and other general parameters

and that the relationships between the parameters were significant ($p < 0.001$).

DISCUSSION AND CONCLUSIONS

It is important to image the pancreas by ultrasound during the prenatal period because abnormal shapes of the pancreas may be associated with congenital malformations [8, 9, 11, 14, 15]. Previous studies on the foetal pancreas have usually been based on pancreatic pathologies [14, 15]. On the other hand, studies on the foetal morphometrics of the pancreas are related to certain weeks of the prenatal period [4, 6, 7, 10]. Moreover, foetal pancreas measurements obtained by ultrasound are sufficiently reliable only after a certain number of weeks, and lack detailed information. This has been attributed to insufficient resolution of the obstetric ultrasound to depict foetal structures clearly [4, 6, 10]. In contrast to previous studies, we performed anatomical dissections in a large series to gather detailed morphometric data on the foetal pancreas. With no pathological or abnormal relation, we observed, by the help of anatomical dissections, that the relationships of the pancreas with neighbouring structures were normal.

The localisation of the pancreas in relation to the A–B–C–D quadrants on the abdominal wall was determined (Fig. 1, Table 2). According to classical text books, the pancreas is generally located behind the stomach, in the upper abdomen, at the level of the L1 and L2 vertebrae in adults [5]. This was also the case in foetal materials [6, 7]. In the present study, we found that the pancreas was located in the right and left upper quadrants (quadrants A–B) in 97% of cases during the foetal life (Table 2). This result was in agreement with the results of studies on the localisation of the pancreas in foetuses and adults alike [5–7]. We also found that, although very rare, the pancreas could be located in quadrants other than the left and right upper quadrants (Table 2). This result needs to be taken into consideration when assessing the localisation of the foetal pancreas in the abdomen by obstetric ultrasound. We believe that data on the localisation of the pancreas in the foetal period will be useful in evaluating the pathologies related to the development of the pancreas and its relations with neighbouring structures.

The foetal period that lasts from week nine of gestation to the parturition is the time when the body rapidly develops and organs mature [9]. Like other viscera, the pancreas grows in size. In the present study on the size of the pancreas during foetal life, we determined the length of the pancreas and the heights of the head and body of the pancreas (Tables 3–5). During the search of literature, we came across the study of Krakowiak-Sarnowska et al. [7], who conducted a research project on pancreas size during the foetal period. We found the means of pancreatic parameters in gestational months to be greater than those of Krakowiak-Sarnowska et al. [7]. This result was interpreted as foetal biometric data being variable across geographical regions, and maternal and foetal factors. Moreover, studies on pancreas dimensions measured using obstetric ultrasound also exist [4, 10]. Such studies reported that the pancreas could be depicted by ultrasound during certain weeks of gestation and that foetal pancreatic parameters were correlated with other general foetal parameters [4, 10]. Visualisation of the foetal pancreas with ultrasound is best achieved towards the end of the second trimester [4, 10]. In our study, we found that the dimensions of the pancreas increased gradually between weeks 9 and 40 of the foetal period (Tables 3–5). Previous studies have reported an increase in the dimensions of the pancreas with gestational age [4, 10]. Data obtained in the present study are in agreement with previous studies. In contrast to previous studies, we gathered our data on morphometric parameters of foetal pancreases from a large series of foetuses aged 9–40 weeks of gestation. We believe that the data on the foetal development of the pancreas acquired in the present study is more detailed.

We also explored the relationships between pancreatic, general foetal, and thoraco-abdominal parameters throughout the foetal period. For this purpose, we looked at the ratio of the length of the pancreas to the thorax width (upper abdominal width). We found this ratio to be stable throughout the foetal period. We also calculated the ratio of pancreas length to thorax width as well as the ratio of the parts of pancreas lying on either side of the median plane. When we compared these ratios between trimester groups, we did not find statistically significant differences ($p > 0.05$). This result indicated that pancreas length increased at a similar rate with the thorax width and that parts of the pancreas on either side of the median plane grew at a similar rate. The absence of any changes in the location of the pancreas in the abdomen and the fact that the growth rate was constant throughout the foetal period were considered indicators of the pancreas staying in the same location throughout the foetal

period. Krakowiak-Sarnowska et al. [7] also reported that the location of the pancreas in relation to the vertebral column did not change throughout the foetal period. This is in agreement with our results.

In our study, we examined certain parameters regarding the localisation of the pancreas not addressed in previous studies. To assess the relationships between the pancreas and surrounding structures, we measured the vertical distances between the tip of the tail of the pancreas and the umbilicus and xiphoid process. There were no sex differences in any of these parameters ($p > 0.05$). There were significant connections between these distances and gestational age and pancreatic parameters ($p < < 0.001$). To establish whether the vertical orientation of the tail of the pancreas changed sometime during the foetal period, we calculated the ratio of the vertical distance between the tip of the tail of the pancreas and the umbilicus with the vertical distance between the xiphoid process and umbilicus. This ratio increased until 17–20 weeks of gestation and remained constant thereafter. There were no significant differences between the second trimester, third trimester, and term groups ($p > 0.05$). In conclusion, the tail of the pancreas was oriented superiorly until midway through the second trimester and assumed its final position afterwards.

The distance of the papilla of Vater point on the inner face of the duodenum to the median plane, umbilicus, and xiphoid process, which had not been calculated in previous studies, was determined in the study (Fig. 2, Tables 3–5). These parameters did not differ between sexes ($p > 0.05$). There were significant relations between these distances and gestational age and pancreatic parameters ($p < 0.001$). We found that the ratios of the distances between papilla of Vater and the median plane, xiphoid process, and the umbilicus did not change and, as presented above, the localisation of the foetal pancreas stayed stable throughout the foetal period.

The limited number of cases in some weeks and the fact that the foetuses were not fresh were the limitations of the study that we observed. It was decided that the study should be supported and reinforced with more fresh foetuses.

We believe that the data obtained in this study will contribute to other studies carried out in obstetrics, perinatology, forensic medicine, and foetal pathology departments, aimed at identifying anomalies, pathologies, and variations of the pancreas and treatment of such cases.

REFERENCES

1. Callen PW (1999) Ultrasonography in obstetrics and gynecology. In: Güner H trans. ed. Atlas press. 3rd Ed. W.B. Saunders Company, Philadelphia, Ankara, p. 401.
2. Capaccioli L, Gheri G, Carpi R (1993) The anteroposterior diameter of the head and the body of the pancreas in healthy Italian children. Ital J Anat Embryol, 98: 165–174.
3. Fleischer AC, Manning FA, Jeanty P, Romero R (2000) Sonography in obstetrics and gynecology principles and practice. In: Yüksel A trans. ed. Nobel press. 5th Ed. A Simon & Schuster Company, Ankara, pp. 425–426.
4. Hata K, Hata T, Kitao M (1988) Ultrasonographic identification and measurement of the human fetal pancreas in utero. Int J Gynaecol Obstet, 26: 61–64.
5. Healy J.C, Borley N.R, Glass J, Ind T (2005) Abdomen and pelvis. In: Standring S, Ellis H, Healy JC, Johnson D, Williams A, Collins P eds. Gray's anatomy. The anatomical basis of clinical practite. 39th Ed. Churchill Livingstone, Philadelphia, pp. 1231–1237.
6. Hill LM, Peterson C, Rivello D, Hixson J, Belfar HL (1989) Sonographic detection of the fetal pancreas. J Clin Ultrasound, 17: 475–479.
7. Krakowiak-Sarnowska E, Flisiński P, Szpinda M, Sarnowski J, Lisewski P, Flisiński M (2005) Morphometry of the pancreas in human foetuses. Folia Morphol, 64: 29–32.
8. Luoma R, Raboei E (2001) Duodenal duplication with pancreas bifidum: a case report. Eur J Pediatr Surg, 11: 55–57.
9. Moore KL, Persaud TVN (2003) The developing human (clinically oriented embryology). 7th Ed. WB Saunders Company, Philadelphia, pp. 264–266.
10. Niederau C, Sonnenberg A, Müller JE, Erckenbrecht JF, Scholten T, Fritsch WP (1983) Sonographic measurements of the normal liver, spleen, pancreas, and portal vein. Radiology, 149: 537–540.
11. Paraskevas G, Papaziogas B, Lazaridis C, Gigis P, Papaziogas T (2001) Annular pancreas in adults: embryological development, morphology and clinical significance. Surg Radiol Anat, 23: 437–442.
12. Park HW, Chae YM, Shin TS (1992) Morphogenic development of the pancreas in the staged human embryo. Yonsei Med J, 33:104–108.
13. Sadler TW (2004) Langman's medical embryology. 9th Ed. Lippincott Williams & Wilkins, New York, pp. 285–319.
14. Vijayaraghavan SB (2002) Sonography of pancreatic ductal anatomic characteristics in annular pancreas. J Ultrasound Med, 21: 1315–1318.
15. Yogi Y, Kosai S, Higashi S, Iwamura T, Setoguchi T (1999) Annular pancreas associated with pancreatolithiasis: a case report. Hepatogastroenterology, 46: 527–531.