

12-1-1991

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Sueblinvong, Virojna; Thaithumyanon, Pimolratn; and Sanpavat, Suwimol (1991) "A pulsed Doppler echocardiographic study of post-natal circulatory changes in the normal Thainewborn infant,"

Chulalongkorn Medical Journal: Vol. 35: Iss. 12, Article 3.

DOI: 10.58837/CHULA.CMJ.35.12.3

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A pulsed Doppler echocardiographic study of post-natal circulatory changes in the normal Thai newborn infant.

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Sueblinvong V, Thaithumyanon P, Sanpavat S. A pulsed Doppler echocardiographic study of post-natal circulatory changes in the normal Thai newborn infant. Chula Med J 1991 Dec; 35(12): 795-802

Post-natal circulatory adaptations were studied with serially pulsed Doppler echocardiographic measures of flow velocity in the main pulmonary artery (PA) and ascending aorta (Ao) in 31 normal full-term neonates at 4 ± 2 , 28 ± 2 and 51 ± 2.5 hours after birth.

In the PA, acceleration time (AT), ejection time (ET) and AT/ET ratio increased significantly ($p < 10^{-6}$) while preejection period (PEP) and PEP/ET decreased significantly ($P < 10^{-6}$) at 4 ± 2 , 28 ± 2 and 51 ± 2.5 hours of age. All of these reflect the physiologic fall in PA pressure.

The Ao, AT, ET, PEP, AT/ET and PEP/ET remained insignificantly changed ($p = NS$) at 4 ± 2 , 28 ± 2 and 51 ± 2.5 hours of age. These also suggest insignificant change in the left-sided circulation.

In conclusion, serially pulsed Doppler echocardiographic findings of flow velocity in the PA from the normal-term newborn heart reflected the physiologic fall in PA pressure during early post-natal life while there was no significant change in the left ventricular circulation during the same period.

Key words : Post-natal circulatory changes.

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Received for publication. August 30, 1991.

วิโรจน์ สืบหลินวงศ์, พิมลรัตน์ ไทยธรรมยานนท์, สุวิมล สรรพวัฒน์. ศึกษาการเปลี่ยนแปลงการไหลของเลือดในเด็กทารกเกิดใหม่ที่ปกติด้วยเครื่องอัลตราซาวนด์. จุฬาลงกรณ์เวชสาร 2534 ธันวาคม; 35(12) : 795-802

ได้ศึกษาเด็กเกิดใหม่ที่ปกติ 31 ราย (ชาย 16 ราย หญิง 15 ราย) อายุเฉลี่ย 4,28 และ 51 ชั่วโมง ในหน่วยทารกแรกเกิด แผนกกุมารเวชศาสตร์ โรงพยาบาลจุฬาลงกรณ์ โดยการวัดการไหลเวียนของโลหิตในหัวใจด้านขวาเปรียบเทียบกับหัวใจด้านซ้ายในด้าน

1. ระยะเวลา ก่อนแวนทรีเคิลฉีกเลือกออก

2. อัตราเร่ง และ

3. เวลาระหว่างแวนทรีเคิลฉีกเลือก โดยใช้เครื่องอัลตราซาวนด์วัดขณะที่เด็กนอนเงียบ ๆ

ผล : 1. เวลาที่แวนทรีเคิลใช้ในการเตรียมตัวก่อนที่จะส่งเลือดจากหัวใจด้านขวาส่งลงเมื่อเด็กอายุมากขึ้น ส่วนค่าของแวนทรีเคิลซ้ายไม่เปลี่ยนแปลง

2. อัตราการเร่งในการส่งเลือดจากหัวใจด้านขวามากขึ้น เมื่อเด็กอายุมากขึ้น ส่วนจากหัวใจด้านซ้ายไม่เปลี่ยนแปลง

3. เวลาที่ใช้ในการปล่อยเลือดจากหัวใจด้านขวามากขึ้น เมื่อเด็กอายุมากขึ้น ส่วนจากหัวใจด้านซ้ายปกติ

4. อัตราส่วนระหว่างเวลาก่อนที่จะใช้ส่งเลือดต่อเวลาที่ใช้ในการฉีกเลือกส่งลงที่แวนทรีเคิล ด้านขวาเมื่อเด็กอายุมากขึ้น แต่หัวใจด้านซ้ายคงเดิม

5. อัตราเร่งต่อเวลาฉีกเลือกจากหัวใจด้านขวายาวขึ้นเมื่อเด็กอายุมากขึ้นส่วนหัวใจด้านซ้ายเหมือนเดิม

สรุป : เมื่อเด็กเกิดใหม่มีอายุมากขึ้น ความดันในปอดจะลดลง และส่งผลให้มีการเปลี่ยนแปลงของเลือดที่ฉีดออกจากหัวใจด้านขวา ส่วนในหัวใจด้านซ้ายพบการเปลี่ยนแปลงน้อยมาก ซึ่งพิสูจน์ได้จากการวัดระยะเวลาของเลือดก่อนที่จะถูกส่งออกไป อัตราการเร่งและระยะเวลาขณะเลือดที่ถูกฉีกเลือกไป

The course of the neonatal circulation in the normal-term infant had been associated with profound changes, especially by a marked decrease in pulmonary artery pressure and pulmonary vascular resistance.^(1,2) Pulsed Doppler echocardiography has been documented as an instrument to measure flow velocity in the main pulmonary artery and ascending aorta.^(3,4) The pre-ejection period (PEP) in the pulmonary artery has been correlated with pressure in this circulation.⁽³⁾ Acceleration time (AT) and ejection time (ET) in the pulmonary artery have been correlated inversely with the pressure in the pulmonary arterial system.^(3,4)

The purpose of this study is to document the course of the alterations of pulmonary arterial pressure and ascending aortic pressure in the early Thai neonatal circulatory changes in our institution by the use of a pulsed Doppler technique.

Materials and Methods

The study population consisted of 31 normal-term neonates (16 males and 15 females). Their mothers had normal pregnancies with no evidence of toxemia, diabetes mellitus or pregnancy-induced hypertension. None of the infants was acutely ill or had any evidence of congenital malformation. They were all born full-term and their Apgar scores were greater than 8 both at 1 minute and 5 minutes.

Doppler studies:

The ultrasound system used in this study was a 2D-Doppler colour flow electronic sector scanning echocardiograph (870 Aloka system).

All neonates were examined while they were lying quietly in the supine position and breathing room air. A twodimensional phase array scanner with a 5 MHz transducer was used to visualize the left semi-parasternal long axis view of the heart at the level of the pulmonary artery immediately distal to the pulmonic valve to record the Doppler flow velocity curve (Fig. 1). Ascending aortic flow was measured from the sub-costal long axis view and the sampling volume was placed in the ascending aorta immediately distal to the aortic valve (Fig. 2). Care was taken to orient the imaging plane so that the main pulmonary artery or ascending aorta could be seen in as long a sweep as possible. The directional blood flow was assumed to be parallel to the wall of each great artery. The angle between the ultrasound beam and direction of flow in the main pulmonary artery and ascending aorta were kept constant at around 0-15 degrees. In this study, blood flow moving toward the transducer was displayed as an upward deflection. Therefore, systolic flow in the main pulmonary artery and ascending aorta moving away from the transducer was displayed as a downward deflection.

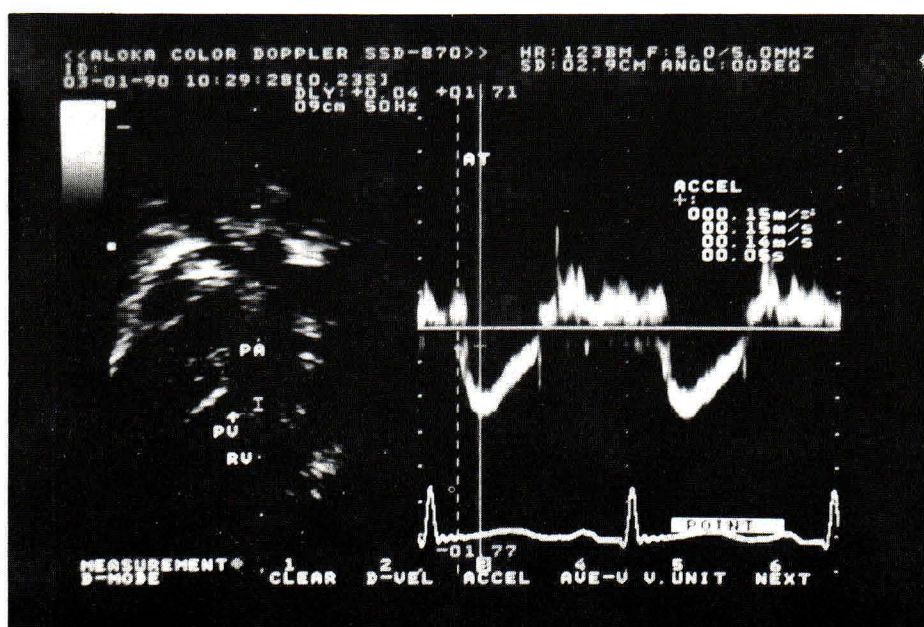


Figure 1. Semi-left parasternal long axis shows Doppler flow velocity curve above pulmonic valve.
PA = pulmonary artery, RV = right ventricle, PV = pulmonic valve.

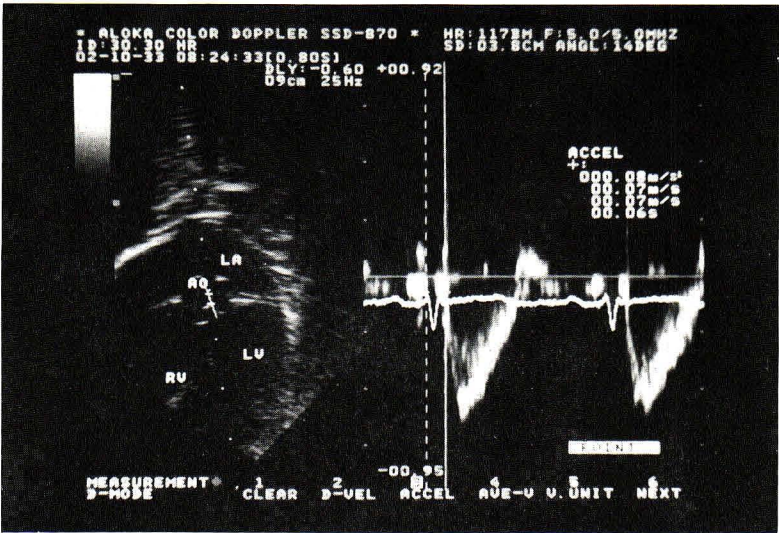


Figure 2. Sub-costal long axis shows Doppler flow velocity curve above aortic valve.
Ao = aorta, LA = left atrium, LV = left ventricle, RV = right ventricle

Pre-ejection period (PEP) was measured from the onset of the Q wave of the simultaneously recorded ECG to the onset of the ejection. Acceleration time (AT) was measured from the onset of ejection to the point of peak flow velocity. Ejection time (ET) was measured from the onset of ejection to the end of ejection. Three Doppler flow indices were measured from the main pulmonary artery and ascending aortic flow tracings : PEP, AT and ET were measured in milliseconds. The ratio of PEP/ET, AT/ET were calculated.

All neonates were studied at a mean age of four hours (at a range of 1-10 hours of age), 28 hours (range 24-34 hours of age) and 51 hours (range 48-58 hours of age).

Statistical analysis:

The data were expressed as the mean ± one standard deviation. Paired Student’s “t” test was used to evaluate the difference in set of measurements between mean ages of 4, 28 and 51 hours. Results with p values less than 0.001 were considered to be statistically significant.

Results

The results of measurements of Doppler flow indices in normal neonates are summarized in Tables 1 and 2 and are illustrated in Figures 3. (A,B), 4 and 5. (A,B).

Table 1. Serial measurements of Doppler flow indices in the pulmonary artery of 31 normal full-term neonates.

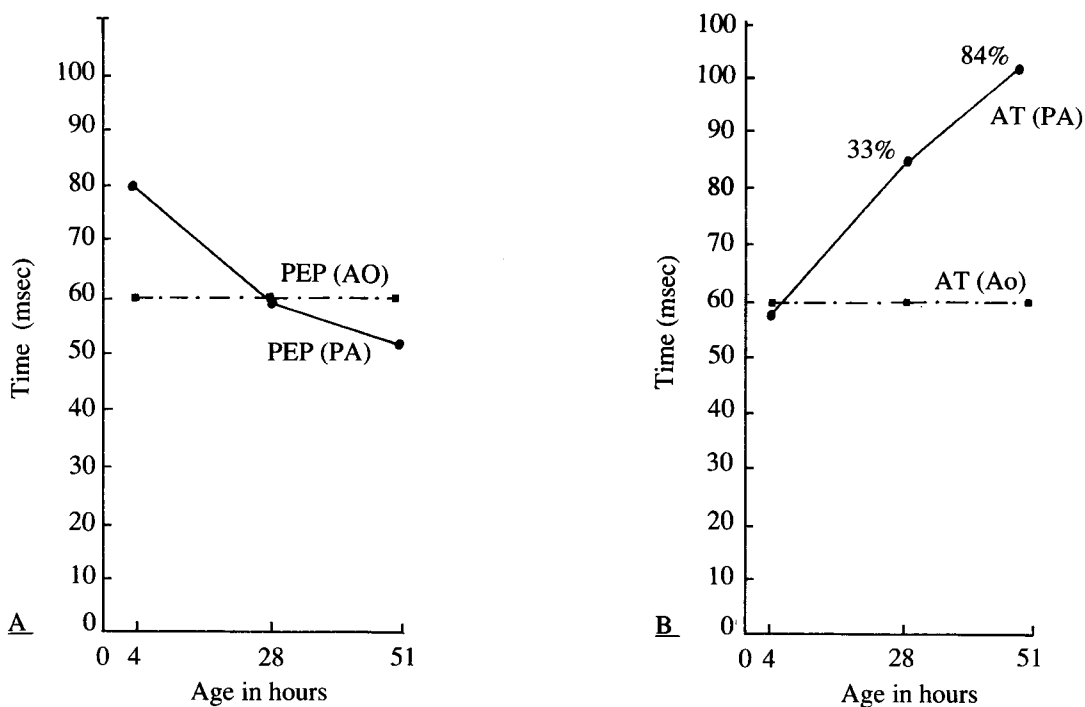
Mean age (hours)	4	28	51	p value		
(range)	(0 – 10)	(24 – 34)	(48-58)	ANOVA	4&28	28&51
PEP(msec)	80 ± 5	60	50 ± 5	< 10 ⁻⁶	< 10 ⁻⁶	< 10 ⁻⁶
(range)	(70 – 90)	(59 – 61)	(48 – 60)			
AT(msec)	58 ± 4	85 ± 8	102 ± 13	< 10 ⁻⁶	< 10 ⁻⁶	< 10 ⁻⁶
(range)	(50 – 60)	(70 – 110)	(80 – 120)			
ET(msec)	206 ± 11	215 ± 9	222 ± 9	< 10 ⁻⁶	< 10 ⁻⁶	< 10 ⁻⁶
(range)	(190 – 230)	(200 – 220)	(200 – 240)			
PEP/ET	0.38 ± .028	0.279 ± .012	0.237 ± .02	< 10 ⁻⁶	< 10 ⁻⁶	< 10 ⁻⁶
(range)	(0.32 – 0.45)	0.26 – 0.30)	(0.21 – 0.30)			
AT/ET	0.28 ± .021	0.39 ± .03	0.45 ± .047	< 10 ⁻⁶	< 10 ⁻⁶	< 10 ⁻⁶
(range)	(0.24 – 0.31)	(0.35 – 0.5)	(0.38 – 0.56)			

PEP = pre ejection period, AT = acceleration time, ET = ejection time

Table 2. Serial measurements of Doppler flow indices in the ascending aorta of 31 normal full-term neonates.

Mean age (hours)	4	28	51	p value		
(range)	(0 – 10)	(24 – 34)	(48–58)	ANOVA	4&28	28&51
PEP(msec)	60	60	60	NS	NS	NS
AT(msec)	59 ± 2	60	59 ± 2	0.605	0.325	0.325
(range)	(58 – 61)	(59 – 61)	(58 – 61)			
ET(msec)	204 ± 9	208 ± 10	209 ± 10	0.43	0.50	0.19
(range)	(190 – 230)	(200 – 220)	(200 – 240)			
PEP/ET	0.29 ± 0.01	0.29 ± .03	0.28 ± .01	0.38	0.49	0.23
(range)	(0.26 – 0.3)	0.27 – 0.3)	(0.25 – 0.3)			
AT/ET	0.28 ± .01	0.286 ± .01	0.283 ± .01	0.72	0.46	0.22
(range)	(0.25 – 0.3)	(0.27 – 0.3)	(0.25 – 0.3)			

PEP = pre-ejection period, AT = acceleration time, ET = ejection time NS = not significant



Ao = aorta, LA = left atrium, LV = left Ventricle, RV = right Ventricle

Figure 3. Changes in A. mean pre-ejection period (PEP) and B. mean acceleration time (AT) in milliseconds of the main pulmonary artery (PA) and ascending aorta (Ao) in normal-term neonates.

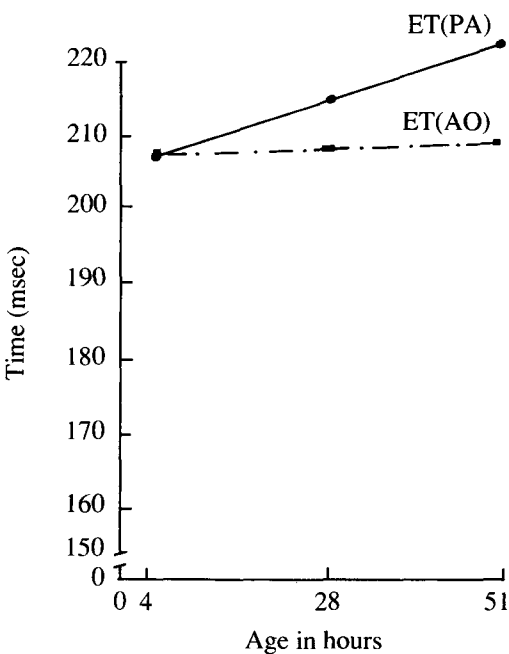


Figure 4. Changes in mean ejection time (ET) in milliseconds of the main pulmonary artery (PA) and ascending aortic (Ao) flow in normal-term neonates.

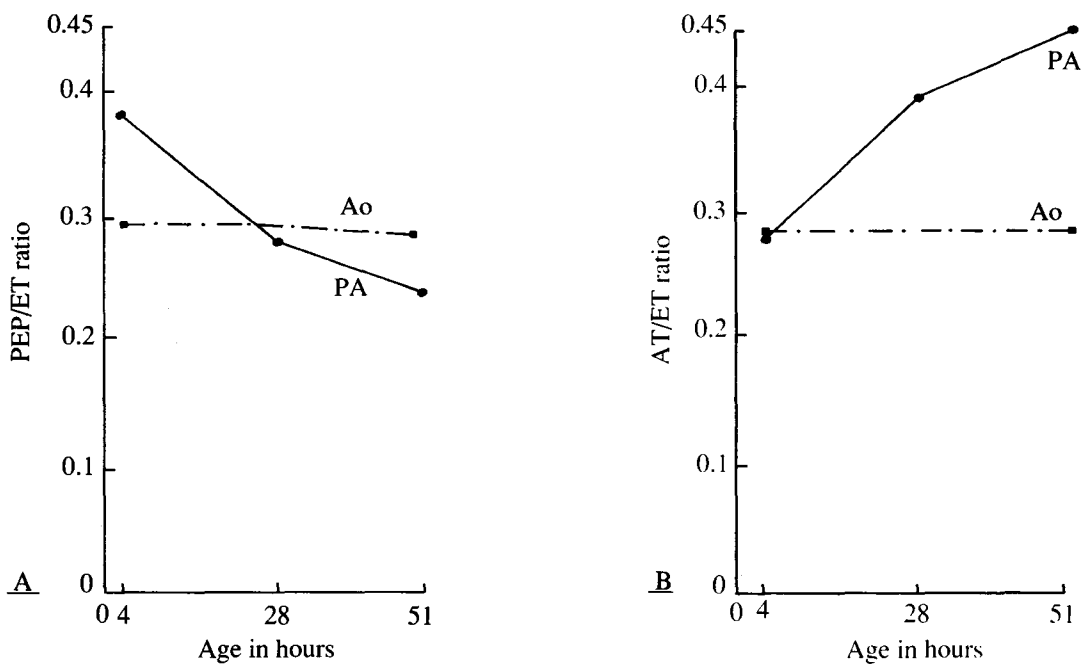


Figure 5. Changes in mean values of the ratios of :
A. Pre-ejection period to ejection time (PEP/ET)
B. Acceleration time to ejection time (AT/ET) in pulmonary artery (PA) and ascending aortic (Ao) flow in normal neonates.

Pre-ejection period: The ascending aortic PEP did not change from 4, 28 and 51 hours of age. In contrast, the pulmonary PEP showed a significant decrease during this time period (p less than 10^{-6}) (Fig. 3A).

Acceleration time and ejection time: The ascending aortic AT did not change from 4, 28 and 51 hours of age. In contrast, pulmonary AT showed a significant increase during this time period (Fig. 3B). Although aortic and pulmonary AT values were similar at four hours of age, pulmonary AT exceeded aortic AT by 33% and 84% at 28 and 51 hours of age, respectively. Ascending aortic ET measurements remained unchanged, while pulmonary ET increased slightly and exceeded aortic ET by 4% and 9% at 28 and 51 hours of age, respectively (Fig. 4).

Pre-ejection period to ejection time ratio: The ascending aortic PEP/ET ratio did not show a significant change. The pulmonary artery PEP/ET ratio decreased significantly between 4, 28 and 51 hours of age (Fig. 5A). The pulmonary artery PEP/ET ratio exceeded the aortic PEP/ET ratio by 35% at four hours of age, while aortic the PEP/ET ratio exceeded the pulmonary artery PEP/ET by 7% and 21% at 28 and 51 hours of age, respectively.

Acceleration time to ejection time ratio: The ascending aortic AT/ET ratio did not show a significant change, while the pulmonary artery AT/ET ratio increased significantly (Fig. 5A) between 28 and 51 hours of age. The pulmonary artery AT/ET ratio exceeded the aortic AT/ET by 39% and 60% at 28 and 51 hours of age, respectively.

Discussion

A gradual decline in pulmonary artery pressure during the first three days of life in normal full-term infants has been documented by cardiac catheterization.⁽¹⁾ Prior to 12 hours of age, the pulmonary artery pressure approached systemic pressure and thereafter a gradual decrease in pulmonary systolic pressure with a faster decline in pulmonary diastolic pressure during the first 48 hours was observed. By the third day, the mean pulmonary pressure was less than 50% of the systemic pressure. The response of the decreasing pulmonary artery pressure and pulmonary vascular resistance in the newborn period shortens the time required to generate sufficient pressure to open the pulmonic valve and prolongs the time needed

to have the valve remain open which is compatible with this study, in which the pulmonary PEP shortened statistically by 7% and 21% from 4 to 28 and 51 hours of age; respectively. The pulmonary ET also lengthened statistically by 4% and 9% from 4 to 28 and 51 hours of age, while there was no significant change in aortic PEP and ET. The after-load of the left side of the ventricle would have been markedly changed after removal of the low-resistance placenta.

Acceleration time in the pulmonary artery is known to correlated inversely with mean pulmonary pressure in children.⁽⁵⁻⁷⁾ In the present study, pulmonary artery AT increased significantly from 4 to 28 and 51 hours of age which is in accord with the known physiological fall in mean pulmonary pressure during this period.^(1,2)

Acceleration phase indices of the aortic flow have been shown to reflect the left ventricular systolic function.⁽⁸⁻⁹⁾ The time to peak aortic flow velocity had been shown to correlate inversely with maximum dp/dt ⁽¹¹⁾ and to be increased in children with impaired left ventricular function.⁽¹¹⁾ During the early neonatal period, the left ventricular output is close to maximum in order to meet the requirements for increased oxygen consumption.⁽¹²⁻¹³⁾ This study confirms that there is no statistically significant change in aortic AT during 4, 28 and 51 hours of age.

Right heart PEP/ET had been utilized to estimate changes in pulmonary artery pressure and pulmonary vascular resistance in infants and children.⁽¹⁴⁻¹⁵⁾ This study shows that the mean values of right heart PEP/ET decreased significantly from 4, 28 and 51 hours of age which reflects the physiologic fall in pulmonary pressure in this period. Left heart PEP/ET is an accepted index of left heart pump function and the mean values of left heart PEP/ET in the present study are statistically insignificant from 4 to 51 hours of age and are similar to previous reports.⁽¹⁴⁻¹⁵⁾

The present study documents the physiologic circulatory adjustment of the circulation especially the pulmonary system in the newborn period. It also provides valuable baseline normative data that will enable future studies of pulmonary circulatory disorders in the neonatal period.

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