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Normal superior vena cava flow and its correlation with left ventricular output in late preterm and term neonates at day one of life

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ABSTRACT

Background: Assessment of systemic blood flow helps in choosing the appropriate drug for managing critically ill neonates with poor perfusion. Superior vena cava (SVC) flow has the potential to become a bedside gold standard method for this purpose. **Aims and Objectives:** To find out normal superior vena cava (SVC) flow and its correlation with left ventricular output (LVOT) in late preterm and term neonates. **Materials and Methods:** A cross sectional observational study was carried out at a tertiary care teaching hospital where SVC flow and left ventricular output were measured in hundred intramural healthy neonates (50 late pre-term, weighing 1500g or more and 50 term, weighing 2500g or more). SVC flow was correlated with LV output in both groups. Pearson correlation coefficient was calculated to correlate between two variables. $p < 0.05$ was considered significant. **Results:** Median SVC flow in late pre-term group was 57.83ml/kg/min, and in term neonates was 56ml/kg/min. In late pre-term babies correlation of SVC flow with LV output was better in comparison to term group (r-0.56, $p<0.0001$, and r-0.40, $p=0.0024$respectively). **Conclusions:** SVC flow better represents systemic blood flow in late preterm neonates in comparison to term neonates.

Key words: SVC flow; systemic perfusion; left ventricular output; newborn

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INTRODUCTION

Assessment of systemic blood flow helps in choosing the appropriate drug for managing critically ill neonates with poor perfusion. Convenient and non-invasive bedside methods like capillary refill time, central and peripheral temperature difference, non-invasive blood pressure, and even invasive methods like intra-arterial blood pressure are not considered reliable markers of perfusion especially in pre-term babies.[1]

Echocardiography based measurement of blood flow is non-invasive and a bedside procedure. Left ventricular output (LVOT) has been reliably used in adults and in older children for assessment of systemic blood flow. However, in neonates both left and right ventricular output tend to overestimate systemic blood flow in the presence of patent ductus arteriosus, and patent foramen ovale respectively. That is why in early days of life especially in pre-term neonates, ventricular output erroneously measures the systemic blood flow.[2,3] Superior vena cava (SVC) flow represents upper body systemic blood flow; around 80% of this blood flow goes to the brain.[4] Moreover, it is not affected by shunts. It has been shown to be a reliable measure of systemic blood flow in neonates in previous studies, but extensive data are lacking. SVC flow has the potential to become the gold standard procedure for measuring systemic blood flow in newborns especially in

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the first few days of life.[5] We planned this study to find out normal SVC flow and its correlation with left ventricular output (LVOT) in late preterm and term neonates.

MATERIALS AND METHODS

A cross-sectional study was carried out at a tertiary care teaching hospital of Western India after approval of Institute's Ethical Committee. One hundred intramural healthy neonates, comprising 50 late pre-term (gestational age 34 to 36 weeks+6 days), weighing 1500g or more and 50 term (gestational age 37 to 41 weeks +6days), weighing 2500g or more, were randomly selected. All those with perinatal complications (like Apgar score less than 7), or having any congenital malformations including congenital heart disease (CHD) or requiring inotropes or respiratory support were excluded. All enrolled neonates, after verbal consent from caregivers for echocardiography, were first screened for presence of any CHD. EPIQ 7C Philip's echocardiography machine, with S-4Hz-12Hz pediatric probe was used, on day one of life by a single trained person, so as to avoid inter-observer error. All measurements were done on 2D and Doppler, freeze images. The neonates were placed supine on a flat surface and studied when neonate was quiet, either awake or asleep. Heart was imaged in apical 4 &5 chamber view, suprasternal long axis and sub-costal view by placing transducer head at apex, suprasternal notch and subcostal region respectively with necessary angulation.

Left ventricular outflow view was obtained in parasternal long axis view and aortic diameter was measured. Aortic velocity time integral was measured in apical five chamber view at the level of aortic annulus, proximal to ascending aorta by 2D color Doppler echocardiography. Mean velocity of blood flow (VTI-velocity time integral) across the aortic valve was calculated from the integral of the Doppler velocity tracings and was averaged from three consecutive cardiac cycles. With these parameters, left ventricular cardiac output was calculated by echo machine software.

The SVC was imaged either from suprasternal or subcostal view, by 2D - mode, and images were frozen and stored. The internal diameter of SVC (at junction of SVC and right atrium) was measured three times from frozen image either in supra or subcostal view and then mean was calculated. Heart rate was calculated from the intervals between two cardiac cycles. Mean velocity of blood flow (VTI) was calculated from the integral of the Doppler velocity tracings and was averaged from 10 consecutive cardiac cycles to allow for variation in flow caused by respiration, and also for any variation within the cardiac cycle.

Blood flow in ml/kg/minute was calculated by machine software from the above measured parameters. The formula used by software was cross sectional area ($\pi \times r^2$) multiplying with VTI and heart rate. Here r stands for half of the diameter of aortic root (in case of LVOT measurement) or SVC (for SVC flow measurement).

SPSS version 22 was used to analyse the data. Quantitative data were presented both as mean and median. Pearson correlation coefficient was calculated to correlate the quantitative variables, and $p<0.05$ was considered significant.

RESULTS

Out of the total 100 neonates enrolled, 59 were male and 41 were female with a sex ratio of 1.43:1. Mean ± SD and median heart rate of the cohort were 129 ± 13.59 and 130 beats per minutes respectively.

Median gestational ages of late preterm and term group were 35 weeks and 39 weeks respectively. Median birth weight of preterm group was 1900gm and for term group it was 3000 gm. Mean SVC diameters were 0.55 ± 0.13 mm and 0.58 ± 0.11mm, and aortic diameters were 0.85 ± 0.15 mm and 0.88±0.14 mm in late preterm and term groups respectively. Median SVC diameters were 0.54 mm and 0.55 mm, and aortic diameters were 0.8 mm and 0.82 mm in late preterm and term groups respectively. Median SVC flow in late pre-term group was 57.83ml/kg/min, and in term neonates it was 56 ml/kg/min. In late preterm group median LVOT was 189.5 ml/kg/min, and in term neonates it was 205 ml/kg/min (Table 1).

Overall SVC flow correlated with LVOT (Pearson r-0.56 and Spearman r-0.40). In late pre-term babies correlation of SVC flow with LVOT was better in comparison to term group (Pearson r-0.56, $p<0.0001$, and Pearson r-0.40, p-0.002 respectively) (Table 2).

Similarly in low birth weight (less than 2.5 kg) babies SVC correlated better with LVOT in comparison to 2.5 kg or more weight group (Pearson r-0.63, p-0.0002, and Pearson r-0.40, p-0.002 respectively). In late preterm newborns mean SVC flow was 30% of mean LVOT on day one of life.

DISCUSSION

In our study SVC flow contributed to 30% of LVOT on day one of life in the preterm group. Previous studies have compared SVC flow with cardiac output, but the results are variable. The findings of Kluckow M et al.,[5] match the results

Table 1: Clinical characteristics and echocardiography derived normal blood flow in late preterm and term neonates

Characteristic	Late preterm			Term		
	Mean ± SD	Range	Median	Mean ± SD	Range	Median
Birth weight (kg)	2.01 ± 0.23	1.5-2.5	1.9	3.10 ± 0.27	≥2.5-3.8	3.00
Gestational age (weeks)	35.77 ± 0.86	34-37	35	39.12 ± 1.01	37-41	39
SVC flow (ml/kg/min)	62.5 ± 20.93	18-143	57.83	58.89 ± 19.11	35-136	56
LVOT (ml/kg/min)	204.88 ± 70.7	115-444	189.5	203.31 ± 61.88	85-348	205

SVC: superior vena cava, LVOT: left ventricular output, SD: standard deviation

Table 2: Correlation between superior vena cava (SVC) flow and left ventricular output (LVOT) on day one of life

Gestational age (weeks)	LVOT (ml/kg/min) Mean ±SD	SVC flow (ml/kg/min) Mean ±SD	r*	P
34 to 37	204.88 ± 70.74	62.5 ± 20.93	0.56	<0.0001
>37	203.31 ± 61.88	58.89 ± 19.11	0.40	0.002

*Pearson correlation coefficient; SD: standard deviation

of our study, SVC flow contributing to 37% of LVOT in the preterm group with closed ductus arteriosus. In a study on healthy adults by Mohiaddin et al.,[6] SVC flow represented 35% of cardiac output. However, in contrast to our study, they used cine magnetic resonance velocity mapping to measure the blood flow. Salim MA et al.,[7] demonstrated the effect of age on the relationship between these two parameters. In their study, SVC flow contributed to 49% of cardiac output in the neonatal age group, and this contribution increased to the highest of 55% at the age two and half years, followed by a slow decline to the adult value of 35% by 6.6 years. We used the mean of SVC diameter to calculate the flow, and compared it with LVOT, whereas Salim MA et al.,[7] used the maximum diameter of SVC flow, and compared it with right ventricular output (pulmonary artery flow).

In our study the mean LVOT was 204.88±70.7 and 203.31±61.88 ml/kg/minute in preterm and term groups respectively (Table 2). In previous studies in term neonates, it has been reported as 222 ml/kg/minute by Groves AM et al.,[8] 231±77 ml/kg/minute by Hudson I, et al.,[9] and 241 ml/kg/minute by Tsai-Goodman B et al.[10]

In the present study SVC flow in term neonates ranged from 35 to136 ml/kg/min with a mean flow of 58.89 ml/kg/min on day one of life. In a study by Moran M et al.,[11] mean SVC flow within 24 hours of life was 70.36±39.5 ml/kg/min in very low birth weight infants. Kluckow M, et al.,[5] in more than 36 weeks gestational age neonates found, median SVC flow to be higher on day two of life in comparison to day one (93 ml/kg/min and 76 ml/kg/min respectively). Mean SVC flow in term small for gestational age (SGA) neonates at day seven of life was even higher (126.28 ±31.23 ml/kg/min) in a study by Banait N et al.[12]

There are only a few studies which have tried to figure out the normal value of SVC flow. As most of these have been done in healthy neonates, it can only suggest a normal range in a healthy group. The exact cut off value to define low SVC flow still needs to be unveiled to have optimum short term and long term outcomes. Moran M, et al.,[11] found good correlation (r = 0.53, p-value 0.005) between SVC flow and cerebral tissue oxygenation in very low birth weight infants on day one of life. Miletin J et al.,[13] found poor correlation of capillary refill time, mean blood pressure and urine output with low SVC flow in very low birth weight infants. In the same study correlation coefficient (r) between SVC flow and serum lactate level was −0.28 (p-0.15). Low SVC flow in very low birth weight infants has been associated with early neonatal death and or severe intra-ventricular haemorrhage.[14] These studies have defined SVC flow less than 40ml/kg/minute as low SVC flow. On the other hand, Groves AM et al.,[8] defined SVC flow less than 55 ml/kg/minute as low SVC flow (less than 5th centile) in a preterm group within the first 48 hours of life.

SVC flow is a new emerging tool for assessment of systemic perfusion in neonates.[15] In the present study mean SVC flow in preterm and term neonates was 62.5 and 58.89 ml/kg/minute respectively on day one. SVC flow in preterm babies contributed to 30% of LVOT on day one of life. As SVC diameter varies with respiration, we took an average of SVC diameter from three freeze images. In comparison to most of the previous studies our sample size is larger. These are the major strengths of our study.

LIMITATIONS OF THE STUDY

Limitations include single measurement and exclusion of preterm neonates of 33 weeks or less gestational age.

CONCLUSION

SVC flow better represents systemic blood flow in late preterm neonates in comparison to term neonates. As the results of normal SVC flow are widely variable in different studies, future research on a more homogeneous group at

different ages with a much large sample size is required to construct a normogram of SVC flow.

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Author's Contribution:
JS-Concept and design of the study; prepared first draft of manuscript; **SV-** Concept, coordination, review of literature and manuscript preparation; **VG-** Interpreted the results, reviewed the literature and manuscript preparation; **MD-** Data collection, coordination, review of literature and manuscript preparation; **SC-** Statistically analysed and interpreted, preparation of manuscript and revision of the manuscript.

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