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Alicja Kędzia[1], Jowita Woźniak[1], Krzysztof Dudek[1, 2]

Relationship of the Radial Nerve and Lateral Intermuscular Septum of the Arm During the Fetal Period

Relacje nerwu promieniowego względem przegrody międzymięśniowej bocznej ramienia w okresie prenatalnym

[1] Department of Normal Anatomy, Wroclaw Medical University, Poland
[2] Institute of Machines Design and Operation, Technical University of Wrocław, Poland

Abstract

Objectives. The aim of the study was to analyze the location of radial nerve transit through the lateral intermuscular septum before its division into its deep and superficial branches during the human fetal period.
Material and Methods. The analysis included 140 preparations of the arms of 70 fetuses (33 female) aged 15–28 weeks (CRL: 90–225 mm). The methods comprised morphological and preparative analysis, digital image acquisition with a digital camera, the Scion Image computer measurement system for Windows v. Alpha 4.0.3.2, and statistical analysis. The point of radial nerve division (point W), the distance between the nerve's septum transition and the lateral epicondyle of the humerus (l_{WB}), and the humeral length (l_{AB}) were measured in each bone. Correlation between the two lengths and age was determined, symmetry and sexual dimorphism were examined, and the clinical significance of the problem discussed.
Results. In the examined material the l_{WB}/l_{AB} ratio was in the range of 0.16–0.42 (mean ± *SD*: 0.28 ± 0.05). The arms were divided into three groups with l_{WB}/L_{AB} as the division criterion. The first subgroup consisted of arms with ratios smaller than the typical range of variability ($\bar{x} \pm s$), the second of arms within the range, and the third of arms with ratios greater than typical.
Conclusions. Of the 140 arms, the level of the nerve's lateral division was higher than 1/3 of the bone length in 23 cases (16%), with similar percentages in the left (16%) and right (17%) arms. The difference was not statistically significant. Sex also did not influence the prevalence frequency of arms with a l_{WB}/l_{AB} ratio > 1/3; the percentages for female and male arms were 17% and 16%, respectively. No statistically significant relationship between l_{WB}/l_{AB} and fetal age was observed (**Adv Clin Exp Med 2009, 18, 2, 231–238**).

Key words: radial nerve, lateral intermuscular brachial septum, arm, fetal period.

Streszczenie

Cel pracy. Analiza umiejscowienia (wysokości) przejścia nerwu promieniowego przez przegrodę międzymięśniową boczną ramienia przed oddaniem gałęzi głębokich i powierzchownych w okresie prenatalnym człowieka.
Materiał i metody. Analizie poddano 140 preparatów ramion 70 płodów w wieku 15–28 tygodni, CRL: 90–255 mm. W grupie tej były 33 płody żeńskie. Wykorzystano analizę morfologiczną i preparatykę, cyfrową akwizycję obrazu za pomocą kamery cyfrowej, komputerowe pomiary w systemie Scion Image for Windows w. Alpha 4.0.3.2 , statystyczną analizę (testy: χ^2 Pearsona, Kołmogorowa-Smirnowa, logarytmiczne modele regresyjne). Dla każdej kości wyznaczono punkt wyjścia nerwu promieniowego (W) – jako odległość między wyjściem przez przegrodę a nadkłykciem bocznym kości ramiennej (l_{WB}) oraz zmierzono długość kości ramiennej (l_{AB}). Wyznaczono korelacje między tymi wymiarami a wiekiem, zbadano symetrię i dymorfizm płciowy oraz omówiono znaczenie kliniczne badanego problemu.
Wyniki. W badanym materiale stosunek wymiarów l_{WB}/l_{AB} mieścił się w przedziale 0,16–0,42 mm (średnia $\bar{x}$ = 0,28, odchylenie standardowe *SD* = 0,05). Badane ramiona podzielono na trzy podgrupy, przyjmując jako kryterium podziału wartość stosunku wymiarów l_{WB}/l_{AB}. Pierwszą podgrupę (*less*) stanowiły ramiona, dla których iloraz był mniejszy niż typowy zakres zmienności ($\bar{x}$), drugą (*typical*) – ramiona mieszczące się w tym zakresie, a trzecią (*more*) – ramiona o ilorazie większym niż typowy.

Wnioski. Wśród 140 ramion poziom wysokości odejścia nerwu na stronę boczną ramienia wyższy niż w 1/3 długości kości zaobserwowano w 23 przypadkach (16%). Odsetek ramion z taką cechą był podobny po stronie lewej (16%) i prawej (17%). Różnica nie była istotna statystycznie, co zweryfikowano testem niezależności χ^2 Pearsona. Płeć również nie miała wpływu na częstość występowania ramion o stosunku $l_{WB}/l_{AB} > 1/3$. Odpowiednie odsetki dla płodów żeńskich i męskich to 17% oraz 16%. Nie zaobserwowano również statystycznie istotnego związku między l_{WB}/l_{AB} a wiekiem płodów (**Adv Clin Exp Med 2009, 18, 2, 231–238**).

Słowa kluczowe: nerw promieniowy, przegroda międzymięśniowa boczna ramienia, ramię, okres płodowy.

The radial nerve penetrates the lateral intermuscular septum before its division into its deep and superficial branches. According to Fleming et al. [5], such a nerve position may cause problems when operating on the humerus. The authors analyzed selective material composed of 140 upper extremities and determined the "predicted point" as being between the proximal two-thirds and the distal one-third of the distance between the lateral border of the acromion process of the scapula and the lateral epicondyle of the humerus. Humeral lengths and the distances between the lateral intermuscular septum penetration site and lateral epicondyle (point W) were measured. The mean distance between the predicted point and the nerve's actual division site was 2.6 mm.

Shah et al. [11] reported that in 2–18% of patients, humeral fractures are always accompanied by radial nerve damage. They analyzed the results and radiograms of 62 patients with humeral fracture and radial nerve damage. Fifteen of them (24%) had penetrating fracture, 73% had primary nerve paralysis, and the others were qualified for secondary nerve analysis. After surgery, 95% of the patients regained normal or almost normal nerve function. Conservative treatment is recommended in patients with radial nerve damage accompanying humeral fractures. Sonnevald et al. analyzed clinical cases of radial nerve damage coexisting with humeral fracture in a similar way, [13]. In their material of 111 patients with humeral fracture, nerve damage occurred in 17 (15%) cases. In early intraoperative examinations the radial nerve remained undamaged in 13 of 14 cases. In the authors' opinion, nerve damage concurrent with humeral fracture is not an indication for early surgical treatment.

Bono et al. [2] examined radial nerve paralysis in 50 adult corpses. They measured the length of the humerus as well as the distance between the site of radial nerve transit through the lateral intermuscular septum (point W) and the distal part of the humerus (point B). The average distance (l_{WB}) was 16 ± 0.4 cm. This value is of a special importance in the risk rating of implantation of the distal part of the humerus as well as in post-fracture bone fixation. Guse and Ostrum [6] carried out postmortem examinations of 24 arms to define the radial nerve's position at the posterior arm surface in relation to the epicondyles of the humerus, the tip of the acromion, as well as the brachial triceps heads and aponeurotic membranes. The nerve length measured on the arm amounted to 124 mm and the mean distance between the lateral epicondyle and the division site on the bone posterior surface was 126 mm; this value was never below 100 mm. Carlan et al. [3] analyzed the course of the radial nerve in 27 cadavers. They examined the correlation between the nerve's location and the risk of intraoperative damage during the reconstruction of humeral fractures. Blackburn et al. [1] analyzed the radial nerve's course between the brachial plexus division site and the lateral epicondyle of the humerus in 40 adult cadavers. They described the distance between the level of the division of the radial nerve's superficial branch running along the arm's lateral surface and the lateral humeral epicondyle and ulnar olecranon. The aim of their studies was to implement the results in brachial surgery.

Shinohara et al. [12] presented one of the few papers in the literature which includes a prenatal analysis describing upper-extremity nerve development in the early embryonic period based on postmortem examinations of eight human embryos (CRL: 5.1–21.1 cm). Between the 38th and 40th weeks of human life (CRL: 9.2–11.5 cm), the radial nerve reaches the hand plate. In the prenatal period, acromial delivery constitutes a danger of brachial plexus injury as well as shoulder girdle fractures. This kind of delivery frequently results from the mother's obesity, diabetes, or fetal macrosomy. Shoulder dystocia is a prolonged head-body delivery time of more than 60 seconds and/or the necessity to use ancillary obstetric maneuvers [9].

The available literature does not include studies analyzing the site of radial nerve transmission through the lateral intermuscular septum in the prenatal period. The objectives of this survey were to make up for this lack and to compare results with those observed in adults.

Material and Methods

The material consisted of 140 preparations of fetal arms aged 15–28 weeks (70 fetuses, 37 male and 33 female) and with crown-rump lengths (CRL) of 90–255 mm. The material was stored in formaldehyde solution and at present it is impossible to conciliate any new one. The fetuses used in the survey were preserved for similar times, so the influence of the agent was similar in all the examined structures. All the material originated from the collection of the Department of Normal Anatomy, Wroclaw Medical University. Their morphological ages were determined according to the dependence described by Scammon and Calkins [4]. The methods applied comprised anatomical and preparative procedures as well as image acquisition with a digital camera and statistical analysis (Pearson's chi-squared test, Kolmogorov--Smirnov test). The measurements were carried out on the Scion Image 4.0.3.2 Alpha System [8]. The photos were prepared using the Gimp 2.2 [7] and Bimp 1.43 programs.

Results

Measurements of the level of radial nerve transit through the lateral intermuscular septum in the arms of the 70 fetuses were statistically analyzed. Table 1 presents the basic statistics of the somatic features characteristic of the examined fetuses. The lengths analyzed in this paper are shown in Fig. 1 and Table 2, including their basic statistics. In the examined material, the l_{WB}/l_{AB} ratio was within the range of 0.16–0.42 (mean ± *SD*: 28 ± ± 0.05). The arms were divided into three subgroups according to this ratio. The first subgroup ("less") consisted of arms for which the ratio was smaller than the expected range of variability ($\bar{x} \pm s$), the second ("typical") contained arms with ratios within the range, and the third ("more") arms with ratios larger than typical. Table 2 also presents the sizes of these subgroups. In the first group were 10 female (15%) and 10 male (14%) arms: 12 (17%) left and 8 (11%) right. In the second (most numerous) group were 52 (70%) male and 45 (68%) female arms: 47 (67%) left and 50 (71%) right. In the third group were 11 (17%) male and 12 (16%) female arms: 11 (17%) left and 12 (16%) right.

The increases in humeral length (l_{AB}) and the distance between the radial nerve's site of division and the lateral epicondyle (l_{AB}) in both the male and female fetuses are exponential (Fig. 2). However, the ratio of these lengths changed with fetal age (Fig. 3). Of the 140 arms, the level of the nerve's division towards the lateral side (l_{WB}) was higher than 1/3 of the bone length in 23 (16%). The percentage of arms with this feature was similar on the left (11 arms, 16%) and right side (12 arms, 17%,

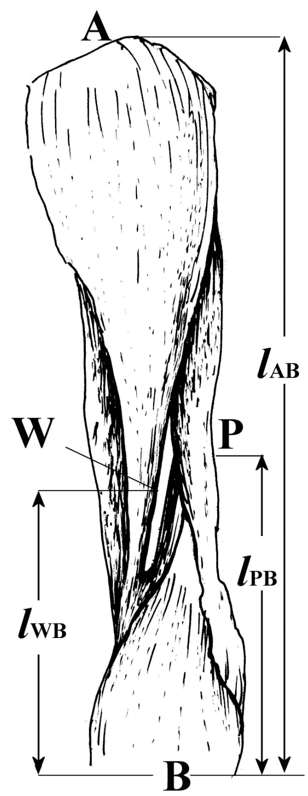


Fig. 1. Left arm: A – humerus proximal point (caput humeri); B – humerus distal point (humerus lateral epicondyle), W – point of nerve divergence towards arm lateral part, P – point at 1/3 of humeral length ("predicted point"), l_{AB} – humeral length, l_{WB} – distance between nerve transit through the lateral intermuscular septum and the bone's distal point

Ryc. 1. Ramię lewe: A – punkt proksymalny kości ramiennej (głowa kości ramiennej); B – punkt dystalny kości ramiennej (nadkłykieć boczny kości ramiennej); W – punkt wyjścia nerwu na część boczną ramienia; P – punkt leżący w 1/3 długości kości ramiennej, tzw. *predicting point*; l_{AB} – długość kości ramiennej; l_{WB} – odległość punktu wyjścia nerwu przez przegrodę międzymięśniową boczną ramienia od punktu dystalnego kości

Table 2). The difference was not statistically significant (Pearson's chi-squared test, Fig. 4). Sex did not influence the prevalence of the l_{WB}/l_{ab} ratio. No correlation between the prevalence of the l_{WB}/l_{AB} ratio and fetal age was found (Fig. 5). The l_{WB}/l_{AB} ratio did not depend on sex or on left or right side and showed a normal distribution with a mean value of 0.28 and a standard deviation of 0.05 (Fig. 6).

Together with the developmental process, the average distance between the nerve division site (point W) and the "predicted point" (l_{WP}) increased towards point A, which is visible in a comparative diagram of developmental age (Fig. 7). A comparison of the authors' material of fetal arms and arms in adults [5] in subgroups with different l_{WB}/l_{AB} ratios (Fig. 8) showed a statistically significant difference.

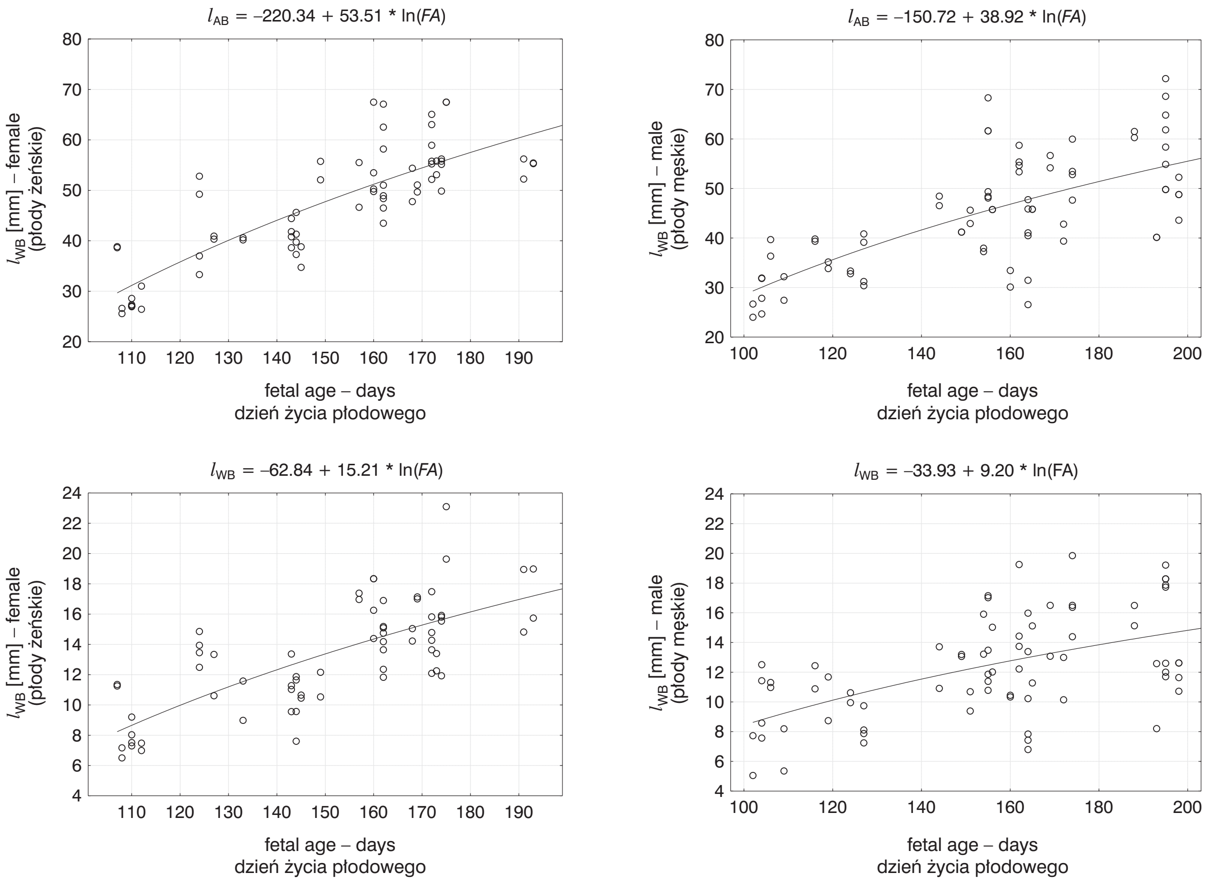


Fig. 2. Correlation diagrams of humeral length (l_{AB}) and nerve divergence height (l_{WB}) in male and female fetuses with morphological age (FA) together with regressive logarithmic models

Ryc. 2. Diagramy korelacyjne długości kości ramiennej l_{AB}; wysokości odejścia nerwu na boczną stronę ramienia l_{WB} płodów żeńskich i męskich z wiekiem morfologicznym oraz logarytmiczne modele regresyjne

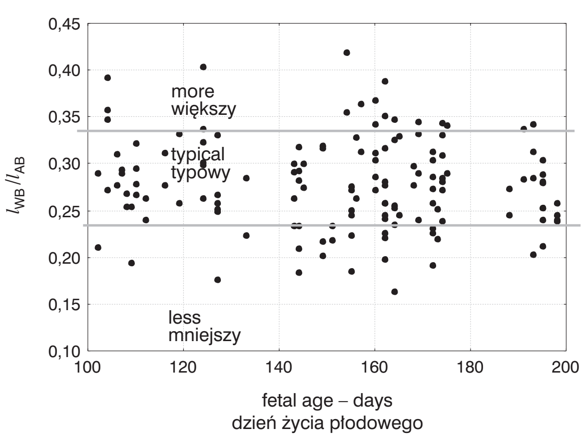


Fig. 3. Correlation diagrams of nerve divergence height and humeral length ratio (l_{WB}/l_{AB}) with morphological age

Ryc. 3. Diagramy korelacyjne stosunku wysokości odejścia nerwu na stronę boczną ramienia do długości kości ramiennej l_{WB}/l_{AB} z wiekiem morfologicznym

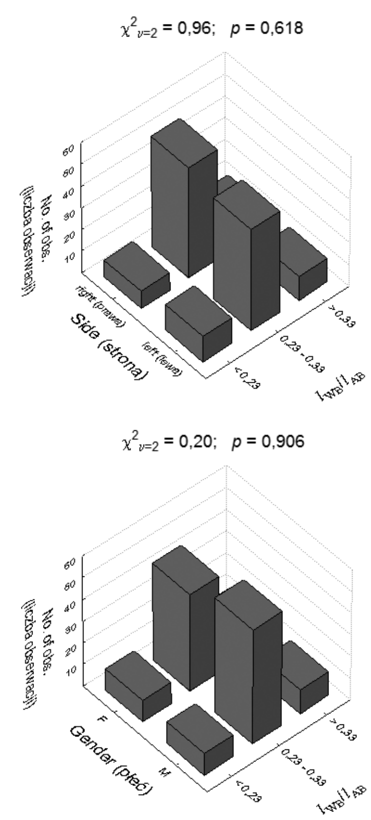


Fig. 4. Numbers of fetuses in the subgroups according to sex and l_{WB}/l_{AB} ratio and to side and l_{WB}/l_{AB} ratio

Ryc. 4. Liczebności płodów w podgrupach różniących się płcią i stosunkiem l_{WB}/l_{AB} oraz stroną i stosunkiem l_{WB}/l_{AB}

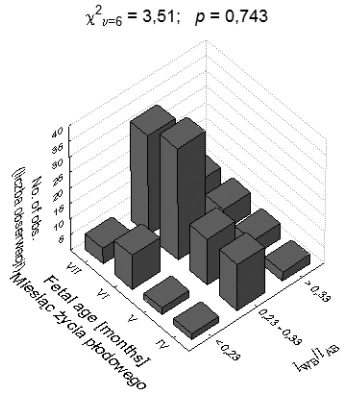
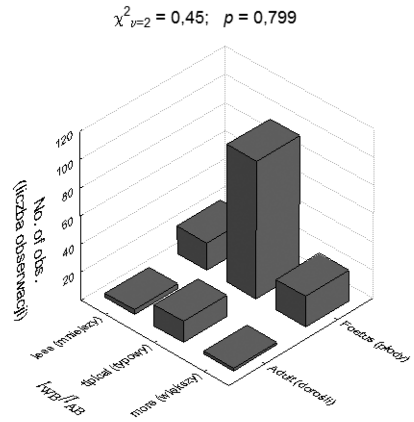


Fig. 5. Numbers of fetuses in the subgroups according to age and l_{WB}/l_{AB} ratio and chi-squared test results

Ryc. 5. Liczebności płodów w podgrupach różniących się wiekiem i stosunkiem l_{WB}/l_{AB} oraz wynik testu χ^2



	fetuses (płody)	adults (dorośli)
less (mniejszy)	$l_{WB}/l_{AB} < 0.23$	$l_{WB}/l_{AB} < 0.327$
typical (typowy)	$0.23 \leq l_{WB}/l_{AB} \leq 0.33$	$0.327 \leq l_{WB}/l_{AB} \leq 0.345$
more (większy)	$l_{WB}/l_{AB} > 0.33$	$l_{WB}/l_{AB} > 0.345$

Fig. 8. Comparison of fetal (own material) and adult [5] arm numbers in subgroups according to l_{WB}/l_{AB} ratio

Ryc. 8. Porównanie liczby ramion płodów (materiał własny) i dorosłych [5] w podgrupach różniących się stosunkiem l_{WB}/l_{AB}

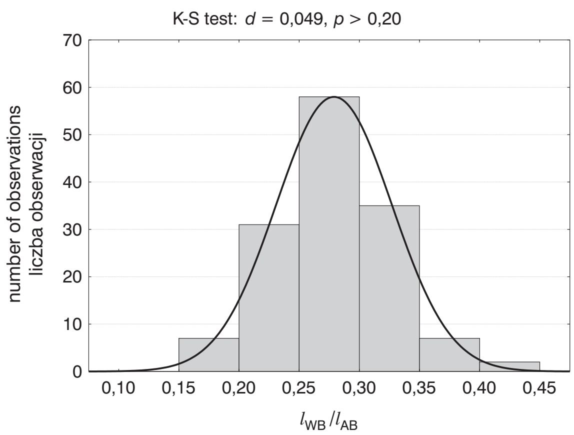


Fig. 6. l_{WB}/l_{AB} ratio histogram with the normal distribution *N* (0.28, 0.05) and normality test results

Ryc. 6. Histogram stosunku wymiarów l_{WB}/l_{AB} badanych płodów na tle rozkładu normalnego *N*(0,28; 0,05) i wynik testu normalności Kołmogorowa-Smirnowa

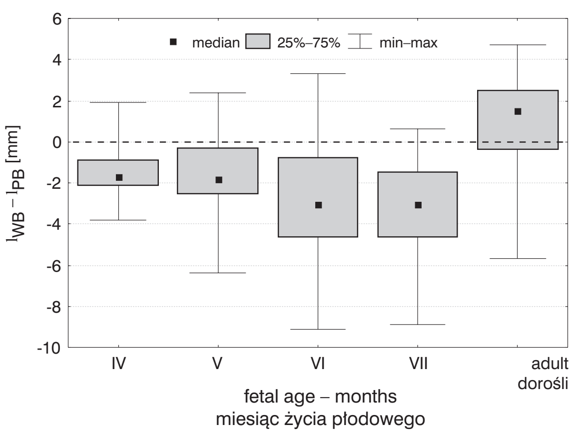


Fig. 7. Comparison of distance points P and W in the four fetal age groups and in adults [5]

Ryc. 7. Porównanie odległości między punktami P i W w czterech grupach wiekowych płodów i u osób dorosłych [5]

Discussion

Schocke et al. [10] examined 11 patients with sensorimotor radial nerve injury after distal humeral fracture with the use of conventional radiography, ultrasonography, electroencephalography, and electromyography. Seven fractures were located at the middle third and four at the distal third of the humerus. The diameters of the left and right radial nerve in the patients and 10 healthy non-fractured persons were not statistically significantly different. The applicability of the ultrasound method in assessing radial nerve damage was evaluated. In ultrasound the radial nerve appears as a hyperechogenic structure with parallel linear echoes on a longitudinal scan and as an oval or round structure with hyperechogenic areas, corresponding to the nerve fascicles, on a transverse scan. The radial nerve penetrates the lateral intermuscular septum and enters the anterior space of the upper arm 10 cm proximally to the lateral epicondyle of the humerus. According to Fleming et al. [5], the mean deviation of radial nerve transit through the lateral intermuscular septum measured from the "predicted point" (1/3 arm length) amounted to 2.6 mm in adult patients. In the present authors' own material, the l_{WB}/l_{AB} ratio was within the range of

Table 1. Characteristics of the analyzed group of fetuses

Tabela 1. Charakterystyka analizowanej grupy płodów

Examined feature of fetus (Analizowane wartości)	Fetal age – months (Wiek płodu – miesiąc)				Total (Razem)
	4	5	6	7–8	
Number of arms N (Liczebność ramion N)	20	22	54	44	140
female (w tym płodów żeńskich)	10 (50%)	10 (45%)	26 (48%)	20 (45%)	66 (47%)
Length (długość *vertex-tuberale*) *CRL* [mm]					
mean (średnia) $\bar{x}$	93.4	139.6	182.2	214.3	172.9
standard deviation (odchylenie standardowe) *SD*	22.1	20.0	18.6	17.6	44.9
minimum (wartość minimalna) x_{min}	90	116	160	160	90
maximum (wartość maksymalna) x_{max}	107	187	255	235	255
Length (długość vertex-plantare) *v-pl* [mm]					
mean (średnia) $\bar{x}$	141.9	189.1	258.8	298.2	243.0
standard deviation (odchylenie standardowe) *SD*	9.8	22.9	18.9	38.2	61.5
minimum (wartość minimalna) x_{min}	130	160	224	208	130
maximum (wartość maksymalna) x_{max}	160	234	295	347	347
Mass (masa) [g]					
mean (średnia) $\bar{x}$	73	197	407	633	396
standard deviation (odchylenie standardowe) *SD*	15	115	114	150	231
minimum (wartość minimalna) x_{min}	50	110	240	225	50
maximum (wartość maksymalna) x_{max}	94	465	606	842	842
Distance (odległość) *sst-xi* [mm]					
mean (średnia) $\bar{x}$	43.7	60.8	109.6	94.1	88.8
standard deviation (odchylenie standardowe) *SD*	3.1	14.0	49.7	20.4	38.1
minimum (wartość minimalna) x_{min}	40	50	28	25	25
maximum (wartość maksymalna) x_{max}	47	90	170	113	170
Distance (odległość) *sst-sy* [mm]					
mean (średnia) $\bar{x}$	88.7	122.8	111.7	178.7	140.3
standard deviation (odchylenie standardowe) *SD*	4.4	22.4	35.6	39.9	48.2
minimum (wartość minimalna) x_{min}	83	105	75	72	72
maximum (wartość maksymalna) x_{max}	92	169	159	206	206

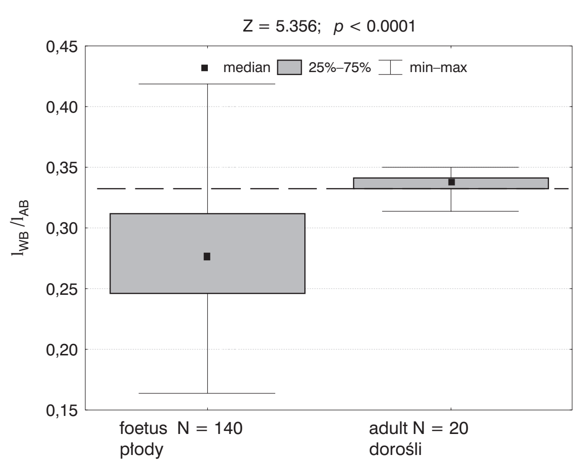


Fig. 9. Comparison of l_{WB}/l_{AB} ratios in fetuses and adults (difference statistically significant)

Ryc. 9. Porównanie stosunku l_{WB}/l_{AB} płodów i osób dorosłych (różnica statystycznie istotna)

0.16–0.42 (mean: 0.28 ± 0.05). Sixteen percent of the examined arms had a ratio less than the typical variability range ($\bar{x} \pm s$), 69% were within this range, and 16% had a ratio greater than normal. Comparing the present results with Flemings' reports it was observed that the W point (point of radial nerve divergence) was shifted upwards in adult patients, together with age (Fig. 9).

Blackburn et al. [1], Bono et al. [2], Carlan et al. [3], and Guse and Ostrum [6] examined arm geometry, the height of radial nerve transit on the arm's lateral surface, as well as the clinical implications connected with the division patterns, applied mainly in brachial surgery. Their papers comprised adult postmortem analyses. The possibility of radial nerve paralysis with humeral shaft fracture at a high level of the division was recognized as an important clinical aspect. It is worth mentioning that such incidents may happen during improper intradermal injection or perinatal damage by brachial dystocia. Long-term observations indicate that such clinical complications may prevail in 13% of the examined population, independent of sex and body side.

The authors concluded that analysis of radial nerve transit through the brachial lateral intermuscu-

Table 2. Basic statistics of the arms' geometry

Tabela 2. Podstawowe statystyki geometrii badanych ramion

Quantitative feature (Cecha ilościowa)	Gender (Płeć)		Body side (Strona ciała)		Total (Razem) N = 140
	F *N* = 66	M *N* = 74	left *N* = 70	right *N* = 70	
l_{AB} [mm] – length of humerus: (Długość kości ramiennej):					
mean $\bar{x}$ (średnia)	47.3	44.9	46.2	45.8	46.0
standard deviation (odchylenie standardowe) *SD*	11.2	11.5	11.6	11.2	11.4
median *Me* (mediana)	49.4	45.7	47.7	45.8	46.5
minimum (wartość minimalna) x_{min}	25.6	24.0	24.7	24.0	24.0
maximum (wartość maksymalna) x_{max}	67.5	72.2	72.2	68.6	72.2
l_{WB} [mm] – distance between lateral epicondyle and the nerve divergence site (Odległość między nadkłykciem bocznym a miejscem wyjścia nerwu na część boczną ramienia):					
mean $\bar{x}$ (średnia)	13.3	12.3	12.7	12.8	12.8
standard deviation (odchylenie standardowe) *SD*	3.5	3.4	3.5	3.6	3.5
median *Me* (mediana)	13.4	12.0	12.3	12.8	12.5
minimum (wartość minimalna) x_{min})	6.5	5.1	6.5	5.1	5.1
maximum (wartość maksymalna) x_{max}	23.1	19.9	23.1	19.9	23.1
l_{WB}/l_{AB} – l_{WB} to l_{AB} ratio (Stosunek wymiarów l_{WB} i l_{AB}):					
mean $\bar{x}$ (średnia)	0.28	0.28	0.28	0.28	0.28
standard deviation (odchylenie standardowe) *SD*	0.05	0.05	0.05	0.04	0.05
median *Me* (mediana)	0.28	0.27	0.28	0.28	0.27
minimum (wartość minimalna) x_{min}	0.18	0.16	0.16	0.18	0.16
maximum (wartość maksymalna) x_{max}	0.40	0.42	0.42	0.39	0.42
$L_{WB} - l_{PB}$ [mm] – distance from "predicted point" (Odległość od „*predicted point*"):					
mean $\bar{x}$ (średnia)	–2.5	–2.7	–2.7	–2.5	–2.6
standard deviation (odchylenie standardowe) *SD*	2.5	2.4	2.7	2.1	2.4
median *Me* (mediana)	–2.3	–2.8	–2.4	–2.7	–2.5
minimum (wartość minimalna) x_{min}	–8.9	–9.1	–8.9	–9.1	–9.1
maximum (wartość maksymalna) x_{max}	2.4	3.3	3.3	2.4	3.3
Number of arms (%) with ratios (Liczba ramion (odsetek) o stosunku wymiarów):					
$l_{WB}/l_{AB} < 0.23$	10 (15%)	10 (14%)	12 (17%)	8 (11%)	20 (14%)
$0.23 \le l_{WB}/l_{AB} \le 0.33$	45 (68%)	52 (70%)	47 (67%)	50 (71%)	97 (69%)
$0.33 < l_{WB}/l_{AB}$	11 (17%)	12 (16%)	11 (16%)	12 (17%)	23 (16%)

lar septum before its division into its deep and superficial branches in the prenatal period proved to be an individual feature which was symmetric and did not show sexual dimorphism. In fetuses this site is located at 5/7 of the humeral length and in adults this point shifts upwards to 2/3 of the humeral length.

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Address for correspondence:

Alicja Kędzia
Department of Normal Anatomy
Wroclaw Medical University
Chałubińskiego 6a
50-368 Wrocław
Poland
Tel.: +48 71 784 00 80
E-mail: jowita_wozniak@yahoo.com

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