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ORIGINAL ARTICLE

Blood pressure in non-critically ill preterm and full-term neonates

Bijana Pejovic · Amira Peco-Antic · Jelena Marinkovic-Eric

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Abstract The neonatal period is a time of extensive hemodynamic changes. It is expected that these changes are most prominent in premature infants during the first week of life. The aim of this study was to examine arterial blood pressure (BP) measured by an oscillometric device in the first month of life in a stable premature population admitted to our neonatal intensive care unit (NICU), and to evaluate the influence of gestational age, postnatal age, birth weight, gender, and sleep state on BP. This prospective study was conducted over 27 months. The study population consisted of 373 hemodynamically stable infants (292 preterm and 81 full-term infants). Overall 12,552 BP measurements were carried out using a non-invasive oscillometric blood pressure monitor. Both systolic and diastolic blood pressure progressively increased during the first month of life. BP increased more rapidly in preterm infants than in full-term infants, and was higher in groups with higher birth weight. Multiple regression analysis showed that mean BP during the first week and on the 30th day increased with gestational age, and also that it was higher in the awake than in the sleep state.

B. Pejovic (✉)
Neonatal Intensive Care Unit, Institute for Neonatology,
Kralja Milutina 50,
Belgrade 11 000, Serbia and Montenegro
e-mail: pejovic9@eunet.yu

A. Peco-Antic
Nephrology, University Children's Hospital,
Belgrade, Serbia and Montenegro

J. Marinkovic-Eric
School of Medicine,
Institute for Medical Statistics and Informatics,
Belgrade, Serbia and Montenegro

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Introduction

Defining what is considered a normal blood pressure (BP) in premature infants is a complex task [1, 2]. There are few BP data reported for such infants after 24 h of life [3–8], and comparison of these normative data on BP from various studies is difficult due to methodological differences [7–10]. BP monitored directly via an indwelling arterial catheter in the radial or umbilical artery provides the most accurate BP readings in newborn infants. However, the procedure itself may be technically difficult, especially in low birth-weight infants. Therefore, direct intra-arterial recordings are the "gold standard" for determination of BP in critically ill neonates whose condition is sufficiently serious to justify arterial catheterization, and generally this method is used whenever arterial access is available [11, 12]. The non-invasive methods of measuring BP represent great progress in the care of non-critically ill neonates. The most common non-invasive alternative method used in neonatal intensive care units (NICU) is automated measurement using oscillometric devices [1].

Blood pressure has been reported to be substantially lower in premature infants compared with full-term infants [5, 6], but the number of participants in these studies is relatively small and additional data are needed to understand the natural history of BP in this special group of infants.

The aim of this study was to examine arterial BP measured using an oscillometric device in the first month of life in a stable premature population admitted to our NICU,

and to evaluate the influence on estimated gestational age (EGA), postnatal age, birth weight (BW), gender, and sleep state on BP.

Materials and methods

This study was carried out prospectively over 27 months (from 9 October 2001 to 12 December 2003) in the NICU of the Institute for Neonatology in Belgrade. The representative study population consisted of 292 premature and 81 full-term hemodynamically stable infants admitted to the NICU during the first 24 h of life. The condition was considered stable based on the following criteria: normal hemoglobin; normal acid-base balance; no renal or renovascular anomalies; no congenital heart disease or patent ductus arteriosus; no chromosomal abnormalities; non-usage of indomethacin, steroids, diuretics, muscle relaxants, narcotics; non-treatment for hypo/hypertension; and that the patients were accessible for investigation for at least the first 7 postnatal days. The patients were not exposed to maternal steroids during the antenatal period, and did not receive any inotropic drug therapy, ventilatory support (also including continuous positive airway pressure) or parenteral nutrition during the period of observation. Gestational age was estimated using clinical assessment [13]. The infants were considered premature if born before the 37th week of gestation and full-term if born at or after the 37th week of gestation (gw). They were categorized into four groups according to the estimated gestational age: A (≤28 gw), B (29–32 gw), C (33–36 gw), and D (≥37 gw). Additional classification was carried out according to birth weight: I (600–999 g), II (1,000–1,249 g), III (1,250–1,499 g), IV (1,500–1,999 g), and V (≥2,000 g). The infants were considered to be of very low birth weight (VLBW) if BW was≤1,500 g and very preterm if EGA was≤32 gw. None of the patients were growth restricted; all were well nourished according to their gestational age, being between the 25th and 75th percentile, as determined by Lubchenco et al. [14]. The newborns whose mothers had chronic hypertension, as well as pregnancy-induced hypertension or any other confirmed pre-existing disease were excluded from this study.

All patients received routine postnatal care by the 7th day of age. Systolic BP (SBP), diastolic BP (DBP), and mean arterial BP (MBP) were measured indirectly using an oscillometric device (555; Corometrics Medical Systems, Wallingford, CT, USA). BP was measured in the supine position while the infant was asleep or was in a quiet awake state in random order at least 30 min after the last feed. An appropriate-sized cuff (covering at least two-thirds of the length of the limb segment and 85% of the limb circumference) was applied to the right upper arm. Three successive BP recordings were taken at 2-min intervals, and the mean of the last two measurements was used for all analyses. BP recordings were carried out daily for 30

Table 1 Clinical characteristics[a] of 373 infants[b] classified by estimated gestational age (*EGA*)[c] and birth weight (*BW*)

	Groups classified by EGA (weeks)						Groups classified by BW (g)						
	A≤28	B 29–32	C 33–36	D≥37	Total	*p* value	I 600–999	II 1000–1249	III 1250–1499	IV 1500–1999	V ≥2000	Total	*p* value
Number of infants (%)	62 (16.6)	146 (39.1)	81 (21.7)	81 (21.7)	373 (100.0)		44 (11.8)	78 (20.9)	94 (25.2)	76 (20.4)	81 (21.7)	373 (100)	
Number of BP recordings	1,594	6,252	2,414	2,292	12,552		774	3,744	3,102	2,640	2,292	12,552	
Male/female	30/32	68/78	40/41	40/41	178/195	n.s.	23/21	40/38	40/54	35/41	40/41	178/195	n.s.
EGA (weeks)	26.9± 1.1	30.6± 1.1	33.9± 0.9	38.6± 1.5	32.5± 4.1	0.000	26.7± 1.2	29.6± 1.5	31.1± 1.3	33.9± 1.9	38.7± 1.5	32.5± 4.1	0.000
BW (g)	890.0± 145.9	1,274.7± 156.7	1,734.8± 195.2	3,256.2± 468.1	1,744.8± 45.6	0.000	810.0± 83.4	1,118.3± 76.6	1,361.3± 75.6	1,792.4± 126.0	3,256.0± 468.1	1,744.8± 45.6	0.000
Birth length (cm)	39.7± 1.8	42.1± 2.6	46.1± 2.8	48.6± 2.8	44.0± 4.1	0.000	39.7± 1.8	40.9± 2.0	43.1± 2.9	46.1± 2.3	48.6± 2.8	44.0± 4.1	0.000
5-min Apgar score[d]	7 (5)	8 (5)	8 (5)	8 (4)	8 (5)	0.000	7 (5)	7 (4)	8 (4)	8 (5)	8 (4)	8 (5)	0.000

[a] Values are expressed as mean ± SD, unless otherwise noted.
[b] All infants were Caucasians. They were not exposed to steroids during the antenatal period. At the time of the BP recordings all were in a stable condition without sepsis, and were not receiving any inotropic drug therapy, ventilatory support or parenteral nutrition. None of patients' mothers had chronic hypertension, pregnancy-induced hypertension or any other confirmed pre-existing disease.
[c] Postnatal clinical estimation of gestational age using the methods of Ballard et al. [13].
[d] Values are median; values in parentheses represent the range.

postnatal days. However, the number of stable infants eligible for BP recording with regard to the study criteria, was not constant during the whole period. As the study population was the largest during the first 7 days (93.6–100%) and on the 30th postnatal day (90.1%), we analyzed only BPs during the first week of life and on the 30th day of life.

Unless otherwise noted, the data were expressed as mean ± SD. One-way analysis of variance (ANOVA) was used to test the starting differences between the groups and repeated measures ANOVA was employed for serial measurements during the study. Multivariate analysis was conducted to assess the independent effects of EGA, body weight, sleep and awake states, and 1- and 5-min Apgar scores on blood pressure. Multiple comparisons and correlations were performed by Bonferroni's and Pearson's tests, respectively. The pairwise comparisons of means were performed using the Bonferroni approach to adjusting for the multiplicity of comparisons. The 0.05 probability level was used to determine statistical significance.

Results

Three hundred seventy-three infants were studied; of these, 292 were preterm with a mean EGA of 30.3± 1.3 weeks, and the remaining 81 were full-term neonates with EGA of 38.6±1.5 weeks. There were 178 males and

Table 2 Systolic (*SBP*), diastolic (*DBP*), and mean (*MBP*) blood pressure during the first week and on the 30th day of life[a]

Blood pressure on postnatal days (1–7 and 30)	Groups by EGA[c]					Multiple comparisons					
	A (n=62)	B (n=146)	C (n=84)	D (n=81)	Mean±SE	A vs. B	A vs. C	A vs. D	B vs. C	B vs. D	C vs. D
SBP 1	42±4	48±6	56±5	63±6	52±0.3	*	*	*	*	*	*
SBP 2	42±4	51±5	58±4	64±6	54±0.3	*	*	*	*	*	*
SBP 3	44±4	53±6	59±5	65±6	55±0.3	*	*	*	*	*	*
SBP 4	45±4	56±6	61±5	67±6	57±0.3	*	*	*	*	*	*
SBP 5	46±4	58±7	62±5	68±6	58±0.4	*	*	*	*	*	*
SBP 6	48±4	59±7	64±5	70±6	60±0.4	*	*	*	*	*	*
SBP 7	50±3	60±7	65±5	71±5	61±0.3	*	*	*	*	*	*
SBP 30	62±3	71±4	72±4	77±5	70±0.3	*	*	*	n.s.	*	*
Mean±SE	47±0.8	57±0.4	62±0.6	68±0.6		*	*	*	*	*	*
F[b]	98.2	483.3	321.5	225.3							
p	*	*	*	*							
DBP 1	26±3	32±6	36±4	40±5	33±0.3	*	*	*	*	*	*
DBP 2	28±4	34±5	38±4	41±5	35±0.3	*	*	*	*	*	*
DBP 3	29±4	35±5	39±4	42±5	36±0.3	*	*	*	*	*	*
DBP 4	31±5	37±5	40±4	43±5	38±0.3	*	*	*	*	*	*
DBP 5	32±5	38±5	41±4	44±5	39±0.3	*	*	*	n.s.	*	*
DBP 6	34±4	40±5	41±4	45±5	40±0.3	*	*	*	n.s.	*	*
DBP 7	35±4	40±4	41±4	46±5	41±0.3	*	*	*	n.s.	*	*
DBP 30	42±7	48±5	50±5	50±4	48±0.3	*	*	*	0.003	0.001	n.s.
Mean±SE	32±0.6	38±0.3	41±0.4	44±0.4		*	*	*	*	*	*
F	95.1	954.5	353.4	206.3							
p	*	*	*	*							
MBP 1	32±3	38±5	43±4	48±4	40±0.3	*	*	*	*	*	*
MBP 2	33±4	40±5	45±3	49±5	42±0.3	*	*	*	*	*	*
MBP 3	34±4	42±5	46±4	50±4	43±0.3	*	*	*	*	*	*
MBP 4	36±5	44±5	47±3	51±5	44±0.3	*	*	*	*	*	*
MBP 5	37±5	45±5	48±4	52±5	45±0.3	*	*	*	0.019	*	*
MBP 6	39±4	46±5	49±4	53±5	47±0.3	*	*	*	0.002	*	*
MBP 7	41±4	47±4	49±4	54±4	48±0.3	*	*	*	0.001	*	*
MBP 30	49±7	56±4	57±4	59±4	55±0.3	*	*	*	0.028	*	n.s.
Mean±SE	37±0.6	45±0.3	48±0.5	52±0.5		*	*	*	*	*	*
F	95.1	954.5	353.4	206.3							
p	*	*	*	*							

[a] Values are expressed as mean ± SD, unless otherwise noted
[b] Repeated measures ANOVA
[c] Postnatal clinical estimation of gestational age using the methods of Ballard et al. [13].
*p=0.000

195 females who were classified by EGA into four groups; the first three groups consisted of pre-terms and the fourth of full-term infants. The majority of patients (71.2%), all from groups A and B, were of very low birth weight (≤1,500 g) and very preterm (≤32 gw). The groups were highly different, not only with regard to EGA (F=1,388.6, p=0.000), but also to BW (F=1,263.9, p=0.000), body length at birth (BL; F=187.7, p=0.000), as well as to 5-min Apgar score (F=16.4, p=0.000). The characteristics of the infants in each group are shown in Table 1. A total of 12,552 BP measurements were carried out, most of them (10,260) in preterm infants. Cuff sizes used ranged from 2 to 5 cm.

The results of BP recordings in four infant groups according to EGA (groups A–D) are presented on Table 2 and Fig. 1, while the data on BP measurements obtained when asleep and in a quiet awake state in five groups of infants divided by BW (groups I–V) are shown in Fig. 2. Figure 3 demonstrates the linear regression of SBP, DBP, and MBP by birth weight and gestational age on day 1 of life, with a 95% confidence limit, which approximates means ± 2 SD.

The analysis of variance showed that blood pressure significantly increased with postnatal age in each group, and was higher in groups with higher gestational age, as well as with higher birth weight. A more rapid rate of rise of BPs with postnatal age was found in preterm than in full-term infants; the highest ones occurred in very preterm infants (≤32 gw) and VLBW (≤1,500 g) infants. The average increments of MBP during the first week and month of life were 26.2% and 51% in infants with EGA≤ 28 gw, 22.8% and 45.5 % in those with EGA 29–32 gw, 18.7% and 34.4% in infants with EGA 33–36 gw, and finally 12.7% and 22.3% in the full-term infants (≥37 gw). BP was lower when measured during the sleep state than when the child was in a quietly awake state (p≤0.001) in all except the premature infants with BW≤1,000 g during the period from the 4th until the 7th day of life (Fig. 2). On the other hand, the infant's gender, with the exception of infants with BW of 1,250–1,499 g (from 3rd to 30th day of life), did not affect the variance of oscillometric BP pressure. When EGA, the state of activity during BP measurement, body weight, and Apgar score were entered as the variables into regression models, the EGA and the state of activity continued to be the highly significant predictors of mean arterial BP during the first week and on the 30th postnatal day (Table 3).

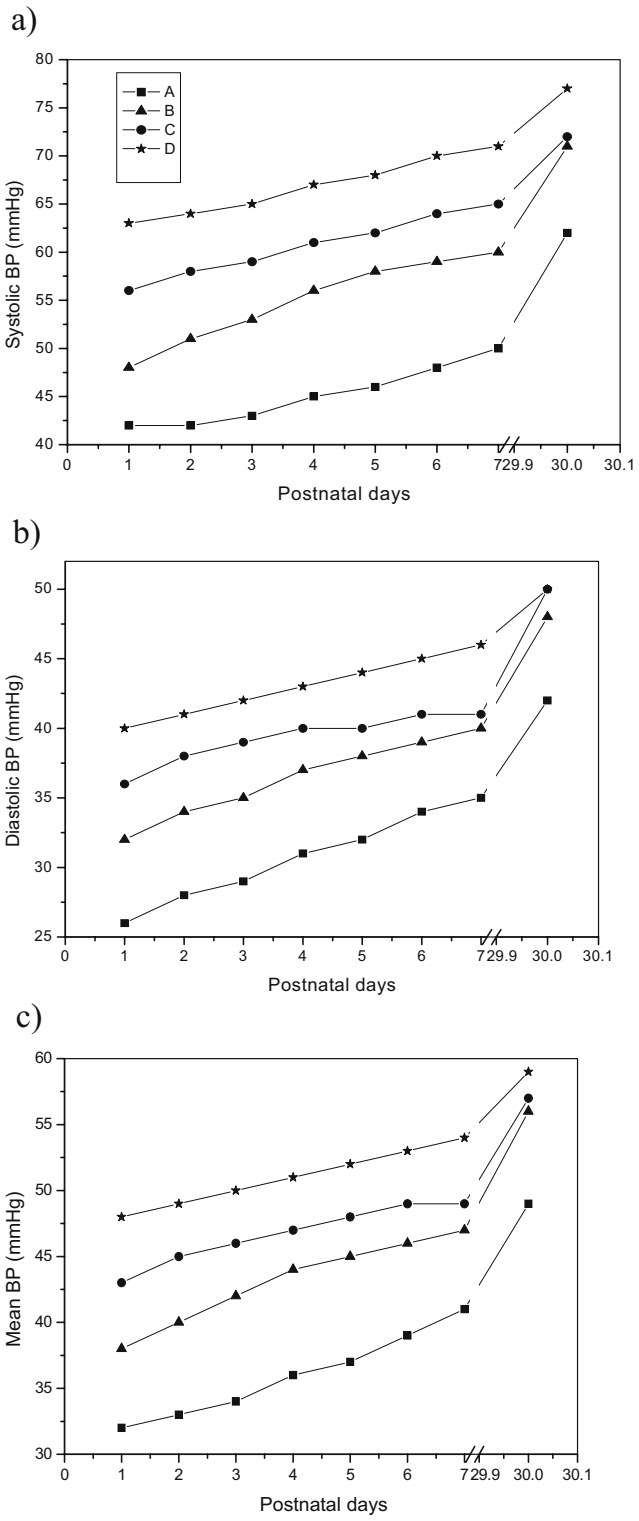

Fig. 1 Increase in **a** systolic, **b** diastolic, and **c** mean blood pressure during the first month of life in groups of infants classified by estimated gestational age: A (≤28 weeks), B (29–32 weeks), C (33–36 weeks), and D (≥ 37 weeks)

Discussion

The neonatal period is a time of extensive hemodynamic changes. It is expected that these changes are most prominent in premature infants since they are deprived of approximately 20–45% of normal gestation during which significant maturation changes in the cardiovascular system

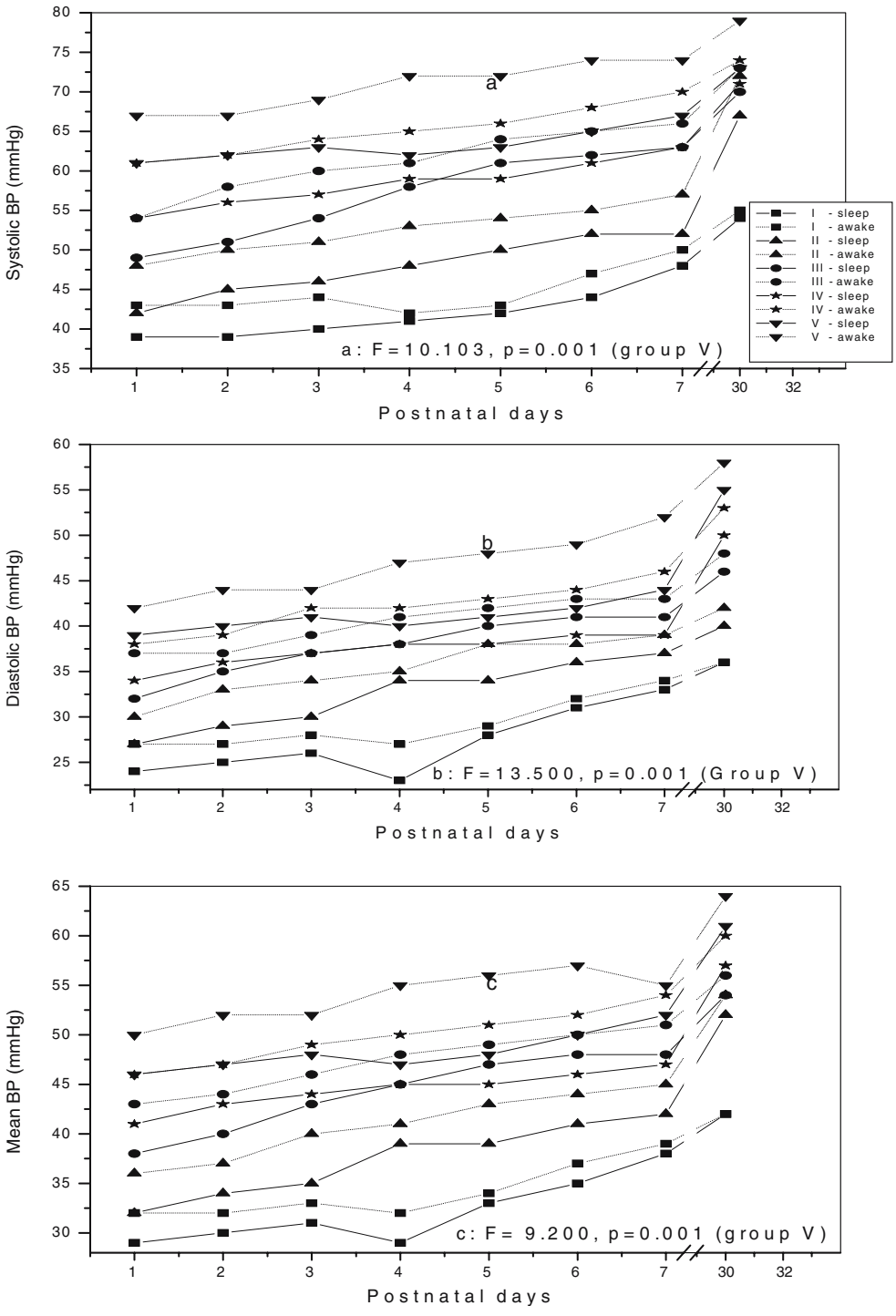

Fig. 2 Comparison of systolic, diastolic, and mean BP in the sleep (*solid line*) and awake states (*broken line*) in the groups (according to birth weight) I (600–999 g), II (1,000–1,249 g), III (1,250–1,449 g), IV (1,500–1,999 g), and V (≥2,000 g) during the first week and on the 30th day of life

normally occur [11]. Therefore, consideration of gestational age is of obvious importance in the assessment of neonatal hemodynamic changes. The need for accurate measurement of BP and clear guidelines as to what levels of BP require active management are an important part of this process. The research base is not yet available to give a definite answer to the question regarding which BP is really normal in very preterm (<32 gw) and very low birth weight (≤1,500 g) infants [6, 11–19]. From the methodological point of view it is very difficult to include in a study a great number of stable or so-called "normal" very low birth weight premature infants who are free from pharmacological, ventilatory, or nutritional support [20, 21]. Namely, the most difficult part of this research was to form and follow up the groups of preterm neonates with very low BW, which would keep the physiology of the age (free from sepsis, intracranial hemorrhage, cardiopulmonary distress, and need for mechanical support) for a relevant period to

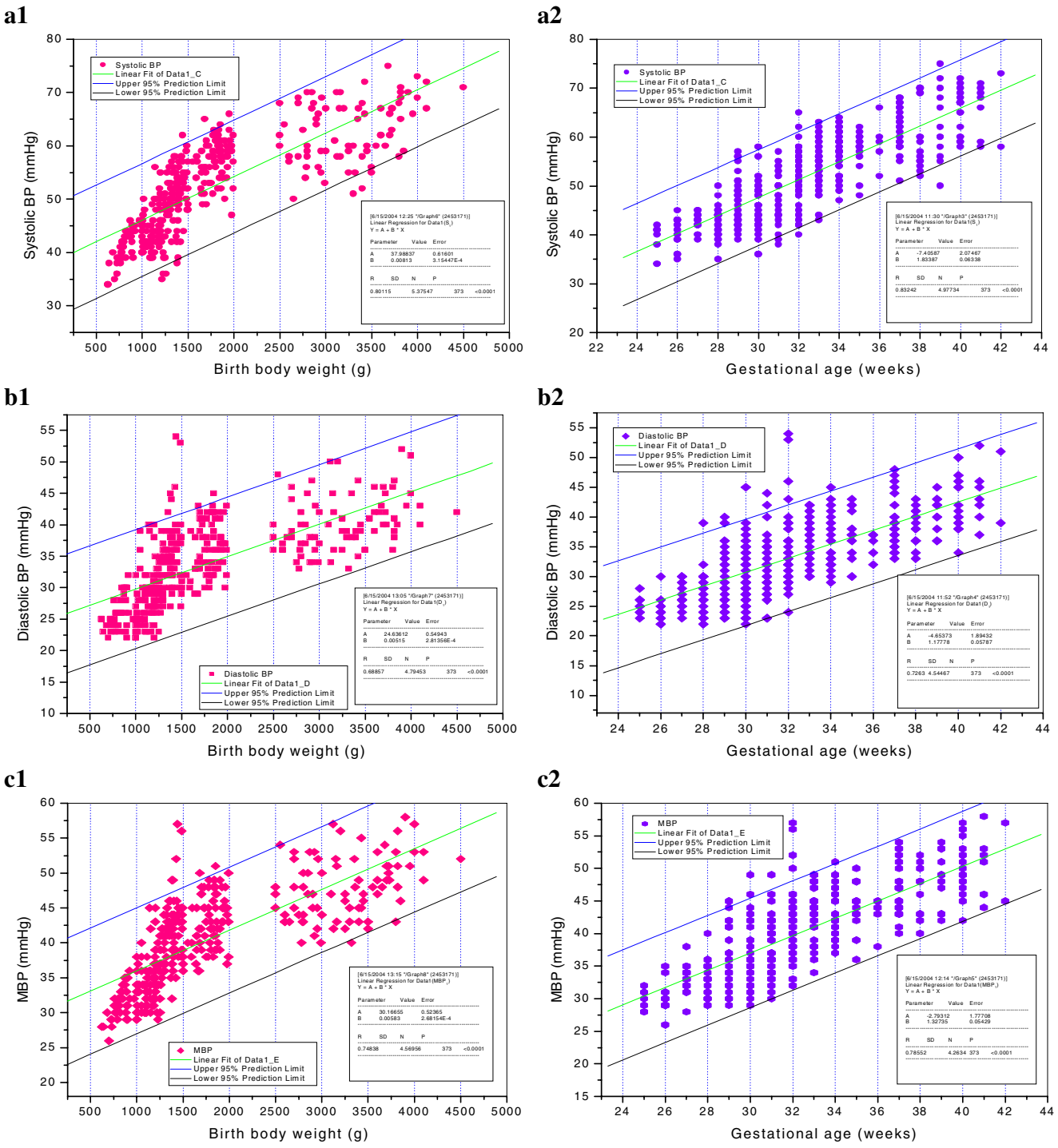

Fig. 3 Linear regression of **a** systolic, **b** diastolic, and **c** mean blood pressure according to birth weight (*1*) and gestational age (*2*) on day 1 of life, with 95% confidence limits (*upper and lower solid lines*). This approximates mean ± 2 SD

monitor BP. That is why the observation period of this study, carried out in a Serbian referral center for premature infants with an average annual number of 1,100 patients, lasted for 27 months.

We used an oscillometric device as an alternative method of performing invasive intra-arterial BP measurement. This method is convenient and easy to use in younger children and neonates in whom it is difficult to accurately hear the Korotkoff (K) sounds by auscultation. Furthermore, the use of this method eliminates the K4–K5 controversy of diastolic BP [22]. The "first-reading" effect, in which the first of several BP readings is 3–5 mmHg higher than the subsequent reading performed a few minutes later, was overcome by repeating BP measurements. When using the

Table 3 Multiple regression analysis of EGA, state of activity during BP measurement (*SA*), actual body weight (*ABW*), and 5-min Apgar score (AS_5) in relation to mean arterial blood pressure

Days	Variables	Mean arterial blood pressure models		*p*
		B	SE	
1	Constant	−2.793	1.777	0.117
	EGA	1.327	0.054	0.000
	SA	4.262	0.473	0.000
	ABW	2.534E–03	0.001	0.001
2	Constant	−6.947	1.753	0.000
	EGA	1.321	0.051	0.000
	SA	3.115	0.420	0.000
	ABW	1.216	0.416	0.004
3	Constant	−0.742	3.576	0.836
	EGA	1.059	0.141	0.000
	SA	3.158	0.419	0.000
	ABW	1.294	0.001	0.048
4	Constant	3.532	2.157	0.000
	EGA	1.144	0.064	0.000
	SA	3.387	0.502	0.000
	AS_5	0.157	4.035	0.838
5	Constant	7.237	2.234	0.001
	EGA	1.191	0.068	0.000
	SA	3.631	0.509	0.000
	AS_5	0.874	0.217	0.000
6	Constant	−1.192	1.729	0.491
	EGA	1.445	0.078	0.000
	SA	2.839	0.413	0.000
	AS_5	0.736	0.252	0.004
7	Constant	28.905	2.255	0.000
	EGA	0.664	0.064	0.000
	SA	2.234	0.321	0.000
	AS_5	0.492	0.237	0.039
30	Constant	33.875	2.255	0.000
	EGA	0.673	0.068	0.000
	SA	3.389	0.495	0.000

oscillometric device we were aware of other issues. While mercury and aneroid devices, when calibrated properly, agree quite well on BP that they detect, oscillometry seems to differ from device to device and it certainly differs according to the auscultatory method used, but comes closest to intra-arterial determinations [23]. BPs obtained by conventional sphygmomanometry and using the oscillometric device should not be used interchangeably for study purposes, because, even with the most accurate of devices, differences exist between the two [23]. Nevertheless, it must be noted that although accurate, readings obtained by the oscillometric device may differ significantly from intra-arterial readings.

When comparing BPs obtained with these two techniques, Fanaroff and Wright reported that mean blood pressure, determined by the oscillometric technique, was higher by about 3 mmHg than readings obtained directly from arterial access during the first 48 postnatal hours [24]. In contrast, Low et al. reported that the average oscillometric pressures were significantly lower than intra-arterial pressures; the SBP was lower by 1 mmHg, the MBP by 5.3 mmHg, and the DBP by 4.6 mmHg [25]. Furthermore, when comparing blood pressures obtained from three different oscillometers, blood pressure monitors (Dinamap, Criticare, Hewlett-Packard), with arterial blood pressure (Hewlett-Packard' invasive unit), Dannevig et al. [26] found two factors to have a systematic effect on the difference between oscillometric and invasive pressures (the measurement deviance): the size of the infant, e.g., the arm circumference, and the monitoring system. For small infants, the non-invasively measured value tended to be too high. The difference between monitoring systems was clearly significant ($p<0.001$) [26].

What is clear from the above-mentioned studies is that direct intra-arterial blood pressure recordings continue to be the gold standard for critically ill neonates, while when relying on indirectly obtained blood pressure using oscillometric devices one must be very prudent with regard to the methodology and the type of devices. Bearing in mind that we did not compare the devices we used in our study (Corometrics, Medical Systems INC 555) with direct intra-arterial BP recording, nor with another oscillometric device that fulfilled the accuracy criteria, the number of BPs provided by our study cannot be generalized, or must be adjusted for other devices. Furthermore, supplies of this device have been discontinued, which is also a limitation of this study. Nevertheless, our data give the additional insight into the natural course of BP in more stable preterm neonates that is lacking in the literature. We have found that BP is developmentally regulated and is dependent upon gestational age and birth weight. BP was higher in groups with higher EGA and BW, higher in the awake state than in the sleep state, and higher with increasing postnatal age. Our observations that BPs increase with postnatal age are consistent with those in other reports [1–3, 5, 12, 15, 16].

Table 4 Comparison of MBP from our study with the reported data of other authors: VLBW neonates (≤1,500 g) during the first week and on the 30th day of life

Days of life	MBP[a] (mmHg)					
	Our values	[4]	[5]	[11]	[12]	[17]
1	34±4	38±9	–	37±13	42±11	34±7
2	36±4	43±9	–	40±13	45±11	–
3	38±4	45±8	–	44±13	48±11	–
4	39±3	47±9	–	–	–	–
5	41±4	48±10	–	–	–	–
6	42±4	48±10	–	–	–	–
7	43±3	49±9	45±2	–	–	44±6
30	51±4	–	–	–	–	52±4

[a] Values are expressed as mean ± SD

Table 5 Comparison of MBP from our study with the reported data of another author: the first day of life in relation to BW

	BW (g)	500	600	700	800	900	1,000	1,100	1,200	1,300	1,400	1,500
Our values	MBP (mmHg)	–	19	21	23	24	26	28	30	32	33	35
[16]	MBP (mmHg)	20	21	22	23	24	26	29	30	32	33	34

Although numerous factors may contribute to the rise in postnatal BP [11], it seems that decreases in the activity and synthesis of vasodilators [27], as well as intrinsic changes in vascular smooth muscle function [12, 28] may be most important. When comparing the rates of postnatal BP increase, as well as its relationship with gestational age and birth weight, some differences among the reported data can be detected that may be due to the study methodology and management protocols within a given institution (Tables 4, 5, 6).

Zubrow et al. [3] reported the findings of a large multicenter study, which included data from 608 infants followed for 1 to 99 days after delivery. On day 1, birth weight and gestational age were strong correlates of SBP and DBP. During the first 5 days of life there was a progressive rise in SBP (2.23 to 2.67 mmHg/day) and DBP (1.58 to 2.02 mmHg/day) regardless of gestational age or weight at birth. After day 5 there was a more gradual increment in the daily SBP (0.24 to 0.27 mmHg/day) and DBP (0 to 0.15 mmHg/day). Postconceptional age was the primary determinant of BP in this population of infants [3].

Hegyi et al. studied blood pressure in the first hours of life in a cohort of 1,105 preterm infants weighing 501–2,000 g over a 34-month period [29]. Of these, only 244 were healthy infants, while others had different additional risk factors of cardiovascular morbidity. In the healthy group during the first 3–6 h of life, minimum and maximum of SBP were 47 mmHg and 59 mmHg, while minimum and maximum for DBP were 24 mmHg and 35 mmHg respectively. They found that in healthy premature infants the limits of SBP and DBP were independent of birth weight and gestational age. Infants with low Apgar scores tended to have lower BP, and infants whose mothers had hypertension had higher BP than infants in the healthy cohort [29].

LeFlore et al. [12] studied 116 VLBW neonates during the first 72 postnatal hours. They found that SBP, DBP, and MBP increased ($p<0.001$) by 33%, 44%, and 38% respectively during the first 72 h. Although neonates weighing ≤1,000 g and 1,001–1,500 g demonstrated gradual increases ($p<0.001$) in systolic, diastolic, and mean BP by the 72nd hour, values were consistently lower ($p<0.01$) in neonates ≤1,000 g. They concluded that the 30–40% BP rise occurring in VLBW neonates in the first 72 postnatal hours was dependent on gestational age and birth weight. Antenatal steroids did not modify BP measurements immediately after birth or during the study period [12].

Georgieff et al. [5] evaluated SBP and DBP in a cohort of 61 non-hypertensive premature (16 VLBW, 22 low birth weight [LBW]), and 23 full-term normal birth weight (NBW) newborn infants admitted to a NICU and followed them to their 4-month age-adjusted outpatient examination. Their results showed significant group differences in MBP. The estimated regression line of BP in VLBW infants had a steeper slope. There was a significant correlation between BPs and weights at each of the measurement points, while gestational age correlated significantly only with the 7th day BP.

The rate of postnatal BP rise in our patients is comparable to those reported by other authors [3, 5, 12]. Like LaFlore et al. [12] and Georgieff et al. [5] we found that postnatal BP is dependent on gestational age and birth weight. In addition to previous reports [1, 3, 5, 7, 11, 12, 29, 30], our data can make a contribution to better understanding neonatal BP in stable infants.

Conclusion

Systolic, diastolic, and mean arterial blood pressure progressively increased during the first month of life. BP increased more rapidly in preterm infants compared with full-term infants. The most predictive factors of BPs were gestational age, birth weight, and postnatal age. BPs were significantly lower when measured during the sleep period than when the child was awake.

Table 6 Comparison of MBP from our study with the reported data of another author: the first day of life in relation to EGA

	EGA (gw)	23	24	26	28	30	32	34	35	36
Our values	MBP (mmHg)	–	19	22	25	28	31	34	36	38
[16]	MBP (mmHg)	20	21	23	26	28	31	34	35	–

References

1. Flynn JF (2004) Neonatal hypertension. In: Portman RJ, Sorof JM, Ingelfinger JR (eds) Pediatric hypertension. Humana Press, Totowa, pp 351–370
2. Al-Aweel I, Pursley DM, Rubin LP, Shah B, Weisberger S, Richardson DK (2001) Variation in prevalence of hypotension, hypertension and vasopressor use in NICUs. J Perinatol 12:272–278
3. Zubrow AB, Hulman S, Kushner H, Falkner B (1995) Determinants of blood pressure in infants admitted to neonatal intensive care units: a prospective multicenter study. Philadelphia Neonatal Blood Pressure Study Group. J Perinatol 15:470–479
4. Hegyi T, Anwar M, Carbone MT, Ostfeld B, Hiatt M, Koons A, Pinto-Martin J, Paneth NB (1996) Blood pressure ranges in premature infants. II. The first week of life. Pediatrics 97:336–342
5. Georgieff MK, Mills MM, Gomez-Marin O, Sinaiko AR (1996) Rate of change of blood pressure in premature and full term infants from birth to 4 months. Pediatr Nephrol 10:152–155
6. Dannevig I, Dale HC, Liestol K, Lindemann R (2005) Blood pressure in the neonate: three non-invasive oscillometric pressure monitors compared with invasively measured blood pressure. Acta Paediatr 94:191–196
7. Nwankwo MU, Lorenz JM, Gardiner JC (1997) A standard protocol for blood pressure measurement in the newborn. Pediatrics 99:E10
8. Tan KL (1988) Blood pressure in very low birth weight infants in the first 70 days of life. J Pediatr 112:266–270
9. Park MK, Menard SM (1989) Normative oscillometric blood pressure values in the first 5 years in an office setting. Am J Dis Child 143:860–864
10. Uhari M (1980) Changes in blood pressure during the first year of life. Acta Paediatr Scand 69:613–617
11. Engle WD (2001) Blood pressure in the very low birth weight neonate. Early Hum Dev 62:97–130
12. LeFlore JL, Engle WD, Rosenfeld CR (2000) Determinants of blood pressure in very low birth weight neonates: lack of effect of antenatal steroids. Early Hum Dev 59:37–50
13. Ballard JL, Khoury JC, Weidig K, Wang L, Eilers-Walsman BL, Lipp R (1991) New Ballard score, expanded to include extremely premature infants. J Pediatr 119:417–423
14. Lubchenco LO, Hansman C, Dressler M, Boyd E (1963) Intrauterine growth as estimated from liveborn birth-weight data at 24 to 42 weeks of gestation. Pediatrics 32:793–800
15. Colan S, Fujji A, Borrow K (1983) Non-invasive determination of systolic, diastolic and end systolic blood pressure in neonates, infants and young children. Comparison with central aortic pressure measurements. Am J Cardiol 52:867–875
16. Versmold HT, Kitterman JA, Phibbs RH, Gregory GA, Tooley WH (1981) Aortic blood pressure during the first 12 hours of life in infants with birth weight 610 to 4,220 grams. Pediatrics 67:607–613
17. Ingelfinger JR (1982) Hypertension in the first year of life In: Ingelfinger JR (ed) Pediatric hypertension. Saunders, Philadelphia, pp 229–240
18. De Swiet M, Fayers P, Shinebourne EA (1980) Blood pressure in first year of life: the Brompton study. Pediatrics 65:1028–1035
19. Walker AM (1993) Circulatory transitions at birth and the control of the neonatal circulation. In: Hanson MA, Spenser JAD, Rodeck CH (eds) Fetus and neonate: physiology and clinical applications, vol 1: circulation. Cambridge University Press, Cambridge, pp 160–196
20. American Academy of Pediatrics (1993) Routine evaluation of blood pressure, hematocrit and glucose in newborns. Pediatrics 92:474–476
21. Ashworth AM, Neligan GA (1995) Changes in systolic blood-pressure of normal babies during the first twenty-four hours of life. Lancet 804–807
22. Elkasabany AM, Urbina EM, Daniels SR, Berenson GS (1998) Prediction of adult hypertension by K4 and K5 diastolic blood pressure in children: the Bogalusa Heart Study. J Pediatr 132:687–692
23. Morgenstern BZ, Butani L (2004) Casual blood pressure measurement methodology. In: Portman RJ, Sorof JM, Ingelfinger JR (eds) Pediatric hypertension. Humana Press, Totowa, pp 77–96
24. Fanaroff AA, Wright E (1990) Profiles of mean arterial blood pressure (MAP) for infants weighting 501–1500 grams. Pediatr Res 205A
25. Low JA, Panagiotopoulos C, Smith JT, Tang W, Derrick EJ (1995) Validity of newborn oscillometric blood pressure. Clin Invest Med 18:163–167
26. Dannevig I, Dale HC, Liestol K, Lindemann R (2005) Blood pressure in the neonate: three non-invasive oscillometric pressure monitors compared with invasively measured blood pressure. Acta Paediatr 94:138–140
27. Joppich R, Hauser I (1982) Urinary prostacyclin and thromboxane A2 metabolites in preterm and full-term infants in relation to plasma activity and blood pressure. Biol Neonate 42:179–184
28. Arens Y, Chapados RA, Cox BE, Kamm KE, Rosenfeld CR (1998) Differential development of umbilical and systemic arteries. II. Contractile proteins. Am J Physiol 274:R1815–R1823
29. Hegyi T, Carbone MT, Anwar M, Ostfeld B, Hiatt M, Koons A, Pinto-Martin J, Paneth N (1994) Blood pressure ranges in premature infants. I. The first hours of life. J Pediatr 124:627–633
30. Joint Working Group of the British Association of Perinatal Medicine in the Research Unit of the Royal College of Physicians (1992) Development of audit measures and guidelines for good practice in the management of neonatal respiratory distress syndrome. Arch Dis Child 67:1221–1227