Anatomical development of the normal urachus during the fetal period

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ABSTRACT

الهدف: الهدف من الدراسة هو تقييم نمو السرر المثاني الطبيعي خلال فترة الحمل.

الطريقة: أجريت الدراسة على ١٤٩ جنين بشري(٨٧ ذكر، و٦٢ أنثى) تراوحت أعمارهم بين ٩ – ٤٠ أسبوعا، تم الحصول عليهم بعد موافقة أسرهم من مستشفى اسبارتا للولادة والأطفال في الفترة ما بين عام ١٩٩٧م و عام ٢٠٠٢م. أجريت الدراسة بقسم التشريح بكلية الطب بجامعة سليمان ديميريل في عام ٢٠٠٤م. تم تقييم وقياس نوع السرر المثاني وتصنيفها من حيث الطول والعمق الأمامي والخارجي. أخيرا تم تقييم العلاقة بين السرر المثاني وشرايين السرة خلال فترة الحمل، من حيث ما إذا كانا متوازيان إلى بعضهما البعض.

النتائج: تمت مراقبة نوعين من السرر المثاني: القمع المنحرف (٨٤٪) والأنبوبي (١٦٪) ازداد طول وعمق وعرض السرر المثاني مع تقدم الحمل في جميع الحالات، تمت ملاحظة تغير بنسبة ٢٪ في الجوار بين السرر المثاني و الشريان السري.

خاتمة: تعد هذه الدراسة أول دراسة أجريت على فترة الحمل باستعمال التسليخ التشريحي لذلك فإن البيانات التي تم الحصول عليها يمكن استعمالها كمعلومة قاعدية مرتبطة بنمو السرر المثاني وينبغي أن يتم استعمال بياناتنا لتقييم السرر المثاني في قسم المسالك البولية للأطفال وقسم جراحة الأطفال.

Objective: To evaluate the development of the normal urachus during the fetal period.

Methods: The study was carried out on 149 human fetuses (male 87, female 62) aged between 9-40 weeks, obtained with families' consent from Isparta Maternity and Children's Hospital, Isparta, Turkey, between 1997 and 2002. The study was carried out in the Department of Anatomy, Faculty of Medicine, Suleyman Demirel University, Isparta, Turkey during 2004. The type of the urachus was assessed and was classified. The length, antero-posterior depth, and the transverse width of the urachus were measured. Finally, the relationship between the urachus and umbilical arteries was evaluated during the fetal period, whether they ran parallel to each other.

Results: Two types of urachus were observed: the inverted funnel (84%) and tubular (16%). The length, depth, and width of the urachus increased with gestational ages in all cases. A 2% variation was observed in the neighborhood between urachus and umbilical artery.

Conclusion: Comparing our results with previous studies, the development of the urachus can be different in neonates and children. The mean urachus length was 14.8±7.7mm during this period. The inverted funnel type is the most common type in our study. Hence, there can be some differences in the relationship between the urachus and umbilical arteries. The data obtained in the present study can be used as base knowledge related to the development of the urachus, and for evaluating the urachus in utero pediatric urology, radiology, pediatric surgery, and fetopathology.

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The urachus is an embryonic remnant resulting from involution of the allantoic duct and the ventral cloaca. Attaching the bladder dome to the umbilicus, this duct becomes progressively obliterated during the fetal life.[1] Normal obliteration occurs during the fourth and fifth gestational months, leaving a fibrous cord extending from the dome of the bladder to the umbilicus.[2] Some types become involuted and regarded as normal while others become pathological, capable of becoming symptomatic.[1] There can be different anatomical types of urachus during the development, and knowing these different types is important in the diagnosis and treatment of the abnormalities. An estimated 2% of

the population has an urachal abnormality; however the majority is diagnosed during autopsy.[2] Different sections of the urachus may not be fully obliterated and can result in urachal fistula, urachal umbilical sinus, vesicourachal diverticulum or urachal cyst.[3] In previous studies, normal urachus and urachal abnormalities were investigated in neonates and adults by ultrasound (US), computed tomography, MRI, fistulography, voiding cystourethrography, and cystoscopy.[4-6] However, there are no studies exploring the development of urachus and its anomalies using anatomical dissections during the fetal period. The development of normal urachus should be well defined to determine urachal anomalies and pathologies, and plan treatments in such conditions. The aim of this study is to explore the development of urachus in a detailed way by anatomical dissections during the fetal period.

Methods. This study is carried out on human fetuses aged between 9 and 40 weeks of gestation obtained with families' consent from Isparta Maternity and Children's Hospital, Isparta, Turkey, between 1997 and 2002. We performed the study at the Department of Anatomy, Faculty of Medicine, Suleyman Demirel University, Isparta, Turkey, during 2004. Measurements were performed on 149 fetuses (87 males, 62 females) with no external pathology or anomaly. The fetuses with pathology or anomaly such as anencephaly, meningocele, and so forth, were separated from the study population at the beginning of the study. Approval from the Ethics Board of Suleyman Demirel University Faculty of Medicine was obtained prior to the commencement of the study.

Gestational ages of the fetuses were determined using crown-rump length (CRL) until 12th week, and biparietal diameter, head circumference, and foot length between 13 and 40 weeks.[1] Fetuses were assigned to one of the 4 groups according to their gestational ages: group I (1st trimester), group II (2nd trimester), group 3 (3rd trimester) and full term (Term). The abdomens of all fetal materials were dissected by anatomical dissection method. The urachus and neighboring structures were exposed and the following steps were followed. First, the type of the urachus was assessed and classified. The urachus types were drawn on a paper during the dissection by the author who dissected the urachus, and at the end of the study all urachus figures were compared with each other and classified. Second, the length of the urachus was measured (the length between apex of bladder and umbilicus). Third, the antero-posterior depth and the transverse width of urachus were measured. These lengths were measured from the caudal and middle parts of the urachus. Measurements at the cranial end (the anteroposterior depth and the transverse width) were not carried out as the cranial part of the urachus where it is attached to the umbilicus was obliterated. Fourth, the relationship between urachus and umbilical arteries was evaluated during the fetal period, whether they ran parallel to each other.

Means of each parameter were computed with respect to gestational weeks and groups using the Statistical Package for Social Sciences version 6.0 (SPSS Inc, Chicago, Illinois, USA). Level of significance was set at 0.05. Relationships between parameters were tested using Pearson's correlation. Data according to weeks were expressed as means, and data according to groups were expressed as mean ± standard deviation. Non-parametric tests were used for comparing groups due to insufficient number of cases. Significant groups according to Kruskal Wallis analysis of variance were

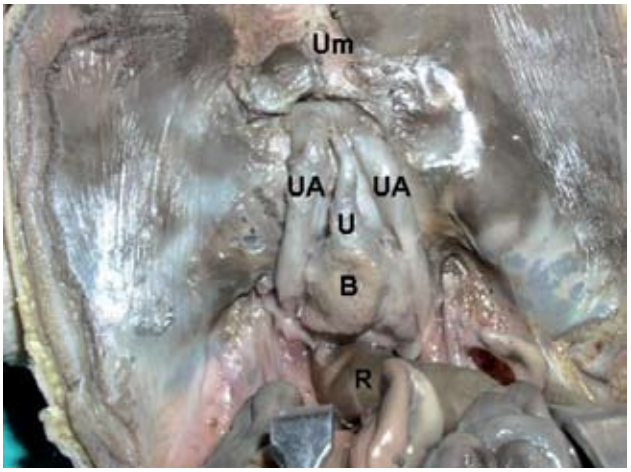

Figure 1 - The urachus. U - urachus, UA - umbilical artery, Um - umbilicus, B - bladder, R - rectum.

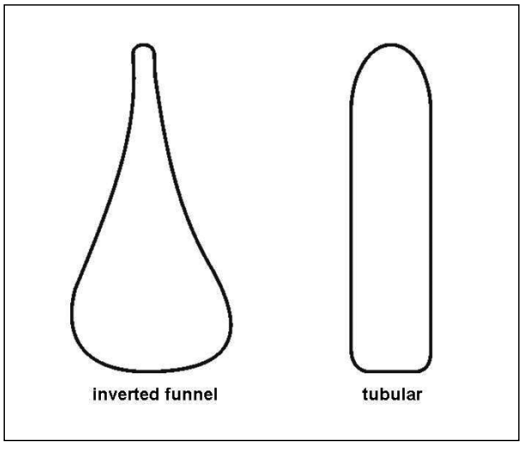

Figure 2 - Types of urachus.

Table 1 - Means of general parameters during the fetal period according to gestational weeks (mm).

Age (week)	N	Crown-rump length	Head circumference	Bi-parietal diameter
9	3	60	63	16
10	3	75	66	18
11	1	80	76	23
12	6	95	78	22
13	9	106	90	22
14	16	120	99	26
15	3	132	112	30
16	3	140	124	34
17	6	147	138	37
18	6	162	150	40
19	6	170	162	43
20	5	175	172	48
21	6	185	187	50
22	9	211	199	53
23	6	218	208	57
24	4	231	219	60
25	2	245	233	63
26	3	248	244	65
27	4	261	254	67
28	5	272	264	71
29	3	280	273	73
30	3	283	282	76
31	6	288	288	78
32	4	300	296	80
33	4	310	303	82
34	2	315	310	84
35	2	325	317	87
36	4	330	324	89
37	1	353	334	91
38	3	360	341	92
39	2	380	347	95
40	8	406	352	97

Table 2 - The number of cases and percentages of the types of urachus during the fetal period according to the trimester groups.

Groups (week)	Type 1 (inverted funnel)	Type 2 (tubular)	Total
1st trimester (9-12)	8 (61)	5 (39)	**13**
2nd trimester (13-25)	69 (84)	13 (16)	**82**
3rd trimester (26-37)	37 (90)	4 (10)	**41**
Full term (38-40)	12 (92)	1 (8)	**13**
Total (9-40 weeks)	**126 (84)**	**23 (16)**	**149**

Percent distribution is calculated along the rows. The difference between groups for all parameters - $p<0.001$, χ^2 : 32.84

compared pair-wise using Mann-Whitney U test. Levels of significance were assessed with Bonferroni correction. With regard to non-parametric data, chi-square test was used for comparisons of percent distributions among groups and p and χ^2 values were presented ($p<0.05$).

Results. We determined the mean values of all parameters of each fetus according to gestational weeks. No differences in any of the parameters between genders were determined ($p>0.05$). Mean values of all general parameters (CRL, head circumference, and biparietal diameter) of each fetus were determined according to gestational weeks. It was revealed that there were no differences in any general parameter between the genders (**Table 1**). The urachus and the neighboring structures were exposed by abdominal dissection (**Figure 1**). Initially, types of the urachus were defined and the urachus were classified into different types. Two types of urachus were observed, the inverted funnel and the tubular (**Figure 2**). The most common type of urachus was the inverted funnel type (84%), with tubular type comprising only 16% of the cases ($p<0.001$, **Table 2**). When the percentage distribution of the cases was compared, there were significant differences between groups ($p<0.001$, χ^2: 32.84, **Table 2**). The length of the urachus (between the apex of the bladder and umbilicus) was measured in the second stage. The length of the urachus increased with gestational ages in all cases (**Table 3**), and there were significant differences between groups ($p<0.05$, **Table 4**). The urachal depth and width pertaining to the caudal and middle parts of the urachus were observed to increase with gestational age in all cases (**Table 3**) and the differences between these parameters and groups were significant ($p<0.05$, **Table 4**). When the relationship between the urachus and the umbilical arteries was examined, we found that the urachus was localized in the median plane, with the umbilical arteries running parallel to it in 146 cases (98%). In the remaining 3 cases (2%) (1 male, 2 females) the relationship of the urachus and the umbilical arteries was different from what it should be. In these cases, the right umbilical artery extended between the anterior abdominal wall and the urachus, the left umbilical artery had a normal course, parallel to the urachus.

Discussion. The urachus is a tubular structure that develops in the early embryonic period, and connects the urogenital sinus and the allantois. During 4-5th months of gestation, the urachus narrows to a small-caliber epithelial tube.[6] It is known that the cranial part of the urachus is the first to involute.[6] In our study, we could not measure the cranial part of the urachus as this part was involuted. Leicher-Duber and Schumacher[7] described

Table 3 - Mean values of the length, depth, and width parameters of the urachus according to gestational ages (mm).

Age (weeks)	Length	Depth		Width	
		Anteroposterior-middle	Anteroposterior-proximal	Transverse-middle	Transverse-proximal
9	4.0	0.2	0.5	0.4	0.9
10	4.0	0.3	0.7	0.5	1.1
11	4.6	0.4	0.8	0.5	1.1
12	7.6	0.5	1.0	0.7	1.8
13	8.0	0.5	1.3	0.7	1.9
14	8.1	0.6	1.3	0.8	1.9
15	9.0	0.6	1.4	0.9	2.0
16	10.6	0.7	1.5	0.9	2.0
17	11.8	0.7	1.7	1.0	2.3
18	12.6	0.7	1.8	1.0	2.5
19	13.0	0.7	2.0	1.0	2.5
20	13.6	0.9	2.1	1.0	2.6
21	14.0	1.0	2.2	1.0	2.7
22	14.1	1.0	2.3	1.0	2.9
23	14.5	1.0	2.7	1.1	3.0
24	15.0	1.0	2.8	1.1	3.1
25	15.8	1.1	2.8	1.1	3.1
26	17.2	1.2	2.9	1.1	3.4
27	17.6	1.2	3.0	1.1	3.4
28	18.0	1.2	3.2	1.1	3.5
29	18.2	1.3	3.2	1.3	3.5
30	18.5	1.3	3.2	1.4	3.8
31	18.6	1.4	3.2	1.4	4.0
32	18.7	1.4	3.3	1.4	4.1
33	19.0	1.4	3.4	1.4	4.2
34	20.0	1.4	3.5	1.5	4.5
35	23.7	1.5	3.6	1.5	4.5
36	25.1	1.5	4.1	1.6	4.6
37	25.7	1.6	4.3	1.6	4.8
38	26.5	1.6	4.5	1.7	4.8
39	28.3	1.8	5.4	1.8	5.9
40	30.0	2.0	5.5	1.8	6.1

Table 4 - Means of length, depth, and width parameters of the urachus according to groups (mm).

Groups (week)	Length	Depth		Width	
		Anteroposterior-middle	Anteroposterior-proximal	Transverse-middle	Transverse-proximal
1st trimester (9-12)	5.8±2.0	0.4±0.1	0.8±0.1	0.6±0.4	1.5±0.8
2nd trimester (13-25)	12.0±5.0	0.8±0.3	1.7±0.7	0.9±0.3	2.4±0.8
3rd trimester (26-37)	19.6±6.5	1.3±0.5	2.9±0.8	1.4±0.4	3.9±0.9
Full term (38-40)	26.4±7.5	1.9±0.6	4.9±2.8	1.6±0.4	5.2±1.5
Total (9-40)	**14.8±7.7**	**1.0±0.5**	**2.2±1.5**	**1.1±0.5**	**3.0±1.4**
The difference between groups for all parameters - $p<0.05$					

2 different types of the urachus in a population spanning one week to 16 years of age by US. Among fusiform and tubular types, they found the tubular type as the most common type (62.5%) in neonates. Zieger et al[6] classified the normal urachus into funnel, tubular, and tubulo-fusiform types in neonates using US. According to the results of their study, the most frequent types in neonates were tubular type (64%) and tubulo-fusiform type (51%) in children. A literature search did not reveal any studies on the types of urachus during the fetal period. We determined 2 different urachal types in our study; the inverted funnel (84%) and the tubular (16%). The inverted funnel type was the most common type in our study. The ratio of the tubular type decreased while the ratio of the inverted funnel type increased with gestational age (**Table 2**). The increase in the percentage distribution of the inverted funnel type with gestational age is thought to be due to the involution of the cranial part of the urachus. Both previous study found the tubular type as the most common type.[6,7] Therefore, there is no agreement between our results and those of the previous study.[6,7] Zieger et al[6] also reported that the funnel type was the most immature type. However, we determined the tubular type as the most immature type. Therefore, we think that the development of the urachus can be different in neonates and children. Moreover, the tissues that surround the organs are not well distinguished by US. Therefore, ultrasonographic measurements may not be adequate to demonstrate the real types.[8]

The mean length of the urachus was found 13±5 mm in a study covering a period of 4 months - 16 years.[9] In another study, spanning a wider age range, the mean length of the urachus was found 13.5± 4.7 mm among subjects aged between 1 month and 91 years.[5] The present study covered the fetal period and the mean urachus length was found 14.8±7.7 mm. Ozbek et al[9] reported that if the urachus length is longer or shorter than its normal values, it can be accompanied by some urological problems. It has also been emphasized that urachal anomalies can be related to the in-utero period.[5,9] In previous studies, Yann et al[5] measured the transverse width and the antero-posterior diameter of the urachus by using US and found 12.6±5 mm in children and 5.2±1.5 mm in adults. Zieger et al[6] found the mean antero-posterior diameter of the urachus to be 3.3 mm in neonates. The transverse width and the anteroposterior diameter of the cranial part of the urachus could not be measured in our study as this part was involuted. We could only measure the transverse width and the antero-posterior diameter of the middle and caudal parts of the urachus. The transverse width of the middle parts was 1.1±0.5 mm and caudal parts were 3.0±1.4 mm, and the antero-posterior diameters were 1.0±0.5 mm and 2.2±1.5. Results show that the mean values of the transverse width and the antero-posterior diameter of the caudal part are greater. We believe that the urachus becomes involuted from cranial to caudal, and it changes its type from tubular to inverted funnel in-utero. Further, our study spans almost the entire fetal period in which the measurements of the normal urachus are given.

Cappele et al[1] described the 4 possible relationships between the urachus and the medial umbilical ligaments in neonates and children. In type 1, the urachus was in the median plane, between and equidistant to both medial umbilical ligaments. In type 2, one of the umbilical ligaments joins the urachus. In type 3, both umbilical ligaments fuse with the urachus and in type 4, the urachus is very short and branches with the 2 umbilical ligaments to give a fibrous plexiform appearance. In our study, we determined a variation in the relationship between the urachus and the umbilical arteries in only 3 of 149 cases. In all these 3 cases, the right umbilical artery extended between the anterior abdominal wall and the urachus, while the left umbilical artery had a normal course and it was parallel to the urachus. The findings of our study and those of Cappele et al[1] were not similar. There was a 2% variation in the course of right umbilical artery in our study and, even if it is not common, there can be some variations in the relation between the urachus and the umbilical artery and these variations can be taken into account in diagnoses and treatments of the anomalies and pathologies.

In conclusion, the length and the type of the urachus are different in different periods of life. According to our study, the tubular type of the urachus observed in early fetal period changes into the inverted funnel type due to the involution of the cranial part in the fetal period. It can also be considered that there can be some differences in the relationship between the urachus and umbilical arteries. Therefore, the normal anatomy and the neighborhoods of the urachus should be known well, and the data obtained in the present study can be used as a base knowledge related to the development of the urachus and should be used for evaluating the urachus in utero for pediatric urology, radiology, pediatric surgery, and fetopathology.

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Illustrations, Figures, Photographs

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