ECHOCARDIOGRAPHIC ASSESSMENT OF SUPERIOR VENA CAVA FLOW IN TERM AND PRETERM NEONATES

By

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ABSTRACT

Background*: Despite significant advances in our ability to monitor complex and clinically relevant hemodynamic parameters, in most neonatal intensive care units (NICUs), cardiovascular function is assessed only by continuous heart rate, invasive blood pressure monitoring, and poorly validated clinical signs such as capillary refill time. Indirect measures for assessment of tissue perfusion, including urine output and serum lactate levels, are especially problematic with the very early preterm neonate in the first postnatal days when complex hemodynamic changes occur during the transition to postnatal life. Functional echocardiography can provide a direct assessment of hemodynamics on bedside, and may be considered as an extension of the clinical examination to evaluate cardiovascular wellbeing in the critically-ill infant.*

Objectives*: The study is designed to assess the superior vena cava flow in normal term, preterm and low birth weight.*

Patients and Methods: *This is a case control study of 50 patient were selected and divided into three groups: full term, preterm and low birth weight. In each patient we measured SVC maximum, minimum, mean dimension from parasternal view while velocity time integral measured from subcostal view and calculate SVC flow from the formula.*

Results: *We found that significant decrease in SVC max, SVC min, SVC mean and SVC flow of preterm and low birth weight groups, compared to control group. While VTI was significant decrease in preterm group, compared to control group, but low birth weight was show non-significant decrease, compared to control group. And a significant decrease in gestational age, Apgar score, weight and length of preterm and low birth weight groups, compared to control group. But there was non-significant difference in heart rate, respiratory rate and capillary refill time in both preterm and low birth weight groups, compared to control group. Systolic and diastolic blood pressure show significant decrease in the mentioned groups, compared to control group.*

Conclusion: *Measurement of SVC flow is important for assessment of hemodynamic status in full term, preterm and low birth weight neonates.*

Key Words: *Superior vena cava, Echocardiography, Preterm.*

INTRODUCTION

The role of functional echocardiography in neonatal intensive care unit is rapidly evolving, and increasingly neonatologists are using it in making clinical decisions in sick infants. Functional echocardiography can provide a direct assessment of hemodynamics on bedside, and may be considered as an extension of the clinical examination to evaluate cardiovascular wellbeing in the critically-ill infant **(Singh et al., 2005)**.

The increasing knowledge of neonatal hemodynamics and the resultant increased understanding concerning the changing physiology of the neonate's cardiovascular system has been driven primarily by neonatologists. Despite significant advances in our ability to monitor complex and clinically relevant hemodynamic parameters, in most neonatal intensive care units (NICUs), cardiovascular function is assessed only by continuous heart rate, invasive blood pressure monitoring, and poorly validated clinical signs such as capillary refill time. Indirect measures for assessment of tissue perfusion, including urine output and serum lactate levels, are especially problematic with the very early preterm neonate in the first postnatal days when complex hemodynamic changes occur during the transition to postnatal life **(Kluckow et al., 2008)**.

A bedside point-of-care echocardiography can provide real-time hemodynamic information by assessing cardiac function, loading conditions (preload and afterload) and cardiac output. The echocardiography has the ability to provide longitudinal functional assessment in real time, which makes it an ideal tool for monitoring hemodynamic assessment in neonates and children **(Singh et al., 2005)**.

Superior vena cava (SVC) flow measurement has been proposed as a better marker of systemic blood flow from upper body and brain as it is not contaminated in presence of shunts **(Kluckow et al., 2000)**.

The superior vena cava (SVC) is formed by the joining of the brachiocephalic veins, and the majority of blood within the SVC represents return flow from the brain; hence, it has been hypothesized that flow within the SVC is a good surrogate marker of cerebral perfusion. FE of SVC flow is unaffected by shunting and has emerged as a useful marker of central perfusion with low SVC flow being linked to a number of adverse outcomes in both the short

and longer term **(McGovern and Miletin, 2016)**.

The presence of the patent foramen oval and patent ductus arteriosus (PDA), respectively, make measurements of right and left ventricular output inaccurate in the preterm neonate **(McGovern and Miletin, 2016)**.

Low SVC flow has been reported to be associated with an increased incidence of intraventricular hemorrhage and impaired neurodevelopmental outcome **(Osborn et al., 2003)**.

AIM OF THE WORK

The study is designed to assess the superior vena cava flow in normal term, preterm and low birth weight.

Ethical consideration:

1- Approval from the ethical committees of both pediatric department and Faculty of Medicine Al-Azhar University.

2- Written consent for the study was obtained from the parents of these neonates participating in this study.

3- The data of the patients and the results of the study are confidential and the patients have the right to keep them.

4- The authors received no financial support for the study or the publication.

5- The patients have the right to withdraw from the study at any time.

6- The authors declared that there is no conflict of interest regarding the study and publication.

PATIENT AND METHODS

This is a case control study of 50 patients were selected from Al-Azhar University Hospitals and El-Gala Teaching Hospital. The work was done in the period from September 2018 to march 2019.

All neonates were divided into three groups:

- The first group consists of 20 full term neonates born after 37 weeks gestation who were apparently normal.
- The second group consists of 15 preterm neonates born before 36 weeks gestation assisted by Ballard Score **(Ballard et al., 1979)** who were apparently normal.
- The third group consists of 15 low birth weight neonates were defined as weight less than 2.500 Kg **(Paneth, 1995)** and who were apparently normal.

Inclusion criteria:

All neonates apparently normal in 1st week of life.

Excluded criteria:

1- Neonates with congenital heart diseases with exclusion of patent foramen oval and patent ductus arteriosus.

2- Neonates with central line.

All the studied cases will be subjected to the following:

1- Thorough history talking: Stressing on: good Cry, good suckling, tachypnea, vomiting, diarrhea, blood loss.

2- Thorough clinical examinations: Stressing on vital data, blood pressure, anthropometric measures, signs of respiratory distress, capillary refill time, assess gestational age, Apgar score, peripheral pulsation.

3- Chest and heart x-ray: Commenting on cardio-thoracic ratio and lung vascularity.

4- Transthoracic Echocardiography (TTE):

The infants were placed in a supine position on a flat surface and were studied when resting quietly or asleep. The heart was imaged by GE VIVID E device with 5 – 7 MHz transducer.

We examined the heart from different views subcostal, apical, parasternal and suprasternal and by different echocardiographic modes, M mode, 2 dimensional, pulsed and color flow mapping.

First we excluded any congenital heart diseases. Patent foramen oval with left to right shunt was accepted in study. It was best seen in subcostal view.

Hemodynamically in-significant patent ductus arteriosus not associated with left atrium and left ventricle dilatation was accepted. Patent ductus arteriosus was best seen in modified short-axis view (ductal view).

Then we examined SVC from subcostal view, SVC flow was identified by angling the beam anteriorly until the flow into the right atrium from the SVC was seen using color Doppler. We did our best to allow visualization of the maximal amount of flow within the SVC before entry into the right atrium. It is important to place the transducer head as close as possible to the umbilicus. The pulsed Doppler recording was made at the junction of the SVC and the right atrium. The Doppler range gate was manipulated in the SVC until the clearest ultrasound velocity spectral displays were obtained and a representative sample of 20–30 cardiac cycles was recorded on to videotape. The SVC flow pattern was pulsatile with two peaks the first associated with ventricular systole (the S

wave) and the other with early ventricular diastole (the D wave). In addition, frequently there were short periods of reverse flow (the A wave), associated with atrial systole.

SVC flow velocity time integral (VTI) was assessed using pulsed wave Doppler from a low subcostal view. Maximum and minimum SVC diameters were measured and the mean was calculated.

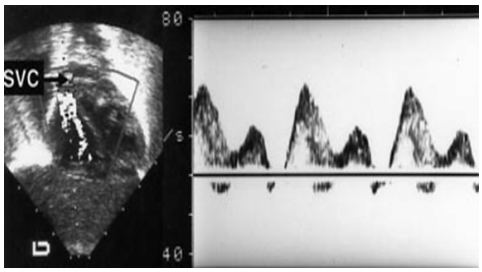

Figure (1): The Doppler range gate positioned at the junction of the superior vena cava (SVC) and right atrium. An example of the spectral display obtained is shown, with the S, D and A wave **(Kluckow and Evans, 1999)**.

SVC diameter was assessed from a high parasternal long axis view, rotated towards the true sagittal plane. The transducer head was placed as close to the midline as possible to acquire directly anteroposterior views of the SVC. Maximum and minimum SVC diameters were assessed for each cardiac cycle, and the mean of these used to quantify volume of flow.

The SVC flow was calculated using the following formula: SVC flow = (velocity time integral × (π × (mean SVC diameter2/4) × heart rate)/body weight **(Kluckow and Evans, 1999)**.

RESULTS

Table (1): Demographic data of neonates of different groups

Parameters \ Groups		Control n = 20	Preterm n = 15	Low birth weight n = 15
Sex	Male	14	6	9
	Female	6	9	6
	Total	20	15	15
Age (Days)	Mean±SD	3.60±1.96	3.07±2.15	2.13±1.41
	Range	(1-7)	(1-7)	(1-6)
Gestational age (Weeks)	Mean±SD	39.35±0.75	34.87±0.52*	37.93±1.10*
	Range	(38-40)	(34-36)	(36-39)
	P-value	--	< 0.0001	< 0.0001
Apgar score	Mean±SD	7.11±0.81	5.56±0.98*	5.99±1.03*
	Range	(4.80-8.11)	(4.80-7.90)	(4.80-7.90)
	P-value	--	< 0.0001	< 0.001
Weight (kg)	Mean±SD	3.46±0.31	2.59±0.47*	2.34±0.18*
	Range	(2.80-4.00)	(1.60-3.15)	(2.00-2.50)
	P-value	--	< 0.0001	< 0.0001
Length (cm)	Mean±SD	50.30±0.73	49±1.07*	48.73±0.59*
	Range	(49-52)	(47-51)	(48-50)
	P-value	--	< 0.0001	< 0.0001

*: Significance VS control group

Table (1) shows significant decrease in gestational age, Apgar score, weight and length of preterm and low birth weight groups, compared to control group.

Table (2): Clinical data of neonates of different groups

Parameters \ Groups	Control n = 20	Preterm n = 15	Low birth weight n = 15

Heart rate (Beat/min)	Mean±SD Range P-value	131.10±15.13 (110-160) --	134.60±7.13 (122-146) NS	138.13±8.75 (130-160) NS
Respiratory rate (cycle/min)	Mean±SD Range P-value	35.80±3.56 (27-43) --	35.80±3.93 (28-43) NS	35±3.34 (29-40) NS
Systolic blood pressure (mmHg)	Mean±SD Range P-value	72.75±3.34 (67-78) --	67.27±3.15* (62-75) 0.0001	68.07±5.30* (61-77) 0.001
Diastolic blood pressure (mmHg)	Mean±SD Range P-value	43.60±6.92 (35-59) --	37.27±3.17* (32-43) 0.001	39.07±4.13* (32-45) 0.01
Capillary refilling time (sec)	Mean±SD Range P-value	1±0.00 (1) --	1.13±0.35 (1-2) NS	1.20±0.41 (1-2) NS

*: Significance VS control group

Data in table (2) illustrate non-significant deference in heart rate, respiratory rate and capillary refill time in both preterm and low birth weight groups, compared to control group. While systolic and diastolic blood pressure show significant decrease in the mentioned groups, compared to control group.

Table (3): The percentage of patent ductus arteriosus in different groups

Group	Total cases n = 50	Full term n = 20	Preterm n = 15	Low birth weight n = 15
Percent	8%	5 %	13%	7%

Table (4): Percentage of patent foramen oval in different groups

Group	Total cases n = 50	Full term n = 20	Preterm n = 15	Low birth weigh n = 15
Percent	16%	20%	20%	7%

Table (3): SVC dimensions and flow of neonates of different groups

Groups / Parameters	Control n = 20	Preterm n = 15	Low birth weight

				n = 15
SVC max (mm)	Mean±SD	6.65±1.14	5.07±1.33*	4.80±0.77*
	Range	(5-8)	(4-8)	(4-7)
	P-value	--	< 0.0001	< 0.0001
SVC min (mm)	Mean±SD	3.55±0.69	2.93±0.96*	2.53±0.64*
	Range	(2-5)	(2-5)	(2-4)
	P-value	--	< 0.01	< 0.0001
SVC mean (mm)	Mean±SD	5.10±0.85	4.00±1.10*	3.67±0.67*
	Range	(4-6.5)	(3-6.5)	(3-5.5)
	P-value	--	< 0.0001	< 0.0001
SVC mean square (mm2)	Mean±SD	26.70±8.76	17.33±10.10*	13.87±5.49*
	Range	(16.00-42.25)	(9-42.25)	(9-30.25)
	P-value	--	< 0.001	< 0.0001
SVC flow (ml/kg/min)	Mean±SD	167.56±47.52	111.23±56.45*	115.13±47.12*
	Range	(103-236.41)	(49.45-190.66)	(54.06-185.15)
	P-value	--	< 0.001	< 0.001
VTI (mm/s)	Mean±SD	0.219±0.04	0.157±0.03*	0.187±0.08
	Range	(0.16-0.33)	(0.12-0.24)	(0.11-0.34)
	P-value	--	< 0.001	NS

SVC: superior vena cava, max: maximum, min: minimum, VTI: velocity time integral.
*: Significance VS control group

Table (3) shows significant decrease in SVC max, SVC min, SVC mean and SVC flow of preterm and low birth weight groups, compared to control group. While VTI illustrate significant decrease in preterm group, compared to control group, but low birth weight was show non-significant decrease, compared to control group.

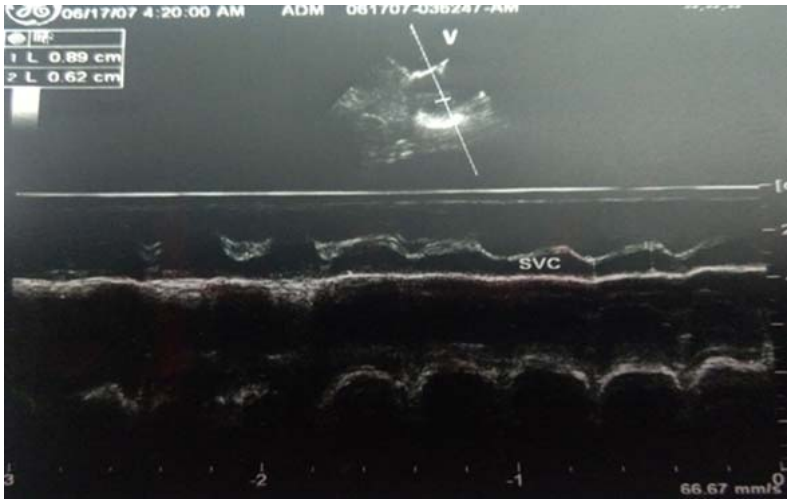

Figure (2): Showing M mode echocardiography of measuring SVC diameter in healthy preterm neonate.

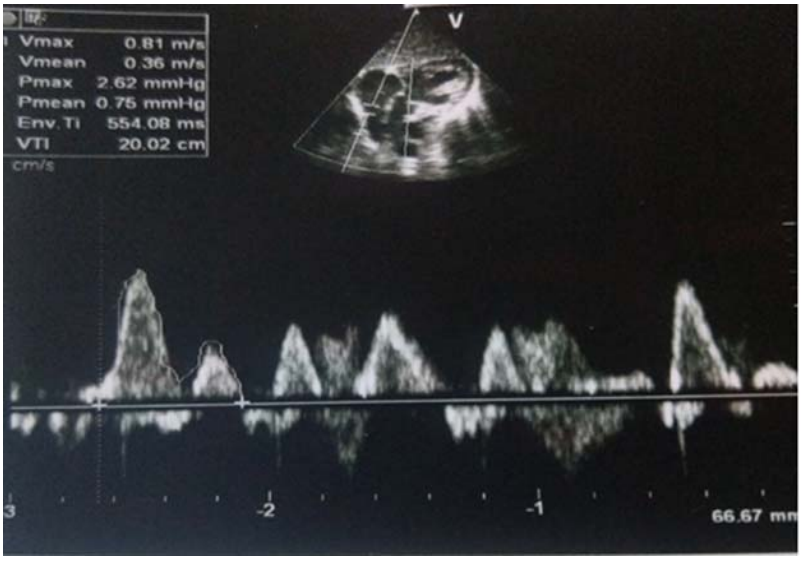

Figure (3): Pulsed Doppler of SVC flow from normal healthy neonate showing D wave, S wave and A wave.

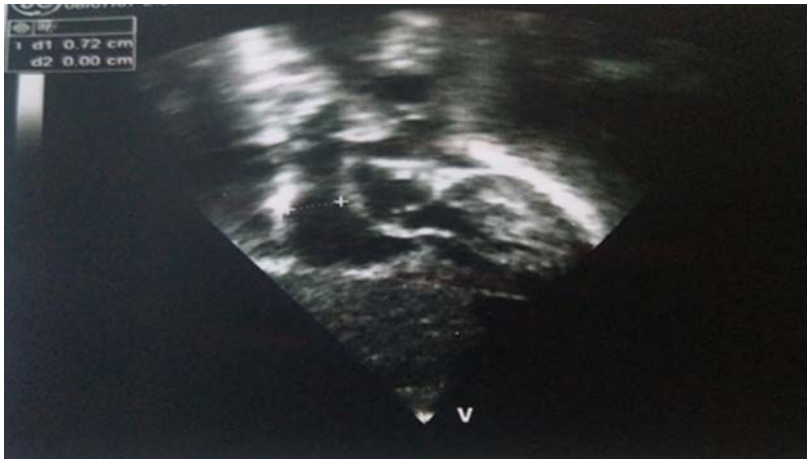

Figure (4): showing two dimensional echocardiography subcostal view, right atrium and superior vena cava in normal health neonate.

DISCUSSION

Assessment of circulatory status is an integral component of care in the neonatal unit. Episodes of low systemic perfusion are associated with adverse outcomes in preterm and term infants **(Groves et al., 2007)**.

Since the late 90s, there has been growing awareness among clinicians that blood pressure (BP) does not equal blood flow. Left ventricular output (LVO) is an established non-invasive measure of systemic circulation. By means of the Doppler ultrasound technique, this is an easy and reliable bedside method which is applied in intensive care units worldwide. However, in newborn babies the fetal shunts, the patent foremen oval (PFO) and the patent ductus arteriosus (PDA) do not close immediately after birth. Because of the persistence of fetal shunts, LVO cannot be used as a measure of systemic output in the newborn infant. It has been shown that shunting across the PDA may overestimate LVO by 100% **(Lee, 2014)**.

SVC flow in premature and term infants can be measured by Doppler echocardiography. The superior vena cava is formed by the confluence of the left and right brachiocephalic veins, which drain blood from the arms, head and brain. Approximately 80% of this blood is estimated to be returning from the brain in infants. Therefore, the measurement of SVC blood flow is potentially a marker of cerebral blood flow that can be performed rapidly and non-

invasively by the bedside of sick infants **(Kluckow and Evans, 1999)**.

In our study we found that SVC flow was significantly decreasing in preterm and low birth weight groups in comparison with full term group. This in agree with **(Hunt et al., 2004)** who found that low superior vena cava flow is common in the first hours after preterm birth. They said that it has a strong association with subsequent periventricular / intraventricular hemorrhage.

As regard SVC flow our study show in full term, preterm and low birth weight they were 159.71, 130.03 and 128.84 ml/kg/min respectively and this in agree with **(Kluckow and Evans, 1999)**, who found that SVC flow were in full term 93ml/kg/min and preterm 86 ml/kg/min. Also they found that in full term the median SVC flow rose from 76 ml/kg/min at 17 hours to 93 ml/kg/min at 42 hours of life and in preterm the SVC flow also increased over the first 48 hours in the 25 uncomplicated preterm babies. Median SVC flow rose from 62 ml/kg/min at 5 hours to 86 ml/kg/min at 48 hours.

Despite of our results were relatively high and wide range of flow seen in three groups, this in agree with **(Groves et al., 2007)** who stated that wide range of flow volumes (40–193 ml/kg/min) means that quantification of SVC flow volume may be a relatively sensitive technique for detecting haemodynamic change in the clinical setting. Most of papers there measurements taken at the first 48 hrs of life but in our study was our measurements were within the 1st week of life.

(Kluckow and Evans, 1999) have used a subgroup of uncomplicated preterm infants (born less than 30 weeks' gestation) enrolled in a larger study to define a normal range for SVC flow in the very preterm infant. These 25 infants were receiving no, or minimal, respiratory support. In this group, they found that an increase in the SVC flow occurred throughout the first 48 hours, possibly as a result of the improvement in myocardial function that occurs as the heart adapts to extrauterine life.

Our study showed that the least normal SVC flow were 103, 49.45 and 54.06 ml/kg/min for term, preterm and low birth weight respectively. This in agree with that reported by **(Groves et al., 2007)** who found that SVC flow volumes below 55 ml/kg/min in the first 48 h of postnatal life in preterm infants may represent low or borderline systemic perfusion. Also **(Miletin and Dempsey,**

2008) said that in very low birth weight low SVC flow on day 1 was defined as flow less than 40 ml/kg/min.

In this study we found that the minimum SVC was in full term, preterm and low birth weight were 3.5, 3.2 and 2.67 mm respectively and the maximum were 6.4, 5.4 and 4.93 mm respectively.

CONCLUSION

Measurement of SVC flow is important for assessment of hemodynamic status in full term, preterm and low birth weight neonates. This technique can assess blood flow from the upper body, including the brain, in the crucial early postnatal period, and might allow more accurate assessment of the status of systemic blood flow and response to treatment.

Limitation of the Study

1. Need to increase number of cases.
2. Because of rapid circulatory changes in early life daily measurements may give better results.
3. We need to compare normal neonates with cases with hypoxic ischemic encephalopathy.

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تقييم تدفق الوريد الأجوف العلوي في الأطفال حديثي الولادةو الخدج بواسطة تخطيط صدى القلب

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يعتبر تقييم الأطفال حديثي الولادة و بخاصة الحالات الحرجة و حالة الدورة الدموية بهم ذات أهمية قصوي و يعتمد تقييم الدورة الدموية في هؤلاء الأطفال علي المعايير الاكلينيكية مثل قياس الضغط و النبض و التنفس و زمن عود امتلاء الشعيرات الدموية (capillary refill time) و لكن هذة المعايير تحتاج إلى الكثير من الدقة.

و لقد ظهر في الفترة السابقة استخدام الموجات فوق الصوتية لتقييم وظائف القلب و الدورة الدموية و قد تم الاستفادة منها كثيرا في الأطفال و الكبار و لكن في الأطفال حديثي الولادة كان يصعب عليهم تطبيقها نظرا لوجود الوصلة الشريانية مفتوحة (PDA) و كذلك عيب الحاجز الأذيني (PFO)في هذا السن مما يؤدي الي ازدياد غير سليم في حساب نتاج القلب.(cardiac output)

و لكن حساب سريان الدم عبر الوريد الاجواف العلوي (superior vena cava flow) لا يتأثر بوجود الوصلة الشريانية المفتوحة او عيب الحاجز الأذيني. كما انه يمتاز بأنه يعطي فكرة مهمة عن سريان الدم في المخ مما يتيح التنبؤ

بحدوث اعتلال المخ الناتج عن نقص الأكسجين (hypoxic ischemic encephalopathy) .

و قد اجريت هذه الرسالة علي 50 طفل حديثي الولادة بوحدات حديثي الولادة بمستشفيات جامعة الأزهر و مستشفي الجلاء التعليمي في الفترة من سبتمبر 2018 الي ابريل 2019.

و تهدف هذه الرسالة لتقييم سريان الدم في الوريد الأجوف العلوي في حديثي الولادة الطبيعيين و الخدج و ناقصي النمو في الاسبوع الاول من العمر من الجنسين.

و تم استبعاد أي حالات بها عيوب خلقية في القلب او الجسم او صعوبة في التنفس او حديثي ولادة بهم كانيولا مركزية.

و يستثني من ذلك حالات الوصلة الشريانية المفتوحة و عيب الحاجز الاذيني غير المصحوبة بأي زيادة في حجم القلب.

و قد تم تقسيم الاطفال الي ثلاث مجموعات: الاول عدد 20 طفل من حديثي الولادة الطبيعيين، الثاني عدد 15 طفل من حديثي الولادة الخدج، و الثالث 15 طفل من حديثي الولادة ناقصي النمو.

و قد ظهر في هذه الحالات زيادة ذات دلالة احصائية في حالات كاملي النمو عنها في حالات الخدج و ناقصي الوزن

بخصوص سريان الدم بالوريد الاجواف العلوي و كذلك مقياس الوريد الاجواف العلوي.

كذلك هناك ارتباط ايجابي بين سريان الدم بالوريد الاجواف العلوي و مقياس الضغط.

و قد وجد اقل كمية لسريان الدم بالوريد الاجواف العلوي هي 104 مل/كجم في الدقيقة في حديثي الولادة كاملي النمو، و 49 مل/كجم في الدقيقة في حديثي الولادة الخدج، و 52.4 مل/كجم في الدقيقة في حديثي الولادة ناقصي الوزن.

و كذلك وجد ان نسبة عيب الحاجز الاذيني 20% في حديثي الولادة كاملي النمو، و 20% في حديثي الولادة الخدج، و 7% في حديثي الولادة ناقص الوزن، اي انها بنسبة 16% في الحالات كلها.

و كذلك وجد انه نسبة الوصلة الشريانية المفتوحة هي 5% في حديثي الولادة كاملي النمو، و 13% في حديثي الولادة الخدج، و 7% في حديثي الولادة ناقصي الوزن.

نستخلص من هذه الدراسة ان سريان الدم في الوريد الاجواف العلوي يختلف بين كاملي النمو و الخدج و انه يساعد في متابعة وظائف القلب و الدورة الدموية و انه لا يتأثر بوجود الوصلة الشريانية المفتوحة او عيب الحاجز الاذيني.

كما نوصي باستخدام سريان الدم في الوريد الاجواف العلوي في حديثي الولادة لتوقع حدوث اي مضاعفات.