Received: 27 April 2023 / Accepted: 28 July 2023 / Published online: 31 August 2023

DOI 10.34689/SH.2023.25.4.022

UDC 616.8-053.32(048)

DIAGNOSIS OF HEMODYNAMIC DISORDERS IN PREMATURE NEWBORNS. LITERATURE REVIEW.

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Abstract

Introduction. The article presents a review of the current literature on studies of hemodynamic disorders in preterm infants. In the pathogenesis of the development and progression of critical conditions in the specified contingent of newborns, the leading place is occupied by arterial hypotension (AH), which usually occurs in the first 24 hours after birth in 40% of infants. At the same time, hypertension plays a significant role in the implementation of perfusion disorders in vital organs, as well as in an increase in the frequency of deaths and severe neurological consequences.

The possibility of early diagnosis of perfusion disorders by using echocardiography, which is a rational and non-invasive method aimed at a comprehensive assessment of hemodynamic disorders in newborns and determining the tactics of their management, has been substantiated.

Aim. To study current data on studies of hemodynamic disorders in preterm infants by conducting a literature review.

Search strategy. Public access articles were studied using the following databases of scientific publications and specialized search engines: PubMed, Google Scholar, Web of Science, Scopus, Cochrane Library. A number of original publications and reviews in the field of research for the period 2012-2022 were analyzed, but also works published earlier than 2012 were included, since they have information on the pathology under study in the neonatal period and classical routine approaches in the treatment and diagnosis of hemodynamic disorders in newborns . The selection of publications was carried out in accordance with the purpose of the review.

Results. Functional echocardiography is a rational and non-invasive method that can play an important role in a comprehensive assessment of hemodynamic disorders in a newborn and tactics of its management.

In a newborn with a normal heart rhythm without significant fetal shunting, left ventricular CO (cardiac output) and superior vena cava (CVVC) blood flow are used to assess systemic blood flow. In the presence of significant shunting, data on the CO of the right ventricle and blood flow in the SVC are used.

The flow in the superior vena cava is one of the valuable parameters for informing clinicians about perfusion and cerebral blood flow. The association of significantly and persistently low blood flow with increased risk of morbidity, mortality, and dynamic measurement of superior vena cava flow beginning early after birth may help detect risk in these infants. The diagnostic accuracy of SVC flow for predicting poor perfusion will improve with the addition of other clinical and diagnostic parameters for comprehensive hemodynamic monitoring. SVC flow and cardiac output are considered key in neonatal shock and can be used for targeted treatment. SVC flow is an excellent monitoring method for assessing heart-lung interactions, ductus arteriosus shunt volume.

Conclusions. The main limitation of measuring SVC flow and cardiac output is that they are not a true measure of myocardial function. Blood flow is the interaction between the heart and blood vessels. The ventricular arterial junction is an excellent parameter of cardiovascular efficiency and pathways to heart failure, but it provides limited insight into intrinsic myocardial function.

In order to progress in research on diagnosing neonatal CVD, we must use well-understood parameters such as SVC flow, recognizing its limitations, and expanding our capabilities. Research and search for new methods of diagnosing the hemodynamic state of newborns can help identify and treat infants at risk of impaired perfusion in the neonatal period.

Key words: *hemodynamics, superior vena cava, premature newborns.*

Резюме

ДИАГНОСТИКА НАРУШЕНИЙ ГЕМОДИНАМИКИ У НЕДОНОШЕННЫХ НОВОРОЖДЕННЫХ ДЕТЕЙ. ОБЗОР ЛИТЕРАТУРЫ.

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Введение. В статье представлен обзор современной литературы по исследованиям гемодинамических нарушений у недоношенных младенцев. В патогенезе развития и прогрессирования критических состояний у указанного контингента новорожденных, ведущее место занимает артериальная гипотензия (АГ), возникающая как правило в первые 24 часа после рождения у 40% младенцев. При этом АГ играет значительную роль в реализации перфузионных нарушений в жизненно важных органах, а также в увеличении частоты смертельных исходов и тяжелых неврологических последствий.

Обоснована возможность ранней диагностики перфузионных нарушений путем использования эхокардиографии, являющейся рациональным и неинвазивным методом, направленным на всестороннюю оценку гемодинимических нарушений у новорожденных и определение тактики их ведения.

Цель исследования. Изучить данные современной литературы об исследованиях гемодинамических нарушений у недоношенных новорожденных

Стратегия поиска. Изучены статьи, находящиеся в открытом доступе, с использованием следующих баз данных научных публикаций и специализированных поисковых систем: PubMed, Google Scholar, Web of Science, Scopus, Cochrane Library. Проанализирован ряд оригинальных публикаций и обзоров по направлению исследования за период 2012-2022 года, но также были включены работы, опубликованные ранее 2012 года, так как они имеют информацию по исследуемой патологии в неонатальном периоде и классические рутинные подходы в лечении и диагностике гемодинамических нарушений у новорожденных. Отбор публикаций осуществлялся в соответствии с целью обзора.

Результаты. Функциональная эхокардиография — рациональный и неинвазивный метод, который может играть важную роль во всесторонней оценке гемодинамических нарушений у новорожденного и тактике его ведения.

У новорожденного с нормальным сердечным ритмом без значимого шунтирования крови через фетальные коммуникации для оценки уровня системного кровотока используется СВ (сердечный выброс) левого желудочка и кровоток в верхней полой вене (КВПВ). При наличии значимого шунтирования – используют данные о СВ правого желудочка и кровоток в ВПВ.

Поток в верхней полой вене является одним из ценных параметров для информирования клиницистов о перфузии и церебральном кровотоке. Связь значительно и постоянно низкого кровотока с повышенным риском заболеваемости, смертности и динамическое измерение потока верхней полой вены, начинающиеся рано после рождения, могут помочь обнаружить у этих младенцев риск. Диагностическая точность потока ВПВ для прогнозирования плохой перфузии будет улучшаться при добавлении других клинических и диагностических параметров для всестороннего гемодинамического мониторинга. Поток ВПВ и сердечный выброс считаются ключевыми, при неонатальном шоке и могут использоваться для целевого лечения. Кровоток в ВПВ - отличный метод мониторинга для оценки взаимодействий сердце-легкие, объем шунта через открытый артериальный проток.

Выводы. Основное ограничение измерения потока ВПВ и сердечного выброса заключается в том, что они не являются истинным показателем функции миокарда. Кровоток представляет собой взаимодействие между сердцем и сосудами. Желудочково-артериальное соединение является отличным параметром сердечно-сосудистой эффективности и путей к сердечной недостаточности, но оно обеспечивает ограниченное понимание внутренней функции миокарда.

Чтобы прогрессировать в исследованиях о диагностике состояния сердечно-сосудистой системы у новорожденных, мы должны использовать хорошо изученные параметры, такие как поток ВПВ, признавая его ограничения, и расширять наши возможности. Исследование и поиск все новых методов диагностики состояния гемодинамики у новорожденных может помочь выявлять и лечить младенцев с риском нарушения перфузии в неонатальном периоде.

Ключевые слова: *гемодинамика, верхняя полая вена, недоношенные новорожденные.*

Түйіндеме

ШАЛА ТУЫЛҒАН НӘРЕСТЕЛЕРДІҢ ГЕМОДИНАМИКАЛЫҚ БҰЗЫЛЫСТАРДЫҢ ДИАГНОСТИКАСЫ. ӘДЕБИТТІК ШОЛУ.

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Кіріспе. Мақалада шала туылған нәрестелердегі гемодинамикалық бұзылуларды зерттеуге арналған заманауи әдебиеттерге шолу берілген. Жаңа туылған нәрестелердің осы контингентіндегі ауыр жағдайлардың дамуы мен өршуінің патогенезінде артериялық гипотензия жетекші орын алады, ол нәрестелердің 40%-ы туылғаннан кейінгі алғашқы 24 сағатта тіркеледі және өмірлік маңызды органдарда перфузиялық бұзылуларды жүзеге асыруда, өлім-жітім мен ауыр неврологиялық салдардың жоғарылауында маңызды рөл атқарады.

Жаңа туған нәрестелердегі гемодинимиялық бұзылуларды жан-жақты бағалауға және оларды басқару тактикасын анықтауға бағытталған ұтымды және инвазивті емес әдіс болып табылатын эхокардиографияны қолдану арқылы перфузиялық бұзылуларды ерте диагностикалау мүмкіндігі негізделген.

Зерттеудің мақсаты. Әдеби шолу жүргізу арқылы шала туылған нәрестелердегі гемодинамикалық бұзылуларды зерттеу деректерін зерттеу.

Ізденіс стратегиясы. Ашық қолжетімді мақалалар келесі ғылыми басылымдар мен мамандандырылған іздеу жүйелерінің дерекқорлары арқылы зерттелді: PubMed, Google Scholar, Web of Science, Scopus, Cochrane Library. 2012-2022 жылдар аралығындағы зерттеу саласындағы бірқатар түпнұсқа жарияланымдар мен шолулар талданды, бірақ 2012 жылдан бұрын жарияланған жұмыстар да қамтылды, өйткені оларда неонаталдық кезеңдегі зерттелетін патология және классикалық күнделікті тәсілдер туралы ақпарат бар. жаңа туған нәрестелердегі гемодинамикалық бұзылыстарды емдеуде және диагностикалауда. Басылымдарды іріктеу шолу мақсатына сәйкес жүргізілді.

Нәтижелер. Функционалды эхокардиография - бұл жаңа туған нәрестедегі гемодинамикалық бұзылуларды жан-жақты бағалауда және оны басқару тактикасында маңызды рөл атқаратын ұтымды және инвазивті емес әдіс. Ұрық байланысы арқылы қанды мағыналы айналып өтпейтін қалыпты жүрек ырғағы бар жаңа туған нәрестеде жүйелік қан ағымының деңгейін бағалау үшін сол жақ қарыншаның жүрек шығысы және жоғарғы қуыс венадағы қан ағымы қолданылады. Егер маңызды айналма жол болса-оң жақ қарыншаның жүрек шығысы деректері мен жоғарғы қуыс венадағы қан ағымы қолданылады. Жоғарғы қуыс венадағы ағын клиниктерге перфузия және церебральды қан ағымы туралы хабарлаудың құнды параметрлерінің бірі болып табылады. Ауру, өлім қауіпінің жоғарылауымен айтарлықтай және тұрақты төмен қан ағымының байланысы және туылғаннан кейін ерте басталатын жоғарғы қуыс вена ағынын динамикалық өлшеу бұл нәрестелердегі қауіпті анықтауға көмектеседі. Нашар перфузияны болжау үшін жоғарғы қуыс венадағы ағынының диагностикалық дәлдігі жан-жақты гемодинамикалық бақылау үшін басқа клиникалық параметрлерді қосқанда жақсарады. Жоғарғы қуыс венадағы ағын және жүректің шығуы неонатальды шок үшін маңызды болып саналады және оны мақсатты емдеу үшін қолдануға болады. Жоғарғы қуыс венадағы қан ағымы-бұл жүрек-өкпе өзара әрекеттесуін, ашық артериялық канал арқылы шунт көлемін бағалаудың тамаша бақылау әдісі.

Қорытындылар. Жоғарғы қуыс венадағы ағыны мен жүректің шығуын өлшеудің негізгі шектеуі-бұл миокард функциясының шынайы көрсеткіші емес. Қан ағымы-бұл жүрек пен қан тамырларының өзара әрекеттесуі. Қарыншалық-артериялық қосылыс жүрек-қан тамырлары тиімділігі мен жүрек жеткіліксіздігінің тамаша параметрі болып табылады, бірақ ол миокардтың ішкі қызметі туралы шектеулі түсінік береді**.**

Жаңа туылған нәрестелердегі жүректің ультрадыбыстық зерттеуінде ілгерілеу үшін біз оның шектеулерін мойындай отырып, жоғарғы қуыс венадағы ағыны сияқты жақсы зерттелген параметрлерді қолдануымыз керек және мүмкіндіктерімізді кеңейтуіміз керек. Перинаталдық перфузияның бұзылу қаупі бар нәрестелерді анықтауға және емдеуге көмектесетін жүректің ультрадыбыстық диагностикасының жаңа әдістерін зерттеу.

Түйінді сөздер: *гемодинамика, жоғарғы вена қысы, шала туылған нәрестелер.*

Bibliographic citation:

Omargazina B.S., Chuvakova T.K., Khamidullina Z.G., Karin B.T., Jaxalykova K.K. Diagnosis of hemodynamic disorders in premature newborns. Literature review // *Nauka i Zdravookhranenie* [Science & Healthcare]. 2023, (Vol.25) 4, pp. 172-181. *DOI 10.34689/SH.2023.25.4.022*

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Introduction

Since 2008, in the statistical reporting of Kazakhstan, in connection with the introduction of the International Criteria for Live Births and Stillbirths, fetuses and newborns born at a gestational age of 22 weeks or more, with a birth weight of 500 g or more and a length of 25 cm or more are taken into account. In the general structure of the population of newborns, children with extremely low (500-999 g) and very low (1000-1499 g) birth weight make up no more than 1%, which corresponds to the indicator of developed countries, for example, Great Britain. However, in the structure of early neonatal mortality (RNM) by weight categories, they occupy a leading position, accounting for 53% [3,71].

The most serious and acute problems of the early neonatal period in premature newborns are hemodynamic disorders, which is due to the continued functioning of fetal communications in the postnatal period, determined by the peculiarities of the transition of the fetal circulation to the blood circulation of the newborn in extrauterine conditions.

In the foundation of the development and progression of critical conditions in newborns, one of the main roles is occupied by arterial hypotension (AH) and, accordingly, against the background of circulatory disorders, insufficiency of perfusion and oxygenation of organs and tissues develops. It is known, for example, that 40% of preterm infants with a gestational age of less than 30 weeks who use mechanical ventilation (ALV) have arterial hypotension (AH), which develops in the first 24 hours of life [27,58,44]. Clinical manifestations of arterial hypotension are extremely ambiguous: from an asymptomatic course to a shock clinic.

Violation of cerebral blood flow, which developed against the background of arterial hypotension, leads to cerebral ischemia, damage to the brain substance and the implementation of periventricular leukomalacia (PVL). In addition, many researchers associate the development of severe intraventricular hemorrhages (IVH) with arterial hypotension. In turn, these brain lesions are the most common cause of severe disability in the described group of children and lead to a violation of their quality of life [5,31,48].

Reduced perfusion and ischemia of organs and tissues leads not only to severe neurological lesions, but also to such severe complications and pathologies as necrotizing enterocolitis, impaired renal function up to ischemic nephropathy and the development of renal failure, which can often cause death. Thus, arterial hypotension underlies multiple organ failure [5,17,31,34].

The process of implementation and further progression of hemodynamic disorders in newborns, especially in preterm infants, is diverse. Most often there is a combination of various factors, often difficult to detect in clinical practice. Early and timely diagnosis of hemodynamic disorders in newborns is a serious problem for clinicians around the world. Modern intensive care in neonatology requires improving the quality of diagnosis and treatment of hemodynamic disorders.

Therefore, the main goal of intensive care in children with very low and extremely low body weight is the timely and early detection of hemodynamic disorders and, first of all, the prevention and prevention of cerebral perfusion disorders immediately after birth by maintaining normal hemodynamic parameters.

Aim. To study data on modern and current studies of hemodynamic disorders in preterm infants by conducting a literature review.

Search strategy. Public access articles were studied using the following databases of scientific publications and specialized search engines: PubMed, Google Scholar, Cochrane Library, Scopus, Web of Science. A number of original publications and reviews in the field of research for the period 2012-2022 were analyzed, but also works published earlier than 2012 were included, since they have information on the studied pathology in the neonatal period and classical routine approaches in the treatment and diagnosis of hemodynamic disorders in preterm infants newborns.

Key words were used: hemodynamics, superior vena cava, premature newborns. *Inclusion criteria:* Publications for a period of 10 years (2012-2022), as well as some publications earlier than 2012 in English and Russian, patient category - premature newborns, type of articles - randomized clinical trials, meta-analysis, systematic review, review articles. *Exclusion criteria:* expert opinions in the form of short messages, repeated publications, publications with unclear conclusions. As a result of the search, we studied 100 publications, this review included 80 publications.

Results

Autoregulation of cerebral blood flow. The leading goal of critical care in very low and extremely low birth weight neonates is to avoid impaired cerebral perfusion by providing adequate tissue oxygenation. Cerebral blood flow is primarily a complex interaction between cerebral blood flow, systemic blood flow and cerebral vascular resistance. The process of autoregulation ensures the maintenance of constancy of cerebral blood flow with various fluctuations in blood pressure, systemic blood flow and resistance. It is known that the body of sick premature babies is not capable of maintaining autoregulation of cerebral blood flow. For this reason, cerebral blood flow, which is passively dependent on systemic blood flow and blood pressure, becomes vulnerable with any of its fluctuations, and in the presence of systemic hypotension, cerebral perfusion also decreases [2,30,39,47,55].

At the same time, it should be remembered that the degree of maturity of vascular autoregulation is directly related to the gestational age of the child, respectively, the shorter the gestational age of the infant, the higher the risk of cerebrovascular accident under the influence of various factors. Also, a clear definition of the blood pressure threshold to justify the need to start treatment is especially important in the category of patients with extremely low and very low gestational age of less than 32 weeks [69].

Blood pressure in newborns

Systemic arterial hypotension occurs in the practice of a doctor in about 50% of cases, and these are patients with a birth weight of less than 1500 grams. Also, about 50% of very preterm infants in intensive care units receive treatment for cardiovascular support through the use of fluid loading, pressor/inotropic drugs, or both, with low blood pressure being the main indication for therapy [6,69]. However, one should not forget that the absolute threshold values of the mean BP are not clearly defined, and it is not advisable to rely on this hemodynamic indicator as the only marker that determines the treatment tactics [26,54].

Mean arterial pressure remains a routinely used marker of hemodynamic disorders, and the gestational age of the child in weeks is considered the threshold value as the equivalent of the norm [12]. In the first 3 days of life, even if the gestational age of the newborn is less than 30 weeks, the mean BP should not be lower than 30 mm Hg, and in preterm infants less than 600 grams, the lower threshold value of the mean BP is 28 mm Hg [1]. At the same time, it should be remembered that the complex processes of adaptation to new conditions of extrauterine life, the immaturity of the cardiovascular system limit the ability to determine the exact boundaries of normal blood pressure values, and, accordingly, focusing only on blood pressure to assess the state of the circulatory system is of very low value and accuracy. This is true for both full-term and preterm infants [20,53].

It would be more correct and expedient to diagnose the adequacy of organ perfusion before starting this or that intervention. However, many diagnostic methods are difficult to access, unsafe for the newborn organism, or costly [6,16]. Currently, the most accurate method for determining blood pressure is to measure it using a central or peripheral arterial catheter. Taking into account the possibility of realization of various complications due to invasiveness, the inexpediency of its permanent and routine use is substantiated. Some studies demonstrate the relationship between BP measured by non-invasive oscillometric method and invasive [19,70].

Currently, there is controversy regarding the relationship between cerebral blood flow and mean arterial pressure in preterm infants. Tyszczuk L. in his study found that cerebral blood flow does not depend on mean arterial pressure in children born between 24 and 34 weeks of gestation, and suggested that autoregulation is preserved in some children with arterial hypotension [77]. In contrast, other researchers have found a significant relationship between mean arterial pressure and cerebral perfusion. The researchers also suggested that with an average arterial pressure of less than 30 mm Hg. in very low birth weight neonates, cerebral blood flow begins to decrease [51,76].

However, more and more studies show that assessing the state of the circulatory system only on the given values of mean arterial pressure is a very simplistic approach to solving a more complex problem, since normal blood pressure does not yet guarantee normal blood flow in target organs. Normal neonatal mean arterial pressure does not always mean normal left ventricular output or adequate cerebral blood flow in preterm infants, even in the subgroup of infants with occluded ductus arteriosus. Problems also arise in assessing systemic blood flow as a result of failure or delay in the normal closure of fetal ducts. Increased blood flow through the ductus arteriosus often causes increased output from the left ventricle by about 2 times, shunting through the atrium through the foramen ovale from left to right causes an increase in output from the right ventricle. In many premature infants with extremely low body weight, systemic blood flow deteriorates sharply in the first hours of life, which is often combined with an increase in peripheral vascular resistance [16,23,37,39,41].

Most children will have normal blood pressure at the start (i.e. are in the compensated shock phase). However, approximately 80% of newborns with initially low systemic blood flow result in systemic arterial hypotension. However, the use of only arterial hypotension as a starting indication for therapy leads to the fact that children with significantly low blood flow are detected late or not detected at all. Hypotension may mask normal or even high systemic blood flow, as is often the case in preterm infants with persistent pulmonary hypertension or in infants with sepsis. These neonates tend to have low systemic vascular resistance and peripheral vasodilation.

As a result of the wide variation in blood pressure levels in children of different gestational and postnatal ages, many authors argue that it is not necessary to focus solely on low blood pressure, it is necessary to use other indirect indicators of hypoperfusion, such as slow capillary filling, oliguria and metabolic acidosis, which are necessary for more or less complete, but non-exhaustive assessment of the hemodynamic status of a premature newborn. In clinical practice around the world, a comprehensive assessment of the adequacy of the functioning of the cardiovascular system in newborns with very low and extremely low body weight is a huge problem than in older children and adults [2]. Features are associated with the small size of the body of the newborn organism, their vulnerability and the frequent presence of blood shunting in the heart. Basically, the assessment of hemodynamic status consists in the clinical assessment of perfusion by assessing capillary refill time, urine output, heart rate and blood pressure. Determination of acid-base balance, the presence of lactic acidosis will provide additional information about hemodynamic disorders, but constant monitoring is also needed [2,23,39,43,62].

In addition, the use of all these parameters in newborns, especially in premature infants, has its limitations and also depends on the capabilities of the clinic and equipment.

Normal and adequate perfusion of organs and tissues is characterized by cardiac output (CO) and total peripheral vascular resistance (TPVR), which determine the level of blood pressure. A decrease in CO and a change in peripheral vascular resistance lead to a decrease in peripheral circulation and impaired organ perfusion. Insufficient tissue perfusion, which is a decrease in volumetric blood flow, can also be observed with normal blood pressure against the background of vasospasm and increased resistance of the vascular bed [64,66,73,78]. In the absence of the ability to measure CO and systemic vascular resistance, clinicians began to use BP as the only indicator of circulatory disturbance. At the same time, many studies confirm that in a premature newborn in the first 48 hours after birth, there is a weak relationship between mean BP and CO. Relying only on the value of the average blood pressure, the doctor can give an erroneous conclusion about the state of the cardiovascular system, interpret the state of shock in the patient, especially in the early neonatal period, when fetal communications are still functioning. The explanation for this may be that fluctuations in peripheral vascular resistance can affect cardiac output, but not affect blood pressure, and the presence of an arterial duct causes an increase in cardiac output from the left ventricle. As a result of this paradox, two children with the same blood pressure may have different cardiac output. Those. the relationship between arterial pressure and left ventricular cardiac output is weak, for example, some children have

mean arterial pressure above 30 mm Hg, while cardiac output is low, less than 150 ml / kg / min, and conversely, some children have low arterial pressure, but while cardiac output is within the normal range [4,46,53,62,67].

Accordingly, hemodynamic evaluation based only on mean BP leads to the fact that circulatory failure or shock may go unnoticed [56,62].

Systemic blood flow (SC), supplying the entire systemic vascular bed of the body, and hence providing blood to all tissues and organs, would be the most informative indicator for assessing the state of hemodynamics. However, in the presence of fetal communications in newborns, especially preterm infants, cardiac output measurements will not reflect MC and will not allow the clinician to adequately assess the patient's hemodynamic status. Left-to-right (L-R) shunting through the ductus arteriosus will increase left ventricular (LV) output, and thus the amount of blood actually reaching the systemic circulation will be overestimated, as LV = SC + ductal L-R- shunt. The shunting of blood through the open oval LR window will increase the right ventricular ejection (RVC), which will lead to an overestimation of the systemic venous return, since RVC = SC + interatrial LP shunt [21,25].

Factors contributing to a decrease in systemic blood flow. In premature newborns, one of the factors in reducing systemic blood flow is the rapid clamping of the umbilical cord at birth. This contributes to a decrease in venous return, a decrease in ventricular preload and a decrease in CO [10,53].

Extracardiac factors can also cause hemodynamic disturbances. Increased intrathoracic pressure due to high mean airway pressure during mechanical ventilation (ALV), tension pneumothorax, or pericardial tamponade can also interfere with venous return. Also, cardiac myopathies with the formation of a small ventricular cavity, for example, in newborns with hypertrophic cardiomyopathy from mothers with diabetes mellitus, may have diastolic dysfunction and decreased cardiac filling [11].

Cardiac output of the left ventricle of the heart (CO) in newborns, in contrast to older children, under the conditions of functioning of fetal communications, is mostly pulmonary blood flow minus left-right shunt through the foramen ovale and/or PDA. Normally, CO values in term infants (236 ± 47 ml/kg/min) correlate with those in preterm infants without fetal shunts (221 ± 56 ml/kg/min). At the same time, in preterm infants with significant ductus arteriosus, left ventricular CO does not reflect systemic blood flow, just as normal CO values do not necessarily prove adequate systemic blood flow. These are different concepts, especially in newborns with fetal shunts, such as open ductus arteriosus, in which cardiac output will change systemic blood flow, as blood ejected from the left ventricle returns to the pulmonary circulation and then to the left ventricle. In such a situation, CO of the right ventricle is used to assess systemic blood flow [11,72].

The right ventricular CO is the volume of blood ejected from the right ventricle per minute. The amount of blood flow is estimated at the level of the bifurcation of the pulmonary artery. Normally, the data correspond to the indicators of the CO of the left ventricle. However, with significant shunting of blood through the foramen ovale, the RVF will also not characterize the systemic blood flow. In this case, in order to indirectly assess systemic blood flow, venous return of blood to the heart is assessed by measuring blood flow in the superior vena cava (CVVC) performed using echocardiography [14,31,59].

Cardiac ultrasound in neonatology provides information about the presence of fetal shunts that cannot be assessed by other methods. Awareness of the presence of such shunts is essential for the correct interpretation of the obtained values of cardiac output [17,47,70,71,75].

Functional echocardiography is the most rational method that can provide not only an objective assessment of cardiac function and cardiac output, identify a hemodynamically significant patent ductus arteriosus, but also allow a reliable assessment of systemic blood flow, the value of which is determined by CO [15,18,55,78]. Due to its non-invasiveness, echocardiography in neonatology is a rational and safe diagnostic method.

The use of echocardiographic diagnostics in a newborn with an extremely low and very low MTR should not be postponed and should preferably be performed on the first day of a child's life, while focusing on four main parameters: cardiac contractility, systemic blood flow, shunting through the ductus arteriosus, and excluding persistent pulmonary hypertension [13,22,27,49,70]. Currently, the problem is that echocardiography may not always be available, depending on the capabilities of the center where the patient is located, and almost always the study can only be carried out by ultrasound diagnostics specialists or cardiologists, but not by neonatologists, which sometimes causes a delay in heart diagnosis and becomes an obstacle for the early diagnosis of hemodynamic disorders.

Blood flow in the superior vena cava. Management of hypotensive neonates based on superior vena cava (SVC) flow data is currently widely discussed, since intracardiac shunting does not need to be considered. SVC blood flow correlates with left ventricular CO values and represents the volume of blood passing through the superior vena cava at the level of its confluence with the right atrium, 70-80% of which is the blood flow in the brain. The blood flow in the superior vena cava increases in the first 48 hours after birth, ranging from 70 ml/kg/min at 5 hours of age to 90 ml/kg/min at 48 hours of age. Given the data on a significant increase in the first 48 hours, the normal values of CVV are 40-120 ml / kg / min [11,31]. A recent study in Italy demonstrates SVC blood flow values ranging from 83-153 ml/kg/min in the first 48 hours in infants less than 31 weeks' gestation [60]. Studies show that impaired blood flow in the SVC is correlated with an increase in mortality and disorders of neuropsychic development in children aged 3 years [7,14,36,63]. Some studies suggest the flow in the superior vena cava as a marker of systemic and cerebral perfusion, realizing the possible errors in the accuracy of measurements, searches are also being made for various methods for studying the flow [28,50].

Early clinical studies have shown that low SVC flow, especially if it lasts for a long time, was associated with the risk of intraventricular hemorrhage, morbidity, mortality, and worse neurodevelopmental outcomes. Studies have also shown that low SVC blood flow is a stronger indicator of poor outcome than blood pressure [45,78]. The most

commonly defined low blood flow is <41 ml/kg/min, based on the lowest value found in 25 stable preterm infants at 24 hours of age [6,40,41].

There are limited data on the treatment of low superior vena cava blood flow and low cardiac output in neonates. In a randomized study by *Osborn D.A.* 42 preterm infants with low superior vena cava flow were studied. In preterm infants with low systemic blood flow (measured by SVC blood flow) on the first day of life, dobutamine at a dose of 10–20 mcg/kg/min is more effective than dopamine at the same doses. However, 40% of infants failed to increase or maintain superior vena cava blood flow in response to any inotrope, and no significant difference in mortality or morbidity was found [52,56,57].

There are also isolated data on the presence of a relationship and correlation of flow in the SVC and other echocardiographic indicators, which requires further research [8,35,68].

The discussion of the results.

Thus, the use of indicators of blood flow in the superior vena cava can help develop evidence-based clinical approaches to the diagnosis and treatment of organ hypoperfusion in preterm infants with functioning fetal communications.

Arterial pressure, determined by cardiac output and systemic vascular resistance, may be normal in the shock compensation phase. However, with insufficient redistribution of blood flow, blood supply and oxygenation of vital organs are disturbed, as a result of which multiple organ failure develops. And only in the phase of uncompensated shock can systemic arterial hypotension be observed [71]. The boundaries of normative blood pressure values for newborns of different gestational ages have not yet been determined, therefore, when assessing the state of the cardiovascular system, one must be extremely careful, taking into account all possible diagnostic and clinical parameters.

As is known, all over the world there are difficulties in early diagnosis and detection of hemodynamic disorders in newborns, especially in premature infants, there are no unified therapeutic approaches in the treatment of hemodynamic disorders, arterial hypotension in newborns, including the appointment of a volume load, the use of corticosteroids in relative adrenal insufficiency in premature newborns. Despite the widespread practice of treating arterial hypotension with volume loading in preterm infants in the first hours after birth, there are more and more doubts about the appropriateness of this approach in relation to children with functioning fetal communications (ductus arteriosus and foramen ovale). Currently, clear indications and contraindications for volume loading, taking into account the gestational age of the child or the specific clinical situation, are still not clearly defined [27,56,59,80].

Summing up, it should be said that complex monitoring and control of hemodynamic parameters with the correct and competent interpretation of the data obtained with a mandatory individual approach to a newborn child has a crucial role in reducing the incidence of various complications and reducing the percentage of deaths in neonatology [37].

The above aspects justify the importance of further research aimed at early assessment and detection of hemodynamic disorders in preterm infants based on blood flow data in the superior vena cava, which can help the selection of therapeutic approaches in the treatment of arterial hypotension in neonatology, taking into account an individual approach to each infant. Such an orientation of the study can undoubtedly help improve the quality of diagnosing hemodynamic disorders, improve the effectiveness of targeted treatment, reduce the percentage of complications and the cost of using expensive drugs.

Thus, functional echocardiography is a non-invasive method, using which one can obtain indicators of a wide range of hemodynamic parameters, and the research method can also play an important role in determining the tactics of patient management. Mastering this method by specialized specialists - neonatologists will improve the quality of diagnosis and treatment of newborn babies in intensive care units, will contribute to the timely and early diagnosis of hemodynamic disorders. It should also be borne in mind that the main task of any monitoring is the analysis of each indicator in dynamics in the process of monitoring the patient and conducting intensive care.

The flow in the superior vena cava is one of the valuable parameters for informing clinicians about perfusion and cerebral blood flow. The association of significantly and persistently low blood flow with increased risk of morbidity, mortality, and dynamic measurement of superior vena cava flow beginning early after birth may help detect risk in these infants. The diagnostic accuracy of SVC flow for predicting poor perfusion will improve with the addition of other clinical parameters such as blood pressure and other measurement methods for comprehensive hemodynamic monitoring. SVC flow and cardiac output are considered key in neonatal shock and can be used for targeted treatment. SVC flow is a monitoring method for assessing heart-lung interactions, ductus arteriosus shunt volume, and diagnosing autonomic dysfunction in hypoxic-ischemic encephalopathy [9,35,68].

The main limitation of measuring SVC flow and cardiac output is that they are not a true measure of myocardial function. Blood flow is the interaction between the heart and blood vessels. The ventricular arterial junction is an excellent parameter of cardiovascular efficiency and pathways to heart failure, but it provides limited insight into intrinsic myocardial function. The addition of an additional assessment of preload parameters, ejection fraction, and measurements of ventricular shape and size are needed to better understand myocardial function and dysfunction.

Conclusions

In order to progress in knowledge of hemodynamic features in newborns, we must improve the available diagnostic methods, find and develop new methods that are possible in neonatology for rational and safe control of hemodynamics, and also use various parameters in practice, such as SVC blood flow, recognizing its limitations and expand our capabilities more and more [49,74].

The study of new methods to improve the diagnosis of the state of the cardiovascular system in premature newborns will help to timely identify infants at risk of impaired perfusion in the perinatal period, will also have a significant impact on the choice of rational therapy, and, accordingly, improve the quality of life and health of such patients in subsequent years of life.

Contribution of the authors: *All authors equally participated in the search, analysis of literary sources and writing sections of the article.*

Conflicts of Interest: *The authors declare no conflicts of interest.*

Funding: *No funding provided by third parties.*

Publication Information: *This material has not been published elsewhere and is not under review by other publishers.*

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