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New Reference Values of Arterial Blood Pressure in Term Newborns

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Summary

Background
Previous arterial blood pressure (BP) values reference in term and late preterm newborns were obtained on a relatively small number of participants, and contain different data on the dependence of BP on birth weight and gestational age.

Methods
This prospective study included 12054 healthy (11904 terms and 150 late preterm) infants aged 36-50 hours of life, who have measured BP on the right arm and leg on a multi-channel monitor using an oscillography.

Findings
The difference in systolic (SAP), diastolic (DAP), and mean (MAP) BP, when measured on the right arm and leg in term newborns, was not statistically significant – Student's t-test was 0.29, 0.49, and 0.35 respectively. The difference in SAP, DAP, and MAP, when measured in terms of boys and girls, was not statistically significant – Student's t-test was 1.21, 0.73, and 0.48 respectively. The difference in SAP, DAP, and MAP when measured in term and late preterm newborns were statistically significant – Student's t-test was 4.36, 3.61, and 2.70 respectively. There was a slight correlation between birth weight and BP because the Pearson correlation coefficient was ≈0.18, 0.06, and 0.1 respectively.

Reference ranges of BP in term newborns in the early neonatal period were determined: data from 97,5 to 2,5 percentiles and data from 3 to -3 z-scores.

Interpretation
The obtained BP data from this research can be used as reference values in term newborns. It is permissible to use both the obtained general normative tables for boys and girls and separate tables. It is possible to use the obtained additional normative tables of BP in term newborns with stratification by birth weight. Further research is needed to determine reference BP in late preterm infants.

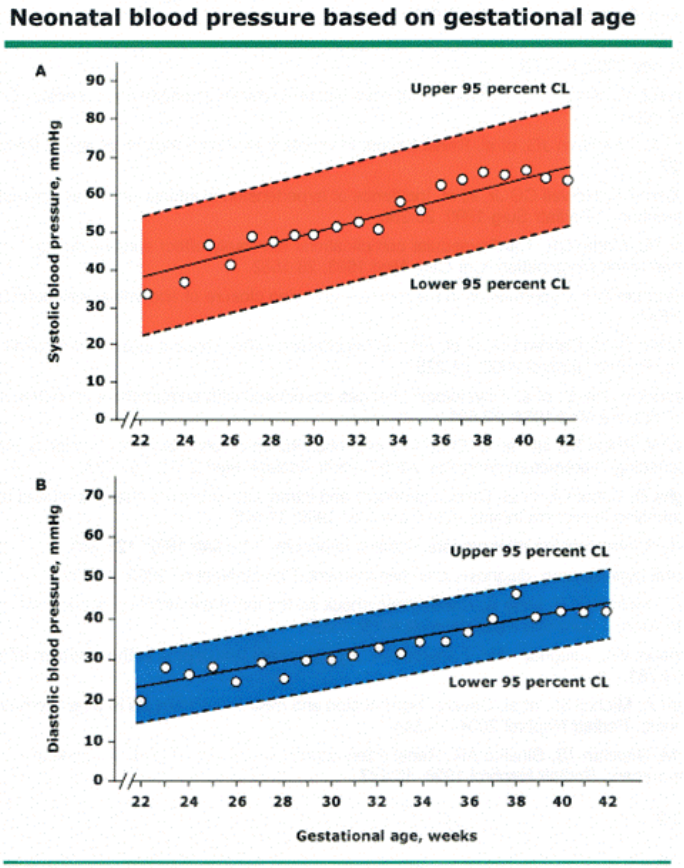
Keywords: Arterial Blood Pressure, Newborn, Late Preterm, Reference Values

Introduction

Measurement of arterial blood pressure (BP) in newborns is one of the most common methods for assessing hemodynamic parameters, especially in the early neonatal period, as well as a potential approach for screening obstructive aortic

defects in two-zone (pre-and postductal BP measurement after ductal closure). Therefore, it is critical to have reliable normative BP values references in newborns [1,2]. However, in pediatrics and, in particular, in neonatology, measurement of BP in routine practice is often absent [3]. As a result, there is a lack of normative BP data in healthy newborns in the early neonatal period [4]. The available previous normative BP values reference in term and late preterm newborns are based on a relatively small number of participants and contain different data regarding the dependence of BP on gestational age and birth weight. Thus, the study by Park M. K. et al. (1989) gives the normative BP values references in healthy term newborns, based on the BP measurement in 219, and Nwokoye I. C. et al. (2015) – in 309 newborns, and demonstrate a positive correlation between birth weight and the value of systolic arterial blood pressure (SAP) and no significant correlation between the value of BP and gender, method of delivery or maternal age [4,5]. Kent A.L. et al. (2007) in their research (n=406 healthy term newborns) note that there is no significant relationship between the value of BP and birth weight or length; besides, the authors indicate that from the first day of life, there is an increase of BP values in healthy term newborns [6]. Moumita S. et al. (2015) in their research included the maximum number of term newborns (n=1617 newborns) and presented the reference BP values comparable to the data obtained by Kent A.L. et al. (2007) [6,7]. However, the results of this research are based on the analysis of a non-representative group of participants (which includes in total of 1427 term and 190 preterm newborns with gestational age of 32-36 weeks).

According to the Moumita S. et al. (2015) study, the mean BP values in boys and girls did not have a statistically significant difference [7]. However, such a distinction was detected when comparing the BP values in term and preterm newborns: in preterm newborns, the BP values were significantly lower. Researches by Patankar N. et al. (2016) (n = 866 newborns gestational age 22-42 weeks), Kent A.L. et al. (2009) (n = 147 preterm newborns gestational age of 28-36 weeks), Pejovic B. et al. (2006) (n = 292 preterm and 81 term newborns), Zubrow A.B et al. (1995) (n = 608 newborns gestational age of 22-42 weeks) demonstrate a statistically significant dependence of BP value in preterm newborns on gestational age [1,8-10]. Some researchers give reference BP values for term newborns, obtained on the data in newborns in intensive care units, that is, obviously unhealthy [1,9,10]. It is important that the most frequently used BP reference in neonatology is based on the research by Zubrow A.B et al. (1995) (Figure 1), which was obtained from BP data in term and preterm newborns (n = 608), some of whom were on respiratory and inotropic therapy [10].



"Figure 1: The most frequently used BP reference in neonatology is based on the research by Zubrow A.B et al. (1995)10."

Thus, previous BP reference values in term and late preterm newborns have been obtained in researches with significant limitations:

- based on a relatively small number of newborns;
- most of the current reference values are based on BP data in term and preterm newborns observed in intensive care units (including those on respiratory and inotropic therapy);

• information on the dependence of BP values on birth weight and gestational age in term and late preterm newborns is scattered and contradictory.

"The described disadvantages and limitations of the available BP references, as well as the tendency to an increase in birth weight over time5, which could lead to a change in the BP values in newborns, necessitate further research in this direction and possible revision of the BP reference values."

Our Research Aimed to:
• determine the BP value references in healthy term newborns,
• assess the correlation between BP values and birth weight,
• evaluate the difference in BP values in term and late preterm newborns and in males and females.

Material and Methods

In the Department of Newborns in National Medical Research Center for Obstetrics, Gynecology and Perinatology named after academician V.I. Kulakov, from the end of 2017 to the present, neonatal screening of critical congenital heart defects (CCHD) has been carried out not only by two-zone (pre-and postductal) pulse oximetry but also using two-zone BP measurement (as the most sensitive method for obstructive aortic arch defects) [1,2]. When newborn screening CCHD by two-zone BP measurement was carried out, the interpretation of the screening results was performed by comparing the value of systolic arterial blood pressure (SAP) pre-and postductal. The difference in SAP of 10 mm Hg and more2 was considered diagnostically significant and indicated the risk of aortic arch obstruction, provided that the preductal SAP value was higher. When assessing newborn screening CCHD results, it needed to evaluate not only the SAP difference but the BP value in general to identify potentially more pathologies (for example, hypo- and hypertension of various etiologies, preductal aortic obstruction). Given the current absence of representative BP reference values in term newborns in the early neonatal period, prospective observational research from 2018 to 2020 was conducted. The study included 12,054 healthy term and late preterm infants aged Me(min-max) =48(36-50) hours of life, who underwent two-zone BP measurements.

Our study included healthy term and late preterm newborns screened for CCHD by pre-and postductal SAP measurement, who have a difference of SAP (preductal SAP-postductal SAP) 9 mm Hb and less and who were discharged home at the age of 2- 5 days of life. The majority of newborns - 11,904 (98.8%) were born in term, and 150 (0.2%) babies were late preterm gestational age Me (min-max) = 36 (35-36) weeks. The newborns included in the study did not require resuscitation measures after birth and during the neonatal period. All studied newborns underwent two-zone pre- and postductal (on the right arm and any leg) BP measurement on a Dräger Infinity Gamma XL multichannel monitor using an oscilloscope method. To measure BP used disposable cuffs (sizes 6-11 cm and 4-6 cm).

The cuff covered at least two-thirds of the length of the right shoulder or thigh and covered the entire circumference of the right shoulder or thigh when BP measurement was performed. BP measurement in newborns was carried out in calm wakefulness or sleep. BP measurement pre- and postductal was carried out subsequentially, with short intervals of time (no more than 1-2 minutes). When the state of activity in newborns changed during measurements (sleep-wakefulness, wakefulness-crying), a second measurement was carried out 5 minutes after reaching a state of calm wakefulness or sleep. All measurements were performed by trained nursing staff.

A standard (Gaussian) distribution was used to visualize the normal BP value distribution. The used calculation formula of standard (Gaussian) distribution:

$$y = y_0 + \frac{A}{\omega\sqrt{\pi/2}} e^{-2\frac{(x-x_c)^2}{\omega^2}}, \text{ where:}$$

where: y_0=0; A- the area under the graph; ω=2δ; δ- standard deviation; π≈3,14…; e≈2,718…; xc-mean value.

The Student's t-test was used (critical value of Student's t-test = 1.972 and a significance grade of p = 0.05) to assess the statistical significance of differences between BP values in various groups of newborns. Pearson's correlation coefficient was used to assess the correlation between blood pressure and birth weight. The interpretation of the Pearson correlation coefficient was assessed according to the Chaddock table (Table 1).

The absolute value of the correlation coefficient	The tightness (strength) of the correlation
< 0,3	weak (insignificant)
0,3-0,5	moderate
0,5-0,7	significant
0,7-0,9	high
> 0,9	very high

Table 1: The Chaddock table

To determine the normative reference SAP, diastolic (DAP) and mean (MAP) arterial BP values in term newborns were carried out the calculations of indicators 97.5; 90; 75; 50; 25; 10; 2.5 percentiles and indicators 3; 2; 1; 0; -1; -2; -3 z-scores. Accordance of z-scores to percentiles is given in Table 2.

z-scores	percentiles
3	99,9
2	97,7
1	84,1
0 (median)	50
-1	15,9
-2	2,3
-3	0,1

Table 2. Accordance of z-scores to percentiles.

Results and Discussion

After two-zone BP measurements in 11904 term newborns, we get the results shown in Table 3.

index	n	standard (Gaussian) deviation, mm Hg			
		δ	mean value	standard error (mean value)	standard error (δ)
SAP (right arm)	11904	6.1	71.3	0.13	0.15
SAP (leg)	11904	6.4	71.3	0.07	0.08
DAP (right arm)	11904	6.98	41.8	0.22	0.25
DAP (leg)	11904	6.95	41.9	0.1	0.11
MAP (right arm)	11904	6.3	51.5	0.26	0.3
MAP (leg)	11904	6.63	51.4	0.04	0.04

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure; δ-standard deviation; n- number of observations (newborns).

Table 3. Preductal (measured on right arm) and postductal (measured on the leg) SAP, DAP, MAP levels in term newborns.

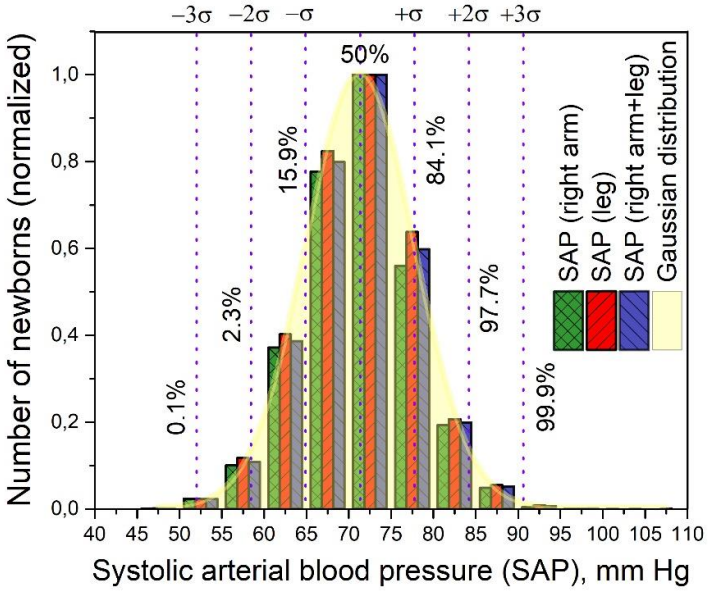
When comparing systolic, diastolic (DAP) and mean (MAP) BP values obtained when measured on the right arm and leg in term newborns, the Student's t-test was 0.29 (p = 0.769450), 0.49 (p = 0.624651) and 0.35 (p = 0.725542), respectively - the differences are not statistically significant (the degree of freedom f = 23806, the critical value of Student's t-test = 1.972, with a significance level of α = 0.05) - see Table 4.

index	n	mean value	standard error (mean value)	p-value	Student's t-test
SAP (right arm)	11904	71.3	0.13	p = 0.769450	0.29
SAP (leg)	11904	71.3	0.07		
DAP (right arm)	11904	41.8	0.22	p = 0.624651	0.49
DAP (leg)	11904	41.9	0.1		
MAP (right arm)	11904	51.5	0.26	p = 0.725542	0.35
MAP (leg)	11904	51.4	0.04		

* the degree of freedom f = 23806, the critical value of Student's t-test = 1.972, with a significance level of α = 0.05; SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure; n-number of observations (newborns).

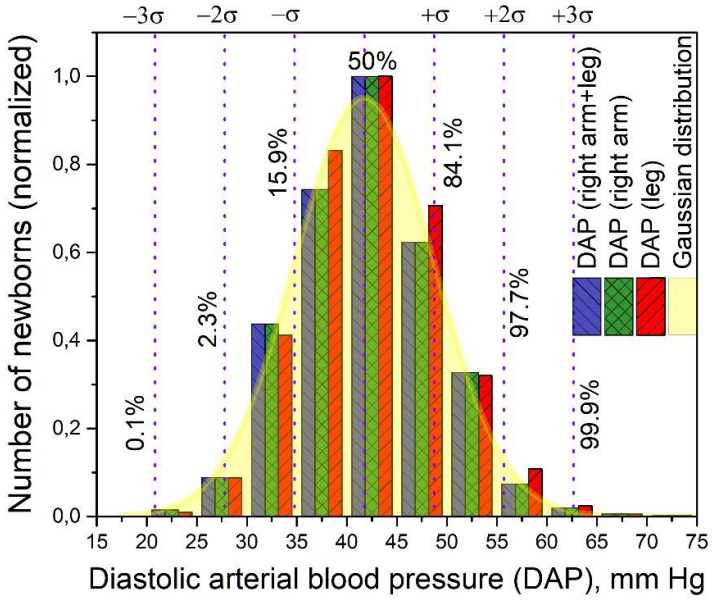
Table 4. Student's t-test for SAP, DAP, MAP values measured on the right arm and leg in term newborns *.

Figures 2-4 show the normal (Gaussian) distribution of BP indicators for the normalized number of newborns when measuring BP on the right arm, leg, and on the right arm and leg in total. Figure 5 shows a comparative characteristic of SAP, DAP, and MAP levels when measured on the right arm and leg in healthy term newborns. Figures 2-5 illustrate the absence of significant differences in SAP, DAP, and MAP when measured on the right arm and leg.



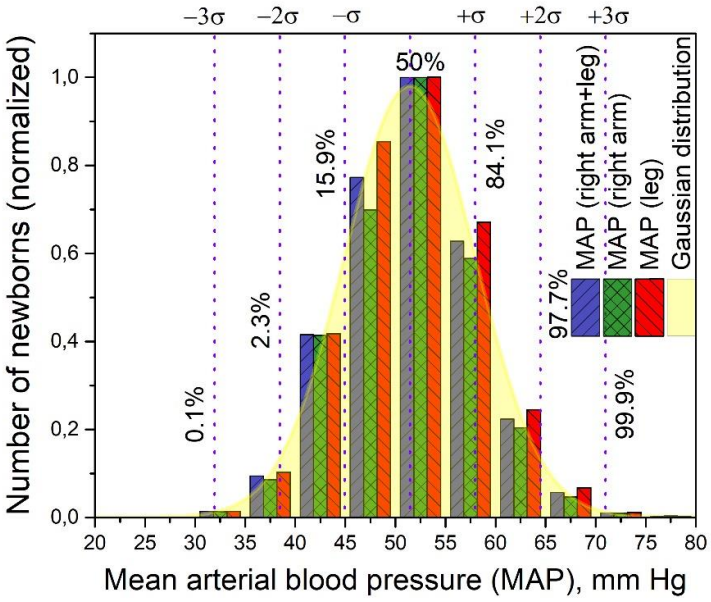
δ-standard deviation; 0,1%, 2,3%, 15,9%, 50%, 84,1%, 97,7%, 99,9% - percentiles.

Figure 2. The normal (Gaussian) distribution of systolic arterial blood pressure indicators for the normalized number of newborns when measuring BP on the right arm and leg.



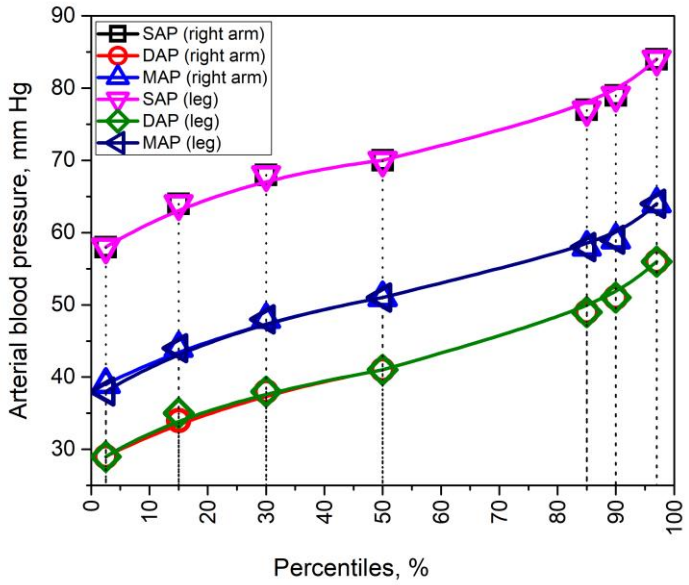
δ-standard deviation; 0,1%, 2,3%, 15,9%, 50%, 84,1%, 97,7%, 99,9% - percentiles.

Figure 3. The normal (Gaussian) distribution of diastolic arterial blood pressure indicators for the normalized number of newborns when measuring BP on the right arm and leg.



δ-standard deviation; 0,1%, 2,3%, 15,9%, 50%, 84,1%, 97,7%, 99,9% - percentiles.

Figure 4. The normal (Gaussian) distribution of mean arterial blood pressure indicators for the normalized number of newborns when measuring BP on the right arm and leg.



SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure

Figure 5. A comparative characteristic of SAP, DAP, and MAP level when measured on the right arm and leg in healthy term newborns.

Given the absence of a statistically significant difference in SAP, DAP, and MAP in term newborns when measuring BP on the right arm and leg, the current study combined the BP data, thus obtaining more measurements for analysis - for healthy term infants n = 11 904 measurements on the right arm + 11 904 measurements on the leg = 23 808 measurements. The obtained BP data is presented in Table 5.

Based on the summarized BP levels we determined the normative reference SAP, DAP, and MAP in term newborns (97.5; 90; 75; 50; 25; 10; 2.5 percentiles and 3; 2; 1; 0; -1; -2; -3 z-deviations) - Tables 6-11.

index	male+female, n=23808				male, n=12090				female, n=11718			
	m	SAP	DAP	MAP	m	SAP	DAP	MAP	m	SAP	DAP	MAP
median	3374	70	41	51	3410	70	42	51	3330	71	41	51
mean value	3372	71	42	51	3409	71	42	51	3333	71	41	51
min	1809	43	20	21	1809	43	21	28	1990	46	15	20
max	5400	107	85	89	5020	107	85	89	5400	98	71	84

n-number of observations (the obtained summarized data when measured on the right arm and leg); m-birth weight, grams; SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 5. The obtained summarized BP data when measured on the right arm and leg.

	Percentiles, %						
	97,5	90	75	50	25	10	2,5
SAP, mm Hg	84	79	75	70	66	62	58
MAP, mm Hg	64	59	55	51	47	43	39
DAP, mm Hg	56	51	46	41	37	32	29

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 6. New reference values of BP in term newborns in the early neonatal period (for males and females), percentiles.

	z-scores						
	3	2	1	0	-1	-2	-3
SAP, mm Hg	90	84	77	70	64	58	50
MAP, mm Hg	72	64	58	51	44	38	31
DAP, mm Hg	66	56	48	41	34	29	22

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 7. New reference values of BP in term newborns in the early neonatal period (for males and females), z-scores.

	Percentiles, %						
	97,5	90	75	50	25	10	2,5
SAP, mm Hg	83	79	75	70	66	62	58
MAP, mm Hg	64	59	55	51	47	43	38,8
DAP, mm Hg	55	51	46	42	37	32	29

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 8. New reference values of BP in term newborns in the early neonatal period (for males), percentiles.

	z-scores						
	3	2	1	0	-1	-2	-3
SAP, mm Hg	90	84	77	70	64	58	50
MAP, mm Hg	72	65	57	51	44	38	30
DAP, mm Hg	67	56	49	42	35	29	23

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 9. New reference values of BP in term newborns in the early neonatal period (for males), z-scores.

	Percentiles, %						
	97,5	90	75	50	25	10	2,5
SAP, mm Hg	84	79	75	71	67	62	58
MAP, mm Hg	64	59	55	51	46	42	39
DAP, mm Hg	56	51	46	41	36	32	29

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 10. New reference values of BP in term newborns in the early neonatal period (for females), percentiles.

	z-scores						
	3	2	1	0	-1	-2	-3
SAP, mm Hg	90	84	81	71	64	57	50,7
MAP, mm Hg	72	64	61	51	44	38	31,7
DAP, mm Hg	65	56	53	41	34	28	22

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 11. New reference values of BP in term newborns in the early neonatal period (for females), z-scores.

Compared to the normative BP references given in A.B. Zubrow et al. (1995), our study determined higher SAP values, a higher upper limit, and a lower low limit of DAP [10]. These differences are because, in our study, the sample consists of BP data in exclusively healthy newborns and not in children observed in intensive care units, including those on respiratory and cardiotonic therapy. The obtained data were evaluated using the Student's t-test to determine the presence or absence of a statistically significant difference in BP values in term newborn boys and girls (see Table 12, Figures 6-8).

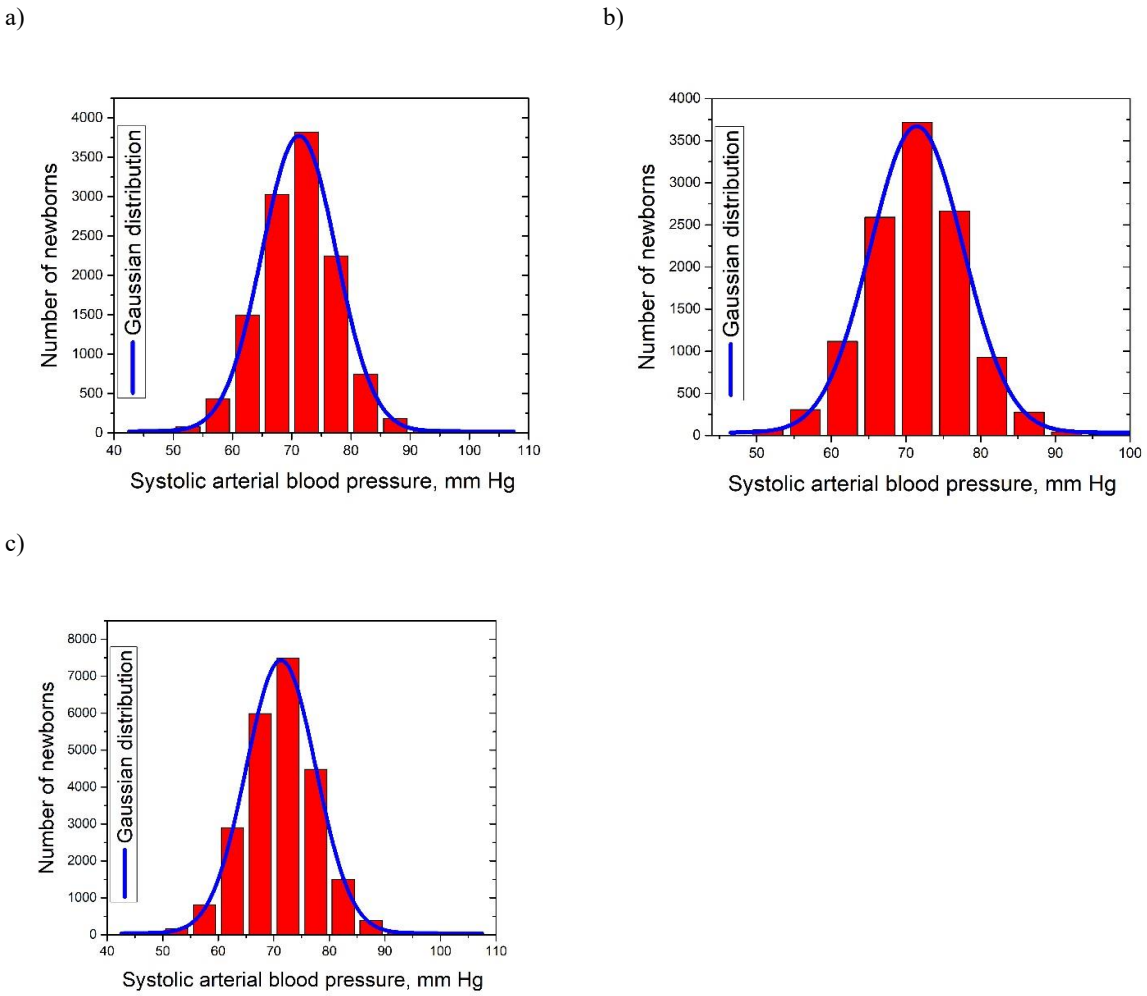
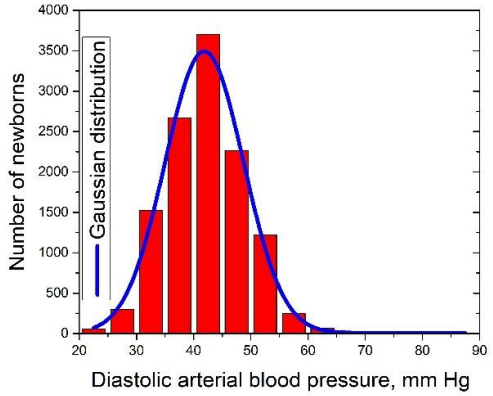


Figure 6. The normal (Gaussian) distribution of systolic arterial blood pressure: a) in girls; b) in boys; c) in girls and boys.

a)



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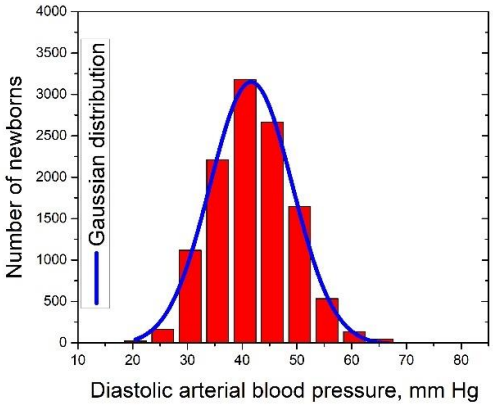

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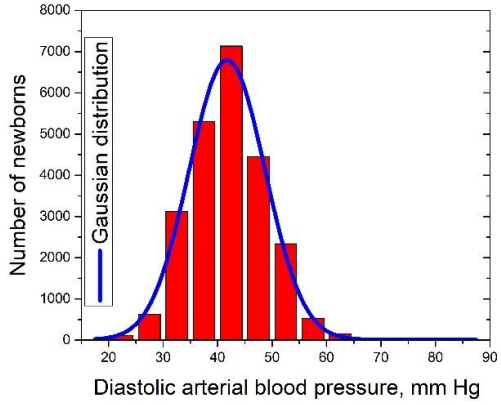
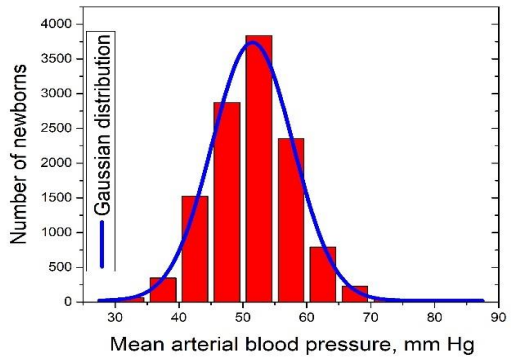


Figure 7. The normal (Gaussian) distribution of diastolic arterial blood pressure: a) in girls; b) in boys; c) in girls and boys.

a)



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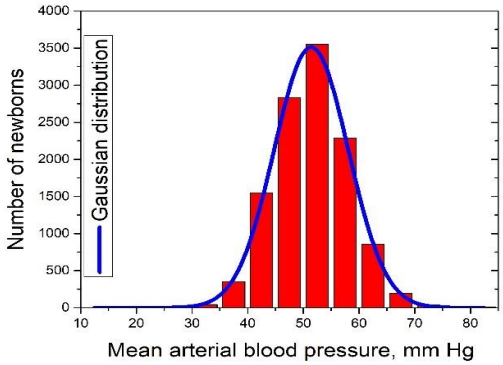


c)

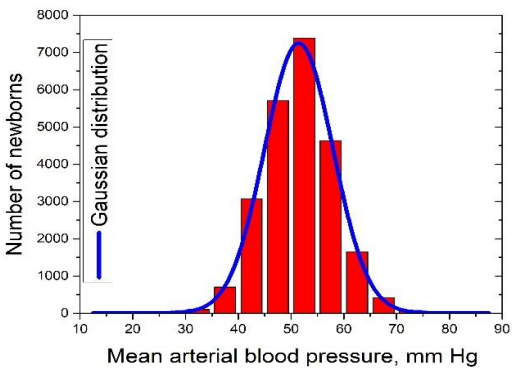


Figure 8. The normal (Gaussian) distribution of mean arterial blood pressure: a) in girls; b) in boys; c) in girls and boys.

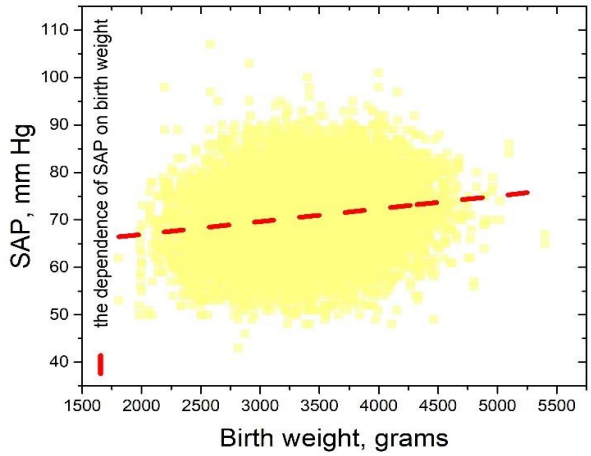
index	n	standard (Gaussian) deviation, mm Hg			
		δ	mean value	standard error (mean value)	standard error (δ)
SAP (males)	12090	6.27	71.3	0.11	0.12
DAP (males)	12090	6.86	41.9	0.25	0.29
MAP (males)	12090	6.34	51.5	0.16	0.18
SAP (females)	11718	6.21	71.4	0.11	0.13
DAP (females)	11718	7.53	41.6	0.17	0.23
MAP (females)	11718	6.66	51.4	0.1	0.12

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure; δ-standard deviation; n- number of observations (the obtained summarized data when measured on the right arm and leg).

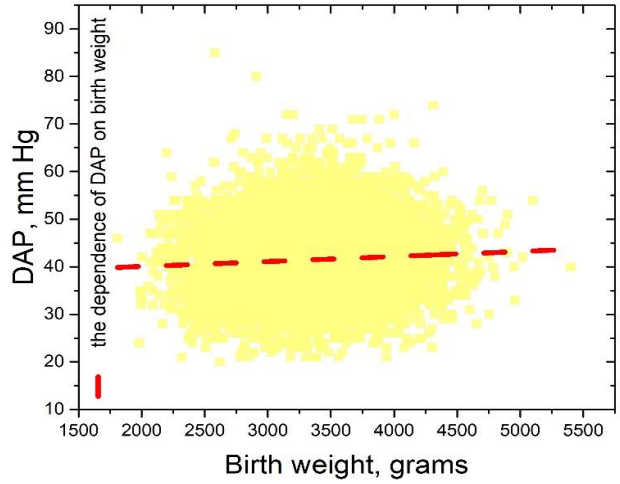
Table 12. SAP, DAP, MAP values in term newborn boys (males) and girls (females).

When comparing SAP, DAP, and MAP in healthy term newborn boys and girls, the Student's t-test was 1.21 (p = 0.227741), 0.73 (p = 0.466556) and 0.48 (p = 0.633814), respectively - the differences are not statistically significant (the degree of freedom f = 23806, the critical value of the Student's t-test = 1.972, with a significance level of α = 0.05) - see Table 13. The resulting absence of a statistically significant difference in BP values in healthy term newborn boys and girls is comparable with the data of the study by Moumita S. et al. (2015) [7]. Given the absence of a statistically significant difference in SAP, DAP, and MAP values in healthy term newborn boys and girls, it is possible to use the obtained combined BP references for girls and boys (Tables 6-7) and obtained separate BP references for girls and boys (Tables 8-11). Considering the large range of birth weight in the investigated term newborns (1809-5400 g), the dependence of BP on birth weight in term newborns was assessed (Figures 9 a), b), c)). According to the obtained data, a weak correlation was found between birth weight and the SAP, DAP, and MAP values (Pearson's correlation coefficient was 0.17792, 0.06396, and 0.1065, respectively). A weak (insignificant) correlation between the birth weight and the SAP, DAP, and MAP values in term infants, identified according to the results of the current study, may cause a discrepancy in the data of previous researchers4-6 in this issue, obtained based on small samples of newborns. The weak correlation between the BP values and birth weight in healthy term newborns allows using the uniform BP references for all term newborns, regardless of birth weight (Tables 8-11).

a)



b)



c)

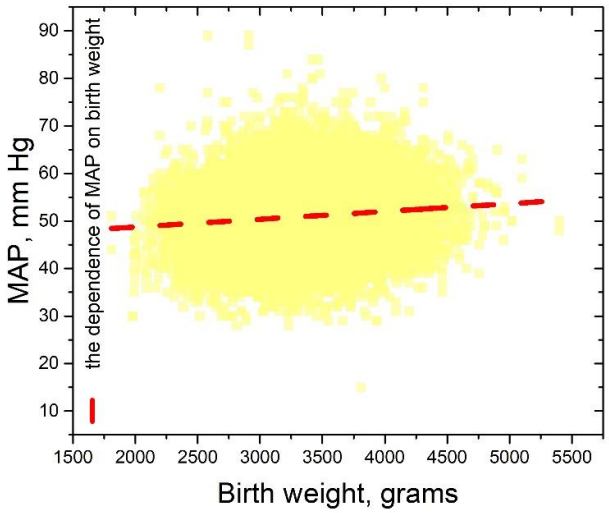


Figure 9. The dependence of a) systolic, b) diastolic, c) mean arterial blood pressure on birth weight in term newborns.

However, when BP values in term newborns are higher than 97,5% or 3 z-score, and are lower than 2,5% or -3 z-score (especially for SAP, given the highest Pearson correlation coefficient), it is possible to use the obtained additional tables of reference BP values with stratification by birth weight.

The subjects were divided into 5 groups (Table 14) to determine the BP value references in term newborns with stratification by birth weight.

index	n	mean value	standard error (mean value)	p-value	Student's t-test
SAP (males)	12090	71.3	0.1	0.227741	1.21
SAP (females)	11718	71.4	0.11		
DAP (males)	12090	41.9	41.6	0.466556	0.73
DAP (females)	11718	0.25	0.17		
MAP (males)	12090	51.5	51.4	0.633814	0.48
MAP (females)	11718	0.16	0.1		

* the degree of freedom f = 23806, the critical value of Student's t-test = 1.972, with a significance level of α = 0.05; SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure; n-number of observations (the obtained summarized data when measured on the right arm and leg).

Table 13. Student's t-test for SAP, DAP, MAP values in term newborn boys (males) and girls (females)*

groups of newborns stratified by birth weight, grams	n (males and females)	n (males)	n (females)
<2500	568	244	324
2501-3000	4022	1816	2206
3001-3500	10308	5056	5252
3501-4000	7294	4026	3268
>4000	1616	948	668

n- number of observations (the obtained summarized data when measured on the right arm and leg).

Table 14. Groups of newborns stratified by birth weight.

Based on the total BP data obtained when measuring the right arm and leg in healthy term newborns, for each group of subjects (stratified by birth weight), normative SAP, DAP, and MAP value references were determined depending on birth weight (97.5; 90; 75; 50; 25; 10; 2.5 percentiles and 3; 2; 1; 0; -1; -2; -3 z-scores) - Tables 15-20.

birth weight, grams	BP, mm Hg	Percentiles, %						
		97,5	90	75	50	25	10	2,5
< 2500	SAP	79	76	72	68	62	59	54
	MAP	61	58	54	49	44	40	36
	DAP	54	50	45	40	34	31	27
2501-3000	SAP	82	77	73	69	65	61	56
	MAP	64	59	54	50	46	41	37
	DAP	55	50	45	40	36	32	28
3001-3500	SAP	83	78	75	70	66	62	58
	MAP	64	59	55	51	47	43	39
	DAP	56	51	46	41	36	32	29
3501-4000	SAP	84	79	76	71	68	64	59
	MAP	64	59	56	51	47	43	39
	DAP	55	50	46	42	37	33	29
> 4000	SAP	85	81	78	72	68	64	60
	MAP	65	61	56	52	48	44	40
	DAP	56	51	47	42	38	34	30

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 15. New reference values of BP stratified by birth weight in term newborns in the early neonatal period (for males and females), percentiles.

birth weight, grams	BP, mm Hg	z-scores						
		3	2	1	0	-1	-2	-3
< 2500	SAP	89	79	74	68	61	54	50
	MAP	70	61	56	49	41	36	30
	DAP	63	54	48	40	32	26	21
2501-3000	SAP	90	2	75	69	62	56	50
	MAP	72	64	57	50	43	37	30
	DAP	67	56	48	40	34	28	21
3001-3500	SAP	90	84	76	70	64	58	51
	MAP	73	64	58	51	44	38	32
	DAP	65	56	48	41	34	29	22
3501-4000	SAP	90	84	77	71	65	59	51
	MAP	71	65	58	51	45	39	31
	DAP	66	56	49	42	35	29	23
> 4000	SAP	92	85	80	72	66	59	50
	MAP	72	65	58	52	46	40	32
	DAP	65	56	49	42	35	29	23

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 16. New reference values of BP stratified by birth weight in term newborns in the early neonatal period (for males and females), z-scores.

birth weight, grams	BP, mm Hg	Percentiles, %						
		97,5	90	75	50	25	10	2,5
< 2500	SAP	79	76	72	68	62	58	52
	MAP	61	58	53	49	44	39	36
	DAP	54	50	44	40	35	31	26
2501-3000	SAP	82	76	73	69	65	61	56
	MAP	64	59	54	50	45	41	37
	DAP	55	50	45	41	36	32	29
3001-3500	SAP	83	78	74	70	66	62	58
	MAP	64	59	55	51	47	43	38
	DAP	56	51	46	41	37	32	29
3501-4000	SAP	84	79	75	71	67	64	59
	MAP	65	59	56	51	47	44	39
	DAP	55	51	46	42	37	33	29
> 4000	SAP	84	81	77	72	68	64	60
	MAP	65	60	56	52	48	44	40
	DAP	54	51	47	42	38	34	29

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 17. New reference values of BP stratified by birth weight in term newborns in the early neonatal period (for males), percentiles.

birth weight, grams	BP, mm Hg	z-scores						
		3	2	1	0	-1	-2	-3
< 2500	SAP	86	79	74	68	60	52	50
	MAP	65	61	55	49	40	36	30
	DAP	59	54	47	40	32	26	24
2501-3000	SAP	92	82	75	69	62	56	50
	MAP	76	64	56	50	44	37	30
	DAP	72	55	48	41	34	29	21
3001-3500	SAP	90	83	76	70	64	58	51
	MAP	73	64	57	51	44	38	31
	DAP	65	56	48	41	34	29	22
3501-4000	SAP	90	85	77	71	65	59	51
	MAP	71	65	58	51	45	39	30
	DAP	63	56	49	42	35	29	24
> 4000	SAP	91	84	79	72	66	60	51
	MAP	73	65	59	52	46	40	33
	DAP	67	55	49	42	36	29	23

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 18. New reference values of BP stratified by birth weight in term newborns in the early neonatal period (for males), z-scores.

birth weight, grams	BP, mm Hg	Percentiles, %						
		97,5	90	75	50	25	10	2,5
< 2500	SAP	79	76	72	67	62	59	54
	MAP	61	58	54	49	44	40	36
	DAP	54	51	46	40	34	31	27
2501-3000	SAP	82	77	73	69	65	61	56
	MAP	63	59	54	50	46	42	37
	DAP	55	50	45	40	36	32	28
3001-3500	SAP	84	79	75	71	67	63	58
	MAP	64	59	55	51	47	43	39
	DAP	56	51	46	41	36	32	29
3501-4000	SAP	84	79	76	72	68	64	59
	MAP	64	59	56	51	47	43	39
	DAP	55	50	46	41	37	33	29
> 4000	SAP	86	82	78	73	68	64	59
	MAP	65	61	56	52	48	44	41
	DAP	56	51	47	42	38	34	30

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

Table 19. New reference values of BP stratified by birth weight in term newborns in the early neonatal period (for females), percentiles.

birth weight, grams	BP, mm Hg	z-scores						
		3	2	1	0	-1	-2	-3
< 2500	SAP	92	79	74	67	61	54	50
	MAP	73	61	56	49	41	36	33
	DAP	64	54	49	40	32	27	21
2501-3000	SAP	89	82	76	69	63	56	50
	MAP	70	64	57	50	43	37	30
	DAP	64	56	48	40	34	27	22
3001-3500	SAP	90	84	77	71	65	58	51
	MAP	73	65	58	51	44	39	33
	DAP	65	56	49	41	34	28	22
3501-4000	SAP	89	84	78	72	66	59	51
	MAP	72	64	58	51	45	39	32
	DAP	67	56	49	41	35	29	22
> 4000	SAP	91	87	80	73	66	58	51
	MAP	70	65	58	52	46	41	34
	DAP	60	56	49	42	35	30	23

SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure.

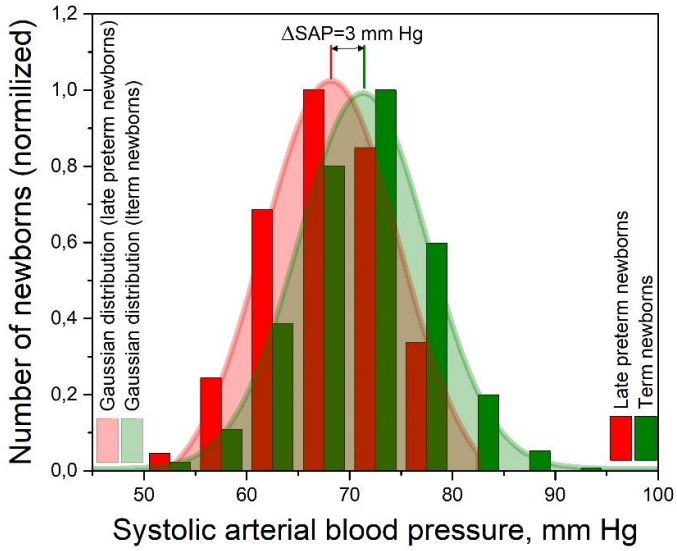
Table 20. New reference values of BP stratified by birth weight in term newborns in the early neonatal period (for females), z-scores.

Given the absence of a statistically significant difference in SAP, DAP, and MAP values in healthy term newborn boys and girls, it is possible to use the obtained combined reference values of BP stratified by birth weight for girls and boys (Tables 15-16) and obtained separate reference values of BP stratified by birth weight for girls and boys (Tables 17-20).

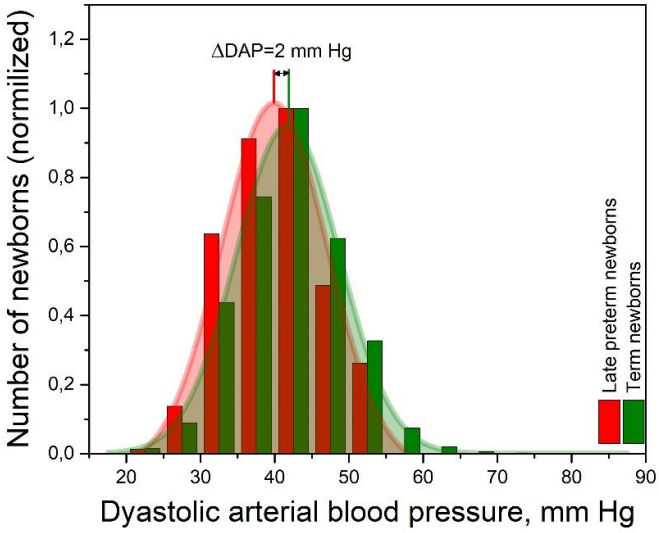
We also evaluated the statistical significance of the BP values difference in healthy term and late preterm infants in the early neonatal period based on the data obtained.

Comparative characteristics of the normal (Gaussian) distribution of BP values in healthy term and late preterm newborns are presented in Figures 10 a), b), c). Figures 10 a), b), c) demonstrated that the maximum BP values difference in term and late preterm newborns are in SAP, where ΔBP (picks of the curves corresponding to the medians of BP values) = 3 mm Hg. For DAP and MAP values, ΔBP is 2 mm Hg. It is also worth noting that Figures 10 a), b), c) show that SAP, DAP, and MAP values in term newborns are higher than in late preterm infants in the early neonatal period.

a)



b)



c)

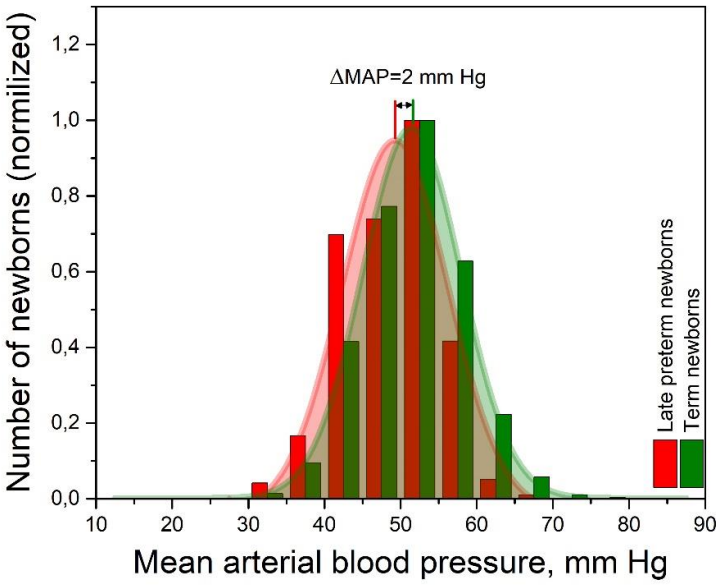


Figure 10. Comparative characteristics of the normal (Gaussian) distribution of a) systolic, b) diastolic, c) mean arterial blood pressure: values in healthy term and late preterm newborns.

When comparing SAP, DAP, and MAP values in term and late preterm infants, the Student's t-test was 4.36 (p = 0.000013), 3.61 (p = 0.000308) and 2.70 (p = 0.006855), respectively - the differences are statistically significant (the degree of freedom f = 24106, the critical value of the Student's t-test = 1.972, with a significance level of α = 0.05) - see Table 21. The obtained results confirm the data of the research by Moumita S. et al. (2015)7, demonstrating the presence of a statistically significant BP difference in term and preterm newborns, as well as registration of higher BP value in term newborns in comparison with preterm newborns, and indicate the need to determine separate SAP, DAP, and MAP values reference in late preterm newborns.

index	n	mean value	standard error (mean value)	p-value	Student's t-test
SAP (term newborns)	23808	71.3	0.09	0.000013	4.36
SAP (preterm newborns)	300	86.5	0.64		
DAP (term newborns)	23808	41.8	0.22	0.000308	3.61
DAP (preterm newborns)	300	39.3	0.46		
MAP (term newborns)	23808	51.5	0.12	0.006855	2.70
MAP (preterm newborns)	300	49.3	0.8		

* the degree of freedom f = 24106, the critical value of Student's t-test = 1.972, with a significance level of α = 0.05; SAP-systolic arterial blood pressure; DAP-diastolic arterial blood pressure; MAP-mean arterial blood pressure; n-number of observations (the obtained summarized data when measured on the right arm and leg).

Table 21. Student's t-test for SAP, DAP, MAP values in term and preterm newborns*

Conclusion

From this study, it follows that the SAP, DAP, and MAP values in healthy term newborns in the early neonatal period:

- have a weak correlation with birth weight;
- do not statistically significantly different when measuring BP on the right arm and leg, and also do not have significant differences depending on gender;
- have statistically significantly different from the BP values in healthy late premature infants, which necessitates further studies to determine individual normative BP reference values in late preterm newborns.

According to the results of the study, the data obtained can be used as normative BP values reference in term newborns, and it is permissible to use commonly obtained BP references for boys and girls, and separate ones. When BP values in term newborns are higher than 97,5% or 3 z-score, and are lower than 2,5% or -3 z-score (especially for SAP, given the highest Pearson correlation coefficient) it is possible to use the obtained additional tables of reference BP values with stratification by birth weight.

Contributors

Oksana V Shumakova, Ekaterina L Bokerija designed and implemented the study, developed the analysis strategy. Oksana V Shumakova analyzed the data and wrote the first draft. All authors reviewed, made inputs to, and approved

the final paper. All authors had full access to all de-identified anonymized data in the study and had final responsibility for the decision to submit the manuscript for publication.

Declaration of Interests

We declare no competing interests.

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Ethics Committee Approval

The study protocol was approved by the Ethics Committee of the FSBI "National medical research center for obstetrics, gynecology and perinatology named after academician V.I. Kulakov" Ministry of Healthcare of the Russian Federation. Written informed consent for participation in the current research study was obtained from all legal representatives of the patients included in the study.

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