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The Comparison of the Stage of Foetal Development on the Basis of Anatomical and Ultrasound Examinations

Porównanie zaawansowania rozwoju płodów na podstawie badań anatomicznych i ultrasonograficznych

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Abstract

Background. Investigations of variations in head dimensions in various biological and medical (obstetric) aspects in order to establish the correlation between its development and the calendar age are still among the topical issues.

Objectives. The aim of the present work was to present and analyse selected anthropometric measurements and analogous ultrasound cephalometric parameters during foetal development of man. The aim of the work was to compare the stage of the development of fetuses assessed on the basis of measurements on autopsy (of miscarried fetuses) with the findings of intravital ultrasound examinations.

Material and Methods. The investigations involved 327 fetuses (165 male and 162 female) between 4 to 8 months of gestation. The material came from the Department of Anatomy, Wrocław Medical University and has been collected since 1965. The foetal material in the border age groups (4th and 8th months) was completed with material coming from the collection of the Department of Histology and Embryology of Medical University in Bydgoszcz. The ultrasound measurements (BDF and OFD) were carried out on 514 fetuses aged from 4 to 11 months of life and were obtained during overall assessment of the stage of their development. Data from ultrasound measurements coming from the Department of Histology and Embryology of Medical University in Bydgoszcz were also used in the study.

Results and Conclusions. The development of the investigated parameters of the head occurs at various rate independently of the sex of the fetuses. The only finding was a tendency to dimorphous changes of the analysed parameters. The head development assessed on the basis of anthropometric measurement of its width (eu-eu) in miscarried fetuses does not differ from the head development assessed intravitaly on the basis of the biparietal diameter (BPD) on ultrasound scanning. The investigated parameters were found to be highly correlated. This allows the conclusion that the investigated parameters can be a useful tool in determining the chronological age of fetuses (*Dent. Med. Probl.* 2003, 40, 2, 225–231).

Key words: foetal development, head measurements: eu-eu, g-op, BPD, OFD.

Streszczenie

Wprowadzenie. Badania w zakresie zmienności wymiarów głowy w różnych aspektach biologicznych i medycznych (położniczym), w celu ustalenia korelacji jej rozwoju z wiekiem kalendarzowym są nadal aktualne.

Cel pracy. Celem pracy jest przedstawienie i poddanie analizie wybranych pomiarów antropometrycznych i podobnych pomiarów ultrasonograficznych głowy w okresie płodowym człowieka oraz porównanie zaawansowania rozwoju płodów uzyskanego na podstawie sekcyjnych badań anatomicznych (płodów samoistnie poronionych) i na podstawie przyżyciowych badań ultrasonograficznych.

Materiał i metody. Badania przeprowadzono na materiale 327 płodów (165 płci męskiej i 162 płci żeńskiej) w wieku 4–8 miesięcy. Materiał płodowy pochodzi z Katedry i Zakładu Anatomii Prawidłowej AM we Wrocławiu i był gromadzony od 1965 r. Materiał płodowy został uzupełniony w skrajnych klasach wiekowych (4 i 8 miesiąc) zbiorami Katedry i Zakładu Histologii i Embriologii AM w Bydgoszczy. Badania cech ultrasonograficznych (BPD i OFD) przeprowadzono na materiale 514 płodów w wieku 4–11 miesięcy, podczas oceny zaawansowania ich rozwoju. W pracy wykorzystano również dane z badań ultrasonograficznych cech pomiarowych, które pochodzą ze zbiorów Katedry i Zakładu Histologii i Embriologii AM w Bydgoszczy.

Wyniki i wnioski. Rozwój badanych cech dotyczących wymiaru głowy odbywa się ze zróżnicowaną szybkością, niezależnie od płci. Zaobserwowano jedynie tendencję w występowaniu różnic dymorficznych analizowanych cech. Rozwój głowy określony za pomocą antropometrycznego wymiaru jej szerokości (eu-eu) na materiale płodów poronionych nie różni się od rozwoju głowy określonego przyżyciowo na podstawie wymiaru międzyciemieniowego (BPD) – uzyskanego z badań ultrasonograficznych.

Stwierdzono wysoką korelację między badanymi pomiarami. Upoważnia to do wysunięcia wniosku, że opracowane w niniejszej pracy cechy pomiarowe mogą być wykorzystywane w określaniu wieku chronologicznego płodów (*Dent. Med. Probl.* 2003, 40, 2, 225–231).

Słowa kluczowe: rozwój płodów, pomiary głowy: eu-eu, g-op, BPD, OFD.

The significance of cephalometry dates back to 1885, when an English physician, Mathews Duncan, first paid attention to the necessity of correct assessment of the dimensions of the head in order to determine and plan appropriate obstetric management of the patient.

A significant contribution to the problem of head development in the fetal life can be found in the work of Scammon and Calkins [1]. The results of their studies are still used in various fields of medicine, and especially in the assessment of fetal development. However, the criticism of these authors, undoubtedly the pioneers of modern gestational age examinations (Kurlej 1979) is highly justified. Reservations concern first of all ethnic heterogeneity of the investigated material, lack of initial selection of the miscarried fetuses, inadequate amount of fetuses in analyzed age groups, and also the fact that the sexual dimorphism and secular trend were not accounted for. The introduction of refined radiological and ultrasound techniques as well as magnetic resonance has increased the possibilities of intravital fetal examinations, eliminating the risk of unfavourable effects resulting from their use [2–7].

The biparietal diameter determined on the basis of ultrasound examination varies even in twins [8]. The obtained information is not reliable, especially in the first trimester, due to a small number of observations (Tab. 1). This is associated with mistakes in determining the calendar age (menstruation) at this stage of development. From the review of literature we can conclude that our knowledge concerning the fetal head development, despite many scientific reports, is still fragmentary.

Thus there is a necessity to refer back to classical somatometric measurements and to combine them with modern ultrasound and magnetic resonance methods. Each of these methods has its advantages and disadvantages. Numerous authors have reported on various methods of elimination of the disadvantages which may occur during anatomical assessment of the fetuses [9]. The unquestionable advantage of the anatomical studies is their universal character, the use of methods of long-lasting penetration, the possibility to use

various anatomical techniques. The advantage of ultrasound examinations lies in the unquestionable access (though short-lasting) to normally developing fetuses in the mother's womb as well as the possibility of longitudinal studies. Thus further research in this field is fully justified for the methodological reasons, and first of all in view of the development of visualizing techniques enabling intravital assessment of the foetus.

The aim of the present work was to compare the stage of foetal development determined on the basis of anatomical autopsy examinations (of spontaneously miscarried fetuses) with the findings obtained from intravital ultrasound examinations.

Material and Methods

The anatomical assessment was carried out on 327 fetuses (165 males and 162 females) between 4 and 8 months of gestational age (Tab. 2–5). The

Table 1. Statistical characteristics of biparietal diameter (BPD) [10]

Tabela 1. Charakterystyki statystyczne pomiaru dwuciemieniowego głowy (BPD) [10]

Age (Wiek)		n	x	s	Min	Max
Month (Miesiąc)	Days (Dni)					
2	43.4	9	34.3	11.1	23	60
3	73.4	51	28.6	10.7	10	70
4	101.5	391	31.5	8.5	17	91
5	126.6	537	42.8	8.9	19	93
6	154.7	605	53.9	7.8	24	87
7	182.3	580	66.2	7.7	26	97
8	210.9	748	77.4	7.1	35	98
9	239.0	862	86.2	6.4	45	106
10	265.9	775	92.1	5.1	67	107
11	289.4	349	94.5	4.4	77	113
12	319.7	15	95.9	4.3	85	103
Total (Razem)	200.4	4922	70.3	21.9	10	113

material came from the Department of Anatomy, Wrocław Medical University and has been collected since 1965. Observations from the 4th and 8th months of gestational life were completed with findings from the Department of Histology and Embryology, Medical University in Bydgoszcz. The analyzed material comes from spontaneous abortions, and its medical records contain information concerning the course of pregnancy (date of last menstruation), the cause of miscarriage maternal and environmental data. Fixation of the material in 10% formalin, verification of the material regarding developmental defects and problems associated with establishing the menstrual age were carried out according to the rules presented by Bożiłow and Sawicki [9].

The ultrasonic measurements (BPD and OFD)

were carried out in 514 fetuses between 4 and 11 month of gestational age as part of the evaluation of their gestational maturity.

Also, ultrasound cephalometric data (4922 observations) from the collection of the Department of Histology and Embryology, Medical University in Bydgoszcz which were used in Lesiński's doctoral thesis [10] were included into the study (Tab. 1).

The image obtained from Aloca SSD 1700, 7.5 MHz with a linear probe was presented in B (brightness) mode in real time and it was integrated. The image was preserved in a picture. Ultrasound scanning was performed for clinical reasons in order to assess: the gestational age, foetal development, predicted birth weight of the foetus, the conditions of the internal organs. The

Table 2. Statistical characteristics of total length of head (g-op)

Tabela 2. Charakterystyki statystyczne długości całkowitej głowy (g-op)

Age – Month (Wiek – miesiąc)	Sex (Płeć)	x of age (x wieku)	N	x	s	Min	Max
4	m	103.2	29	32.4	5.2	19	39
	f	104.8	32	33.3	4.6	20	37
5	m	128.3	38	51.5	5.6	34	65
	f	127.6	34	51.3	5.7	35	66
6	m	153.9	39	67.5	5.3	56	80
	f	154.6	36	66.9	5.7	58	79
7	m	179.7	33	80.8	4.9	71	90
	f	152.5	35	80.6	4.5	75	88
8	m	212.2	26	94.8	3.8	88	98
	f	212.6	25	93.5	3.9	90	96
Total (Razem)	m	147.0	165	62.2	16.7	19	98
	f	149.6	162	62.6	16.4	20	96
	m+f	148.7	327	62.5	16.5	19	98

Table 3. Statistical characteristics of total width of head (eu-eu)

Tabela 3. Charakterystyki statystyczne szerokości całkowitej głowy (eu-eu)

Age – Month (Wiek – miesiąc)	Sex (Płeć)	x of age (x wieku)	N	x	s	Min	Max
4	m	103.0	29	26.8	4.9	15	33
	f	103.1	32	27.0	5.0	15	33
5	m	128.5	38	42.1	6.1	27	52
	f	127.8	34	42.0	5.8	28	50
6	m	153.8	39	54.3	4.8	40	66
	f	152.5	36	53.6	4.9	43	61
7	m	180.8	33	63.2	4.0	56	70
	f	178.5	35	62.6	4.2	53	70
8	m	212.2	26	73.7	3.7	67	80
	f	212.0	25	74.8	4.0	69	77
Total (Razem)	m	147.0	165	49.7	12.7	15	80
	f	149.6	162	49.3	12.7	15	77
	m+f	148.7	327	50.7	12.7	15	80

Table 4. Statistical characteristics of biparietal diameter (BPD)**Tabela 4.** Charakterystyki statystyczne pomiaru dwuciemiowego głowy (BPD)

Age – Month (Wiek – miesiąc)	Sex (Płeć)	x of age (x wieku)	N	x	s	Min	Max
4	m	99.9	21	28.5	4.1	23	36
	f	99.5	22	29.8	4.6	20	35
5	m	125.4	20	41.9	4.9	31	52
	f	126.4	20	39.9	5.7	28	48
6	m	153.5	24	53.5	5.2	41	62
	f	156.7	21	55.6	4.9	48	64
7	m	184.1	22	67.2	5.7	57	75
	f	183.7	25	67.7	6.2	52	77
8	m	208.6	29	77.1	5.5	67	90
	f	209.2	25	75.9	4.9	68	86
9	m	240.2	48	86.5	5.7	61	96
	f	242.1	34	86.2	5.1	72	95
10	m	269.0	53	92.9	4.6	75	99
	f	269.0	53	91.8	4.2	78	99
11	m	288.4	37	95.5	3.1	90	101
	f	289.0	50	94.1	3.3	84	100
Total (Razem)	m	225.3	254	78.2	21.4	23	101
	f	228.6	250	78.1	20.4	20	100
	m+f	227.9	504	78.0	21.0	20	101

Table 5. Statistical characteristics of occipitofrontal diameter (OFD)**Tabela 5.** Charakterystyki statystyczne pomiaru potyliczno – czołowego głowy (OFD)

Age – Month (Wiek – miesiąc)	Sex (Płeć)	x of age (x wieku)	N	x	s	Min	Max
4	m	100.0	19	34.8	5.0	29	44
	f	101.7	19	34.8	7.1	20	42
5	m	125.3	24	50.0	6.5	35	58
	f	127.7	20	50.1	7.7	39	60
6	m	151.2	23	63.2	6.3	50	72
	f	156.1	27	66.8	6.2	56	78
7	m	182.3	18	80.8	8.8	67	94
	f	182.7	20	85.3	6.9	74	100
8	m.	206.9	21	93.2	7.3	79	105
	f	209.8	19	94.3	7.9	81	112
9	m	238.1	25	104.0	8.4	84	116
	f	240.8	20	102.3	6.2	87	114
10	m	268.9	20	107.4	5.2	98	117
	f	267.4	23	103.0	7.6	90	111
11	m	289.8	18	108.5	5.8	103	116
	f	287.3	19	108.2	5.5	98	116
Total (Razem)	m	193.3	168	81.6	26.1	29	117
	f	200.1	167	83.0	25.1	20	116
	m+f	194.4	335	81.1	25.8	20	117

following measurements were selected to determine the gestational age: biparietal diameter (BPD) and occipitofrontal diameter (OFD).

Analyzed measurements: 1. maximum head length (g-op), which is the distance from *glabella* point situated between the superciliary arches and

the *opisthocranium* situated on the external occipital protuberance, 2. maximum head width (eu-eu); which is the distance between *eurion* points, most laterally situated points on the head within the cranium. 3. ultrasound measurements of the head width – biparietal diameter (BPD). In classical

cephalometry, this corresponds to the eu-eu measurement. The cerebral falx echo was assumed as the medial plane for this measurement. The cephalometry was made inside the external contour of the skull [17]. 4. Ultrasound measurement of the head length – occipitofrontal diameter (OFD).

The material was analyzed statistically by means of “Statistica” program. Mean measurements were provided in identical intervals of the calendar age.

Results and Discussion

Variability of Investigated Cephalometric Parameters

The maximum head length (g-op) increases with age at a decreasing rate (Tab. 2). This parameter does not differ statistically significantly between sexes. In male fetuses however the head length was characterized by higher variability.

The maximum head width (eu-eu) increases with age; the rate of increase decreases from the 7th month of life (Tab. 3). Sex differences of this parameter are statistically insignificant.

The rate of growth of biparietal diameter (BPD) in both sexes was found to be changeable over the investigated period. Starting from the 8th month of life, the rate of growth of BPD decreases, being more pronounced in males (Tab. 4).

The rate of growth of the occipitofrontal diameter (OFD) increases between the 6th and 7th month of life in males, and it slows down evenly (Tab. 5). In females the rate of growth of this parameter increases until the mid-7th month of life and next it slows down.

The analysis of cephalometric parameters in the majority of cases revealed only a tendency to dimorphous changes. The differences between sexes were statistically insignificant. However the majority of investigated parameters reveal dimorphous changes in the variations of the rate of growth. Sexual dimorphism in the foetal life was stressed by many authors [11], including cephalometry [12]. For this reason foetal measurements should be carried out separately for both sexes.

The Comparison of the Stage of Development Assessed on the Basis of Anatomical and Ultrasound Cephalometry

The comparison of the stage of foetal development assessed on the basis of anatomical examinations of spontaneously aborted fetuses and intravi-

tal ultrasound scanning was accomplished by: 1. comparison of the g-op anthropometric measurement with the ultrasound OFD measurement (Fig. 1), 2. comparison of the head width determined by anthropometric eu-eu measurement with the ultrasound BPD measurement (Fig. 2).

The obtained findings showed that the head length determined on anatomical assessment (g-op) was larger than cephalometric findings obtained on ultrasound scanning (OFD). The error

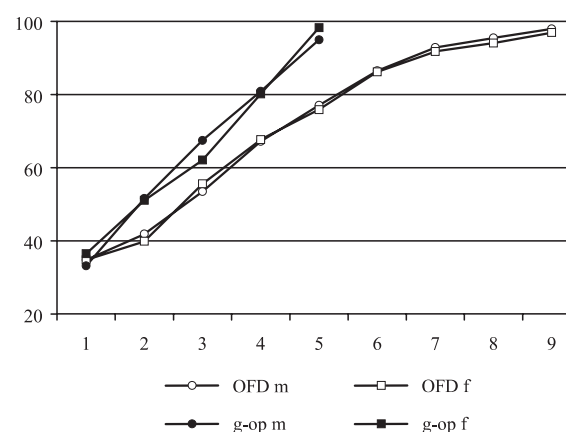


Fig. 1. Developmental curve of the total length of the head: OFD (occipitofrontal diameter) – ultrasound measurement; g-op (glabella – opistocranium) – anthropometric measurement (m – male sex, f – female sex)

Ryc. 1. Krzywa rozwojowa całkowitej długości głowy: OFD (wymiar potyliczno-czołowy) – przyżyciowy pomiar ultrasonograficzny; g-op – pomiar antropometryczny uzyskany na materiale płodów poronionych (m – płęć męska, f – płęć żeńska)

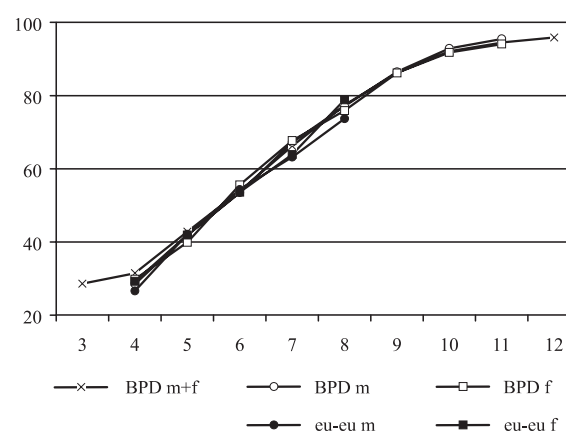


Fig. 2. Developmental curve of the total width of the head: BPD (biparietal diameter) – ultrasound measurement; eu – eu (euryon – euryon) – anthropometric measurement (m – male sex, f – female sex).

Ryc. 2. Krzywa rozwojowa całkowitej szerokości głowy: BPD (wymiar dwuciemienny) – przyżyciowy pomiar ultrasonograficzny; eu-eu – pomiar antropometryczny uzyskany na materiale płodów poronionych (m – płęć męska, f – płęć żeńska).

in both findings was due to various endpoints employed in both methods. The assessment of the foetal age on the basis of this measurement also was not free from error, which may result from inborn shape of the head (bradycephaly, dolichocephaly) or from the foetal lie, foetal lie at multiple pregnancy, oligohydramnios. The error may account for from few to several days' difference depending on the age of the foetus.

The assessment of the stage of development of spontaneously miscarried fetuses based on anthropometric eu-eu measurement does not differ from the developmental stage determined on the basis of the BPD measurement on intravital ultrasonography.

The findings are especially interesting in view of a general belief that the development of aborted fetuses is delayed in relation to the development of fetuses in normal pregnancy.

Obtained results indicate that the assessment of gestational maturity on the basis of head width measurement is more precise than this based on other parameters. This is also due to a common usage of the BPD measurement in ultrasound assessment of gestational maturity.

The reports by Bożilow [9], Kurlej [13], Palacz-Marchwińska [14] clearly indicate that the periods of increased and slowed down rates of development alternate at various age intervals in the prenatal development. The differences in the dimensions and rate of growth are associated with sexual dimorphism and become observable by means of various methods starting from the 4th month of gestation. Our observations have confirmed this phenomenon. The differences can be established only on the basis of screening examinations. Developmental norms which do not involve sexual dimorphism are inappropriate as they are inaccurate and unreliable.

Developmental norms based on ultrasound findings were determined on the basis of routine examinations (from one to six in low risk pregnancy) in various populations. In Poland, according to the guidelines of the Polish Group of

Medical Consultants for Gynaecology and Obstetrics from 1995, ultrasound examinations of the fetuses are recommended between 18th and 22nd weeks of pregnancy.

The newest reports dealing with the assessment of foetal maturity on the basis of anatomical examinations of miscarried fetuses and intravital ultrasound foetal scanning prove that the problems in determining the biological and the chronological age of the fetuses may be resolved successfully. The error in determining the chronological age on the basis of maternal history of last menstruation in some cases reached as much as 30 days. Statistical trials to eliminate the error in determining the age and measurement errors in the effect may cause narrowing of natural biological variation between individuals and failure to include the effect of investigated environmental and genetic factors on the course of organogenesis and growing. The curve of BPD growth approximates the linear course with slight, gradual decrease of the growth rate following 196 day of gestation. Similar results were obtained by Adamczyk [15] and Palacz-Marchwińska [14].

Obtained correlation coefficients between the investigated anthropometric parameters (from 0.986 to 0.984) indicate very high correlation between the parameters [10]. It means that every of the discussed parameters may be used in the assessment of gestational maturity and determination of chronological age of the miscarried fetuses and fetuses examined paravitally by means of ultrasound methods. This will enable the development of national norms and templates taking into consideration sexual and even regional differentiation. Such trials have already been undertaken [4]. The studies should include anatomical examinations of fetuses since the assessment of age on the basis of ultrasound scanning alone, taking into regards the developmental norms of other populations and not considering sexual dimorphism, arises numerous controversies. Foetal age assessed in this way reaches up to the values of 12 month of life (Tab. 1).

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