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Research Article

Comparability of the Hemodynamic Data Measured by Doppler Echocardiography and Non-Invasive Ultrasound Monitoring Assessment of the Cardiac Output Parameters

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Abstract

Hemodynamic disorders accompany any severe pathology in patients of all age groups, including newborns. Functional Doppler echocardiography and assessment of the cardiac output parameters by an Ultrasound Cardiac Output Monitor (USCOM) appears to be an informative and available method of non-invasive hemodynamics control in newborns. Aim of study is to compare results of measurements of hemodynamic findings obtained by the ultrasound Doppler echocardiography (Doppler) and monitoring of non-invasive cardiac output parameters by USCOM. Hemodynamic parameters were defined using the left-sided trans-aortal access by the USCOM device Ultrasound Cardiac Output Monitor (Australia) following classical approach in mature newborns treated in the intensive care unit (ICU). The following parameters were chosen to be compared: stroke volume, heart rate and cardiac index. Statistical processing was performed using Wilcoxon test and Bland-Altman method comparison. Comparability of these methods indicates that mean difference (MD) calculated by Bland-Altman method is a well allowable value and constitutes: by the stroke volume finding – (-1,151); by the heart rate (HR) finding - (0,4667) and by the cardiac index finding - (-1,062). Hemodynamic parameter measurements by these methods have good comparability. Values compared by two methods of examination are within the standard deviation 1.96. It is widely known that if standard deviation meaning ± 1,96 SD does not have clinical significance, then two methods of examination can be interchangeable. Further research studies are necessary to specify the obtained data.

Keywords: *Non-Invasive Monitoring; Hemodynamic; Newborns*

Abbreviations

USCOM: Ultrasound Cardiac Output Monitor; Doppler: Ultrasound Doppler Echocardiography; CO: Cardiac Output; CI: Cardiac Index; HR: Heart Rate

Introduction

Hemodynamic disorders are considered to be the basis of critical conditions in patients of all age groups including those in the neonatal period [1,2].

Clinical manifestations of hemodynamic disorders, especially in children of the early ages, are considerably delayed, are not specific and, as a result, are not timely recognized by pediatricians [3,4]. Expanded hemodynamic monitoring is necessary for all patients, this is especially essential for newborns and infants of the first years of life. Objective assessment of the cardiac output and factors determining it is a must; what is more, this assessment should be performed not only in absolute figures occurring once, but in the process of intensive care performance.

The most available and sufficiently informative methods of non-invasive monitoring of hemodynamics are methods based on ultrasound echography in combination with the Doppler effect. They include functional ultrasound Doppler echocardiography (Doppler) (demanding considerable technical competences and long-lasting training for both – application of the technique and interpretation of the obtained data) and assessment of the cardiac output by non-invasive ultrasound monitor USCOM (Ultrasound Cardiac Output Monitor, Australia) [5,6].

Comparability of the results of hemodynamic measurements when using Doppler and USCOM devices appears to be an actual issue nowadays.

Aim of Study

To compare results of measurements of the stroke volume (SV) and particular hemodynamic values when using ultrasound Doppler echocardiography and ultrasound monitoring of non-invasive control of the cardiac output parameters – performed by the USCOM device.

Materials and Methods

26 mature newborns being treated in the intensive care unit (ICU) were examined in the study. The average body mass of infants at birth was 3535 ± 444 g, height - 53 ± 2,33 cm, gestational age - 39,58 ± 1,1 weeks, Apgar score on the first minute was 4,62 ± 1,86, on the fifth minute 6,12 ± 1,4. Cerebral ischemia, II-III degree, suppression syndrome of the central nervous system and intra-uterine infection of unspecified etiology were the main diagnosis when admitted in the ICU. The patients did not receive hemodynamic support. Infants with congenital defects were excluded from the study. The examination was performed on the first-second days of life.

All children were parallely performed investigation of hemodynamics by ultrasound Doppler echocardiography using classical technique at rest without application of medication sleep, and ultrasound monitoring of non-invasive control of the cardiac output parameters by USCOM. The interval between investigations constituted 5 - 10 minutes.

The following values were chosen to be compared: the stroke volume as a value mostly dependent on the transducer position; the heart rate as a value independent on the operator qualification; and the cardiac index considering both previous values and the patient's body surface area calculated by the devices.

Since the data obtained were characterized by a wide scatter, the processing was performed using non-parametric Wilcoxon test to compare the significance of values diversity. Bland-Altman method was used to define the line of agreement.

Research Results

60 investigations were performed in 26 infants. Table 1 demonstrates the results of Wilcoxon test, that has been applied to compare the significance of the diversity of values obtained by the Doppler operator and the USCOM operator. Zero hypothesis was rejected when $p < 0,05$. Research results are given in the table 1.

Values	Doppler	USCOM	«p» (Wilcoxon test)
SV, ml	5,7 (3,38;7,2)	5,65 (3,2;8,7)	0,97
HR, min	135 (108;179)	135 (107;178)	0,63
CI, l/min/m^2	3,6 (1,83;6,07)	3,57 (2,1;5,9)	0,189

Table 1: *Results are given in the form of a median line, lower and upper quartiles.*

As one can see, the median lines obtained are practically congruent; no statistically significant differences are obtained comparing results.

Comparability of the given methods demonstrates that a mean difference calculated by Bland-Altman method is a fully allowable value and constitutes: by the SV value - (-1.151) (Figure 1); by the HR value - (0.4667) (Figure 2); by the CI value - (-1.062) (Figure 3).

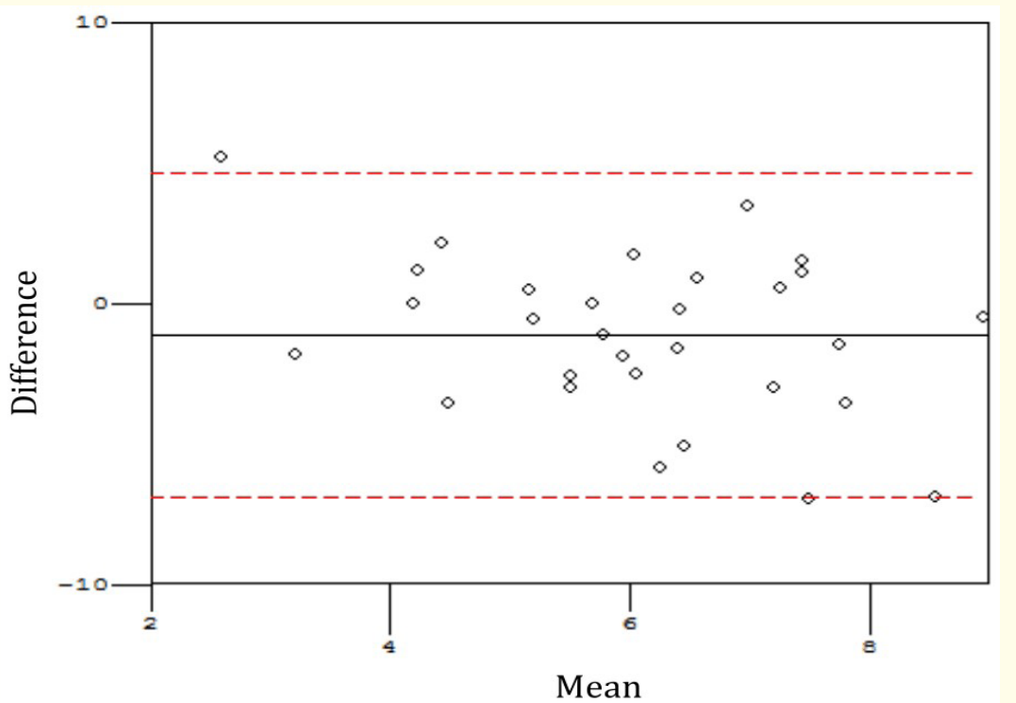

Figure 1: *Mean difference on the SV value.*

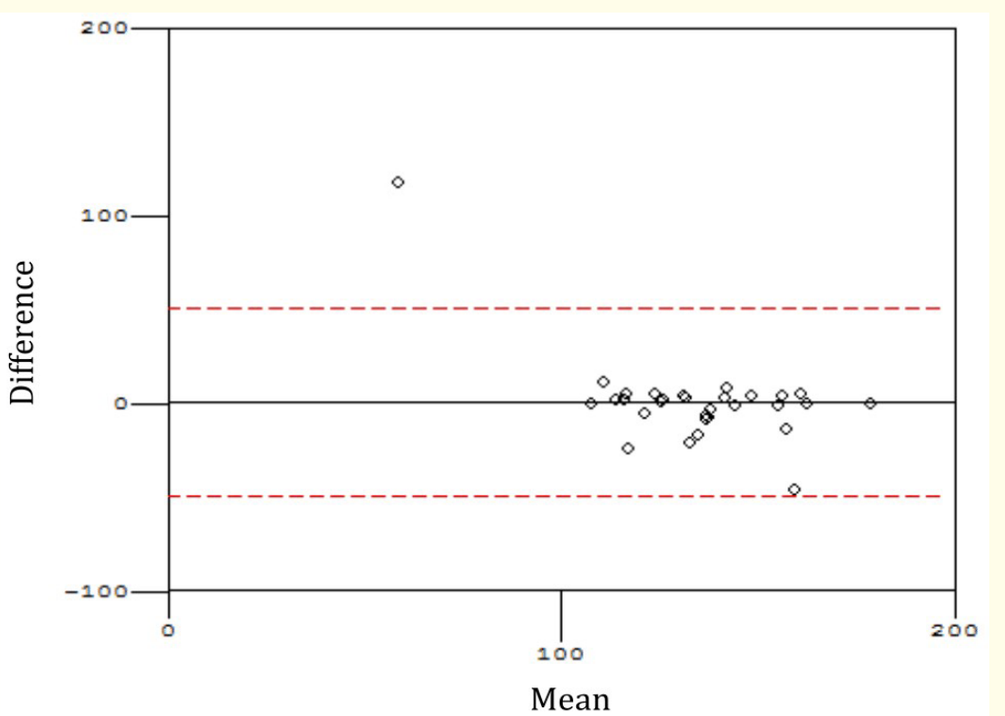

Figure 2: *Mean difference on the HR value.*

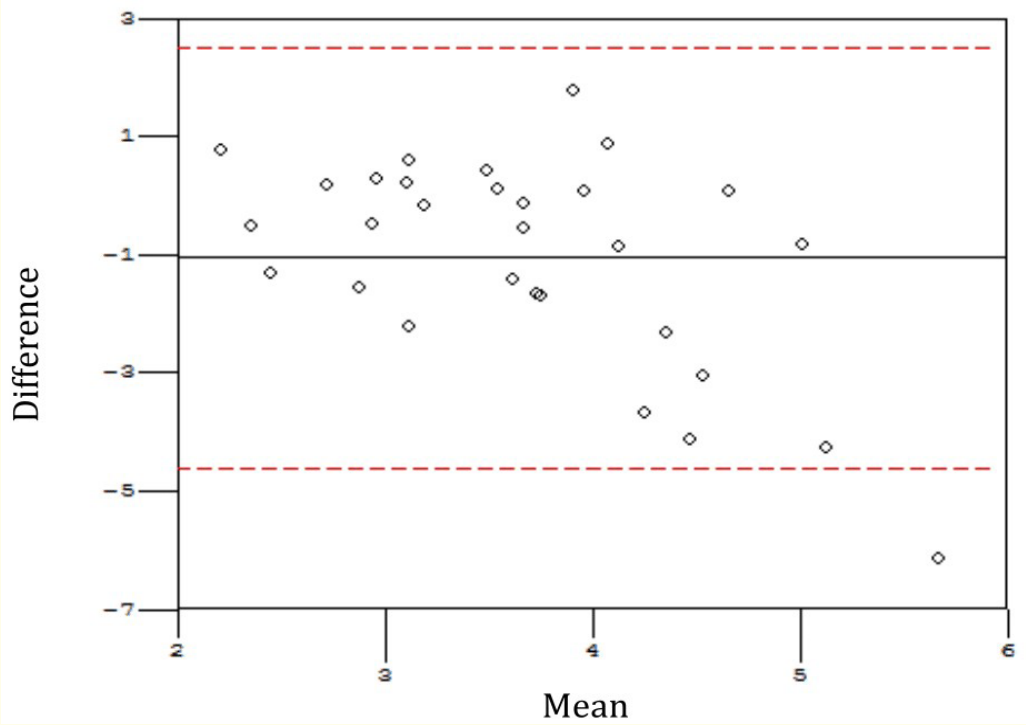

Figure 3: *Mean difference on the CI value.*

Thus, hemodynamic values obtained by the two methods of investigation are within the standard deviation SD 1.96.

Discussion

The fact, that any severe pathology in patients of all groups including newborns is associated with hemodynamic disorders, is widely known today. Even small – but timely unrecognized and uncorrected – changes of hemodynamic status can result in severe systemic disorders with the development of shock and polyorgan insufficiency; this extends length of hospital stay of patients in the resuscitation and intensive care unit and can even cause fatal outcome [1,2].

Monitoring of hemodynamic parameters allows detecting minimal deteriorations of vital body functions at early stages, providing timely beginning of intensive therapy and its qualitative performance.

Methods of non-invasive monitoring of hemodynamic parameters are considered to be the most actual in pediatrics [7]. Doppler echocardiography appears to be a prevailing non-invasive technique of hemodynamics assessment in children, but its performance needs significant technical competences; this fact, in combination with long terms of teaching to the given technique and peculiarities of interpretation of the obtained data, restricts its routine use by clinicians [6].

An ultrasound monitor of non-invasive control of cardiac output parameters (USCOM device) has a simple system of transducer management; thanks to this fact, a pediatrician, who is not experienced in the Doppler echocardiography performance, is able to assess hemodynamic values at patient's bed in real-time mode. Moreover, 15 - 20 measurements in an adult and up to 30 measurements in a newborn are enough for the better recovery rate of results monitored by an unexperienced physician with the help of USCOM [8].

The main limitation of the hemodynamic assessment technique with the help of USCOM is the same as in Doppler echocardiography - a transducer location is carried out blindly. This can result in an error due to an angle excursion of transducer insonation and cause significant values variations obtained by various operators [9]. However, proper correlation of findings obtained by various researchers regardless of their colleagues' results is reported about in several research works [10]. The method of hemodynamic assessment using USCOM is considered to be attractive due to its non-invasiveness and simplicity of measurements.

Research studies devoted to comparability of hemodynamic values obtained using ultrasound Doppler echocardiography and ultrasound monitoring of non-invasive control of cardiac output parameters, especially in pediatrics, are occasional according to the MedLine database.

In 2006 Phillips RA, Paradisis M, Evans NJ measured hemodynamic values in 37 preterm newborns (an average weight 1.13 ± 0.47) by USCOM and Doppler (r = 0.91). Authors concluded that USCOM was not able to replace Doppler echocardiography but was a supplementary measurement when bedside monitoring of hemodynamics was necessary [11].

In 2009 Todd D.A., Meyer S having examined 12 newborns with the gestational age 34.1 ± 3.7 weeks, weighed 2.268 ± 0.872, concluded that USCOM was appropriate for measurements of the cardiac output in newborns. In addition, they detected a significant difference between cardiac output values of the right and left ventricles; this fact can be explained by the presence of physiological shunts [12].

It is significant to consider anatomical peculiarities of the cardiovascular system in neonates and infants, namely, presence of physiological (an open arterial duct and oval window) and pathological (congenital heart diseases) shunts, when assessing hemodynamic parameters obtained by ultrasound methods of examination, such as USCOM and Doppler [9].

Data similar to results of our study were obtained by He S., Cheng Z in 2011 and Zheng ML, Sun X in 2013. It should be mentioned that the first study included 90 healthy newborns examined in their first three days of life, the second study included 20 mature and 29 preterm neonates being in the physiological departments for newborns; the examinations were performed using USCOM and Doppler. He S, Cheng Z [13] reported about the high rate of coincidences of cardiac output values measured by USCOM and Doppler. Zheng ML, Sun X recommended to assess cardiac output of the left ventricle using USCOM, since comparability of this value with the data obtained by Doppler was sufficiently high [14].

Nguyen HB, Banta DP, Stewart G [15], Wongsirimetheekul T, Khositseth A [16] in their works presented the opposite view point indicating at unreliable correlation between parameters obtained by USCOM and parameters measured by Doppler. Neil Patel, Melissa Dodsworth having examined 56 healthy newborns (hemodynamically unstable neonates, neonates with extremely low body mass and intracardiac shunts were excluded from the study) came to the conclusion that further studies had to be done to precisely detect cardiac output with the help of these two techniques.

It should be pointed out that all authors supported relevance and importance of the given variant of non-invasive monitoring for assessment of hemodynamic values in dynamics.

Conclusions

Hemodynamic values obtained when examining newborns by ultrasound Doppler echocardiography and ultrasound monitoring of non-invasive control of the cardiac output parameters – by USCOM device – are within the standard deviation SD 1.96. It is known, that if deviations of the mean difference ± 1.96 SD do not have clinical significance, then two studied methods of investigation are compatible and can be interchangeable. Further research studies are necessary to specify the obtained data.

Ultrasound monitoring of non-invasive control of the cardiac output is applicable to assess hemodynamic values in dynamics in newborns.

Conflict of Interest

None.

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