Effects of nasal continuous positive airway pressure on cerebral hemodynamics in preterm infants

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Research article

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Abstract

Background To evaluate effects of different positive end-expiratory pressure (PEEP) levels on cerebral hemodynamics of premature infants when using nasal continuous positive airway pressure (nCPAP) during the first 3 days of life.

Methods Forty-four preterm infants treated with nCPAP were divided into very preterm infant group (gestational age 1 (GA1) group, GA<32 weeks, n=24) and moderate and late preterm group (GA2 group, GA 32-37 weeks, n=20). During the monitoring process, the PEEP was set at 4→6→8→4 cmH 2 O and cerebral hemodynamics was assessed by near-infrared spectroscopy (NIRS). Life signs, peripheral oxygen saturation (SpO 2) and transcutaneous carbon dioxide pressure (TcPCO 2) were recorded at the same time.

Results Tissue oxygenation index (TOI), cerebral blood volume (△CBV) and the difference between oxygenated hemoglobin (△HbO 2) and deoxygenated hemoglobin (△HHb) (△HbD) were all significantly positive correlated with gestational and postnatal age and the fluctuation of GA1 group was greater. △CBV and △HbD were also significantly positive correlated with TcPCO 2 . PEEP of 4-8 cmH 2 O had no significant influence on cerebral hemodynamics, life signs, SpO 2 or TcPCO 2 .

Conclusions No significant differences were observed in cerebral hemodynamics when the PEEP was set from 4 to 8 cmH 2 O. These findings confirmed the safety and reliability of nCPAP at regular pressure levels to the nervous system of preterm infants.

Introduction

Introduction

Neonatal respiratory distress syndrome (NRDS) is one of common respiratory diseases in premature infants. Noninvasive respiratory support is the optimal respiratory support method for NRDS. Nasal continuous positive airway pressure (nCPAP), one of the most common noninvasive assisted ventilation methods, is widely used in neonatal intensive care unit (NICU). Although managements of NRDS are improving, nCPAP is still a crucial therapeutic measure of NRDS [1].

In recent years, more and more researchers pay attention to the effects of nCPAP on cerebral hemodynamics [2–4]. Some researchers considered that the positive end-expiratory pressure (PEEP) of nCPAP increases intra-thoracic pressure, decreases venous return and cardiac output (CO), which may decrease cerebral perfusion finally[5]. Moreover, decreased cerebral blood flow (CBF) which result in insufficient cerebral perfusion may increase the occurrence of hypoxic-ischemic brain damage (HIBD). NCPAP also raises central venous and intracranial pressure and even leads to intraventricular hemorrhage (IVH) and other brain damage [5].

NCPAP should be started from birth in all babies at risk of NRDS with a starting pressure of 6–8 cmH_2O via mask or nasal prongs[1]. Then, the PEEP should be individualized depending on clinical condition, oxygenation and perfusion[1]. Until now, there is no agreement on the optimal PEEP pressure for preterm NRDS and 4–6 cmH_2O is a common range applied in NICU[3–4]. However, some researchers prefer to use 8 cmH_2O or even higher pressure[6–7]. Some studies found that infants with a pressure of 8 cmH_2O have larger end-expiratory volume and tidal volume, as well as lower respiratory rate and thoracoabdominal asynchrony than using 2–6 cmH_2O[6–7]. However,

over pressures such as 10 cmH_2O and even more in premature infants may restrict pulmonary blood flow and CO, cause hypercapnia and the fluctuation of CBF[7–8]. Therefore, in premature infants, how to choose an appropriate PEEP to reduce brain injury is still needed to explore.

Although it has been demonstrated that the nCPAP using decreases cerebral perfusion in healthy adult volunteers [8], the results of studies about preterm infants are different. Dani *et al* found that PEEP of 2–6 cmH_2O didn't affect cerebral oxygenation or cerebral blood volume in preterm infants with NRDS during the first 10 days of life [3]. Bembich S *et al* also did not find obvious fluctuation of CBF in preterm newborns using nCPAP with PEEP 3–8 cmH_2O during the first 7 days of life [4]. However, there is no data available about the effects of nCPAP pressure on the cerebral hemodynamics in premature infants during the first 3 days of life.

It is suggested that nCPAP should be started in the delivery room [1]. Fifty percent of premature infants who were given nCPAP early could avoid mechanical ventilation (MV) or pulmonary surfactant (PS), which may decrease the risk of lung injury [9]. It is well known that the the first 3 days after birth is important for NRDS treatment, and the application of nCPAP in this period is vital for the cure of premature infants with NRDS. However, in this period, the CBF of premature infants is very unstable which may cause IVH, HIBD and other brain damages. It is important to understand the adaptive change of the cerebral circulation of premature infants during the first 3 days of life would reduce the incidence of cerebral injury [10–11]. In this study, therefore, we investigated effects of nCPAP pressure on the cerebral hemodynamics in premature infants during the first 3 days of life.

Near-infrared spectroscopy (NIRS) is a noninvasive device applied in NICU which could continue monitoring regional cerebral oxygenation and hemodynamics. It helps to discover and prevent cerebral hypoxic and ischemic in neonates especially premature infants [12]. Therefore, we applied NIRS to observe effects of nCPAP pressure on cerebral hemodynamics in preterm infants during the first 3 days of life.

In this study, the preterm infants using nCPAP within the first 3 days of life were selected to detect the cerebral hemodynamics using NIRS when PEEP varies from 4 to 8 cmH_2O. To our knowledge, this is the first study assessing the safety and stability of nCPAP on cerebral hemodynamics in premature infants during the first 3 days of life. The purpose of this study is to provide the theoretical basis for selecting a safe and effective nCPAP pressure level in premature infants with NRDS early after birth.

Materials And Methods

Participants

This study was conducted in the NICU of Children's Hospital of Nanjing Medical University from April 2018 to October 2018. The inclusion criteria were as follows: (1) preterm infants with gestational age (GA) less than 37 weeks; (2) preterm infants diagnosed with NRDS and using nCPAP within 3 days after birth; (3) Apgar score>7. The exclusion criteria were one or any combination of the following: (1) Peripheral oxygen saturation (SpO_2), was unable to maintain in the normal range during the monitoring process; (2) infants can't keep quiet during the monitoring process; (3) serious brain injuries caused by asphyxia, birth injury, intrauterine infection or others; (4) genetic metabolic diseases; (5) congenital heart disease, nervous system malformation and other congenital diseases or serious complications. This study was approved by the ethics committee of Children's Hospital of Nanjing Medical University and achieved agreements from infants' parents.

All enrolled infants were divided into 2 groups according to the GA: (1) very preterm infant group (GA1 group, GA<32weeks, n = 24): ▯ One day group: monitoring within 24 hours after birth (n = 7); ▯ Two days group: monitoring between 24 to 48 hours after birth (n = 9); ▯ Three days group: monitoring between 48 to 72 hours after birth (n = 8); (2) moderate to late preterm infant group (GA2 group, GA 32–37weeks, n = 20): ▯ One day group: monitoring within 24 hours after birth (n = 6); ▯ Two days group: monitoring between 24 to 48 hours after birth (n = 7); ▯ Three days group: monitoring between 48 to 72 hours after birth (n = 7).

Procedure

NCPAP was provided by the Stephan CPAP systerm (Stephan; Bocholt, Nordrhein-Westfalen, Germany). The pressure was initially set at 4 cmH_2O (T_0) and the data was recorded for 30 min. Subsequently, the pressure was raised to 6 cmH_2O (T_1) and 8 cmH_2O (T_2) for additional 30 min recording respectively. Lastly, the pressure was returned to 4 cmH_2O (T_3) for further 30 min. The nCPAP pressure was keeping constant in each time period. All infants were supine position with mouth closed using pacifiers and were quiet or sleeping during the monitoring process.

From the beginning of T_0 to the end of T_3 period, CBF and oxygenation were continuously monitored by NIRS (EGOS–600A, EnginMed; Suzhou, Jiangsu, China). The trans-cutaneous carbon dioxide tension ($TcPCO_2$) was measured by TCM4 Combim (Radiometer; Brea, California, United States). SpO_2, heart rate (HR), respiratory rate (RR), and noninvasive mean systemic arterial blood pressure (MABP) were measured by a pulse oximeter (N–300®, Nellcor; Minneapolis, Minnesota, United States) placed on the right hand. Arterial hemoglobin (Hb) was detected within 12 hours before beginning the study.

NIRS measurements

During the recording time, each stage recorded 30 minutes. Tissue oxygenation index (TOI), deoxygenated hemoglobin (△HHb), oxygenated hemoglobin ($\triangle HbO_2$) and total hemoglobin (△tHb) were recorded by NIRS. Then the cerebral blood volume (△CBV) and the difference between $\triangle HbO_2$ and △HHb (△HbD) were calculated according to the reported formula: △CBV = △tHb×0.89/Hb and $\triangle HbD = \triangle HbO_2 - \triangle HHb$ [3].

Statistical analysis

SPSS 22.0 was used for statistical analysis. The measurement data which is subject to normal distribution were presented as mean value ± standard deviation (*x±s)* and *t* test was used for comparison between two groups. *F* test was used for comparison among multiple groups and if the difference was statistically significant, the *q* test was used for further comparison. Counting data was presented as number of cases or percentages (%) and ^{2} was used for comparison between two groups. Pearson Correlation was conducted to analyze the correlation of data and $P<0.05$ was considered statistically significant.

Results

Demographic variables

From April 2018 to October 2018, 44 preterm infants using nCPAP were enrolled into this study. The clinical and demographic data are presented in Table 1. Except GA and birth weight (P = 0.00), there were no significant differences in sex composition, multiple birth, mode of production, Apgar scores, prenatal use of glucocorticoids and premature rupture of fetal membranes between the two groups (P>0.05). Between two subgroups in each group, there were also no significant differences in GA and birth weight (P>0.05).

Table 1

Related factors analysis of cerebral hemodynamics

TOI was significantly positive correlated with GA (r = 0.749, P<0.05) and postnatal age (r = 0.799, P<0.05) (Fig. 1 A). △HbD was significantly positive correlated with GA (r = 0.546, P<0.05), postnatal age (r = 0.844, P<0.05) and $TcPCO_2$ (r = 0.826, P<0.05) (Fig. 1 B). Similarly, △CBV was significantly positive correlated with GA (r = 0.905, P<0.05), postnatal age (r = 0.821, P<0.05) and $TcPCO_2$ (r = 0.887, P<0.05) (Fig. 1 C).

Figure 1

Effects of GA and postnatal age on cerebral hemodynamics

As shown in Figure 2, TOI, △HbD and △CBV of GA2 group were all significant higher than that of GA1 group at the same postnatal age (P<0.05). TOI, △HbD and △CBV of GA1 group were gradually increased during the first 3 days of life and differences between three groups are significant (P<0.05). In GA2 group, compared with one day group, TOI and △CBV obviously increased in two days group and three days group (P<0.05). However, TOI and △CBV did not show significant difference between two days group and three days group$P$>0.05), while △HbD between three groups showed significant difference (P<0.05).

Figure 2

Effects of different nCPAP pressure levels on the life signs, SpO_2, $TcPCO_2$ and cerebral hemodynamics

In the very preterm infant group (Fig. 3A) and the moderate to late preterm infant group (Fig. 3B), PEEP of 4–8 cmH_2O had no significant influence on the life signs, SpO_2 or $TcPCO_2$ (P>0.05). Also, PEEP which was set from 4 to 8 cmH_2O had no significant influence on cerebral hemodynamics neither in very preterm infants (Fig. 4A) nor in moderate to late preterm infants (Fig. 4B). Though the △HbD and △CBV tended to decline at 8 cmH_2O, the difference was not significant (P>0.05).

Figure 3

Figure 4

Discussion

NRDS is a clinical syndrome caused by PS deficiency and is one of the main causes of neonatal death, especially in premature infants. Even though therapeutic methods of NRDS keep constantly improving, PS and PEEP are still the most important methods of NRDS. NCPAP, the most common respiratory support used in NICU, delivers continuous positive pressure air into the airway through the nasal catheter. NCPAP could improve oxygenation through maintaining lung volume, obtaining larger pulmonary functional residual capacity and reducing airway resistance.

Hansen *et al. [*13] followed up 252 premature infants who used nCPAP during the neonatal period for 5 years and found 49% of these kids had moderate to severe mental deficiency. Aly *et al.* [14] carried out another study on very low birth weight infants who using nCPAP during the early days of life and the results showed 35 of 340 infants had severe IVH. Hence, it is worthy notice that the use of nCPAP may increase the incidence of brain injury in preterm infants.

NIRS is a noninvasive device extensively applied in NICU for monitoring cerebral hemodynamics of newborn infants. Due to the low thickening scalp and calvarium in premature, NIRS has the capability to continuously and noninvasively monitor cerebral oxygenation and CBF of preterm infants. Previous findings even indicated that cerebral hemodynamics reflected by NIRS are similar to the results indicated by electroencephalography (EEG) evidence [15]. Therefore, NIRS can provide valuable information for the pathogenesis, therapeutic method evaluation and prognosis judgment of nervous system injury during perinatal stage [16].

We have made several novel and interesting findings in this work: 1) TOI, △HbD and △CBV were all significantly positive correlated with GA and postnatal age. TOI, △HbD and △CBV of GA2 group were significant higher than that of GA1 group at different postnatal ages. TOI, △HbD and △CBV of GA1 and GA2 groups were all gradually increased during the first 3 days of life and the fluctuation of GA1 group was even greater; 2) △HbD and △CBV were also significantly positive correlated with $TcPCO_2$; 3) PEEP of 4–8 cmH_2O had no significant influence on the life signs, SpO_2, $TcPCO_2$ or cerebral hemodynamics of preterm infants.

TOI is a parameter measured directly by NIRS and could simply reflect the oxygen content in local brain tissue. △HbD is reported to be a powerful target which could sensitively reflect CBF [17–18]. △CBV reflects the cerebral blood volume and is also correlated with CBF. Our results showed that TOI, △HbD and △CBV were all significantly positive correlated with GA and postnatal age, which is consistent with other reports [17, 19]. TOI, △HbD and △CBV of GA2 group were significant higher than that of GA1 group at different postnatal ages. Through using Doppler color ultrasonography, Pezzati *et al.* found that with increased GA, resistance index (RI) decreased and then cerebral blood flow velocity (CBFV) significantly increased both in the anterior cerebral artery and in the right and left middle cerebral arteries [20]. Therefore, we believe that the cerebral oxygenation and CBF improve with increased GA through declining the RI of cerebral vessel and increasing CBFV. Consisted with previous findings [21], we also demonstrated that cerebral oxygenation and CBF were significantly correlated with postnatal age in preterm infants during the early days of life. The reasons may include the increased CO, arterial ductal closure and the decreased intracranial pressure after birth [22]. It is noticeable that although cerebral hemodynamics of two groups was both gradually increased during the first 3 days of life, the fluctuation of GA1 group was greater than the GA2 group. It could be speculated that premature infants of smaller GA have weaker autoregulation of cerebral hemodynamic, which lead to the bigger blood flow fluctuation and the greater possibility of brain injury at last. So, clinicians need

to avoid the blood flow fluctuation of premature infants especially extremely preterm infants during the first days of life in order to reduce brain injuries.

$TcPCO_2$ is another related factor of cerebral hemodynamics. Our results monitored by TCM showed that $TcPCO_2$ has a certain correlation with CBF indexes including △HbD and △CBV. In recent years, more and more researchers began to realize the close relationship between carbon dioxide pressure ($PaCO_2$) and brain injury in preterm infants. It has been demonstrated that either over-high or over-low $PaCO_2$ both could damage cerebral autoregulation and increase the fluctuation of CBF, which cause brain injuries such as IVH [23–24]. Greisen *et al.* reported significant neurological abnormality at 18 months of very low birth weight infants who endured severely hypocapnia within 24 hours of life [25]. While Dix *et al.* [23]showed that acute increase in $PaCO_2$ diminished brain activity, which may lead to adverse neurologic outcomes in preterm. Therefore, clinicians also should keep the level of $PaCO_2$ in a reasonable range and avoid its fluctuation during the first days of life in order to reduce brain injuries. Dix *et al. [*23] also found that an acute increase in $PaCO_2$ is associated with an increase in cerebral oxygenation. However, Naulaers *et al.* [19] found TOI was independent of $PaCO_2$, which consistent with our results. The exact relationship between $PaCO_2$ and cerebral oxygenation remains further studies.

SpO_2 is one of the most common and intuitive indicators used in NICU. Some studies found higher SpO_2 could prevent brain damage through decreasing the incidence of intermittent apnea, hypoxemia and bradycardia [26–27]. However, our results did not reveal the correlation between SpO_2 and cerebral hemodynamics. The reasons may be as follows: 1) it is reported that there is the correlation between SpO_2 and cerebral oxygenation when the SpO_2 is severe low [28]. However, the values of SpO_2 were high (91–98%) in our study and the exact relationship between SpO_2 with cerebral oxygenation was hidden; 2) the high peripheral oxygenation does not necessarily transform to the high cerebral oxygenation in preterm infants [4]. Thus, SpO_2 may not represent the cerebral oxygenation and CBF precisely in preterm infants.

In this study, MABP didn't obviously affect cerebral oxygenation or CBF. It is reported that MABP may change CBF when MABP is below 30 mmHg [29], but infants have autoregulation ability to remain CBF stable when MABP is in a certain range such as above 30 mmHg [30–31]. Therefore, some neonatologists recommended that maintaining the MABP above 30 mmHg may reduce the incidence of cerebral white matter lesions and IVH [32–33]. Besides, Michelet *et al.* found that MABP would not remarkably influence cerebral oxygenation and CBF unless it has a huge fluctuation[34]. In this study, MABPs of infants were all above 30 mmHg and without big fluctuations, which may be the reason why no correlation between MABP and cerebral hemodynamics was discovered.

Some researchers considered that nCPAP might decrease cerebral perfusion via increasing intra-thoracic pressure, declining CO, rising central venous pressure and intracranial pressure [5, 35–36]. However, Beker *et al. [*37] found that the CO and MABP were not changed at PEEP levels of 4, 6, and 8 cmH_2O in preterm infants. Moritz *et al.* [38]also demonstrated that nCPAP with a mean level of 4 cmH_2O (up to 7 cmH_2O) does not influence CO in preterm infants. Our results also showed that PEEP which was set from 4 to 8 cmH_2O had no significant influence on cerebral hemodynamics. We speculated that infants may be able to quickly compensate for increased intrathoracic pressure caused by PEEP because of the highly compliant chest wall, which finally reduces the effect of PEEP on cerebral hemodynamics [10–11]. Two studies respectively found that nCPAP at the pressure level of 10 and 12 cmH_2O could decrease CBF in adults [8, 39]. Hsu *et al.* [40] also observed that nCPAP would affect the neonatal CO when PEEP was 10 cmH_2O. These findings suggested that extra high PEEP would affect cerebral hemodynamics.

However, our results showed that PEEP at a level of 8 cmH_2O had no significant effect on cerebral hemodynamics of preterm infants. Hence, cerebral hemodynamics of premature could stay relatively stable when PEEP is set within the range of 4–8 cmH_2O. Therefore, nCPAP used in a proper range is safe and reliable for brain in premature.

In conclusion, the cerebral hemodynamics of preterm infants with smaller GA or postnatal age is more unstable. Maintaining the stability of $TcPCO_2$ is crucial to reduce the fluctuation of CBF. NCPAP used at 4–8 cmH_2O pressure levels does not affect cerebral hemodynamics and is safe for preterm infants. A limitation of this study is that it was a pilot study with a small sample size; it would be advantageous to enlarge the sample size. Furthermore, this study only recorded short-term effects and long-term follow-up is needed. We hope the results of this study could help clinicians to choose optimal pressure level of nCPAP and reduce brain damage caused by nCPAP in preterm infants.

Declarations

Ethics approval and consent to participate All applicable institutional and national guidelines for preterm infants were followed. The agreements also achieved from infants' parents.

Consent for publication Not applicable.

Availability of data and materials The datasets generated and analyzed during the current study are not publicly available due to privacy protection but are available from the corresponding author on reasonable request.

Conflict of Interest The authors declare that they have no competing interests.

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Author Contributions

Jie Qiu conceptualized and designed the study, coordinated and supervised the experiments, provided research materisl/reagents, reviewed and revised the manuscript.

Han Zhou conducted the experiments and collected data.

Youyan Zhao analyzed data and drafted the initial manuscript.

Rui Cheng and Xuewen Hou were involved in data interpretation and manuscript preparation.

All authors approved the final manuscript for the submission and agreed to be accountable for all aspects of the work.

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Tables

Table 1. Clinical and Demographic Characteristics of Neonates

	Very preterm infant group (n=24)			Moderate and late preterm group (n=20)		
	One day group (n=7)	Two day group (n=9)	Three day group (n=8)	One day group (n=6)	Two day group (n=7)	Three day group (n=7)
emale)	3/4	5/4	4/4	3/3	4/3	3/4
irths	1 (14.3)	3 (33.3)	2 (25.0)	1 (16.7)	1 (14.3)	2 (28.6)
l age eks)	28.6±1.8	29.0±1.5	28.8±1.5	34.4±0.8*	33.6±1.5*	33.3±3.6*
ght g)	1174±170	1314±281	1161±209	2151±125*	2070±184*	1913±298*
ın	3 (42.9)	6 (66.7)	6 (75.0)	4 (66.7)	5 (71.4)	5 (71.4)
gar	8.0±1.0	7.7±1.8	7.6±2.1	8.3±1.0	8.7±1.1	8.6±0.8
gar	8.9±0.7	7.7±0.6	8.8±0.5	9.3±1.0	9.4±0.5	9.3±0.5
se of ıids [n	4 (57.1)	6 (66.7)	5 (62.5)	3 (50.0)	4 (57.1)	3 (42.9)
upture branes	4 (57.1)	4 (44.4)	3 (37.5)	2 (33.3)	5 (71.4)	3 (42.9)

and birth weight of GA2 group were all significant higher than that of GA1 group at the same postnatal

Abbreviations

nCPAP	nasal continuous positive airway pressure
PEEP	positive end-expiratory pressure
NICU	neonatal intensive care unit
GA	gestational age
NRDS	neonatal respiratory distress syndrome
SpO_2	peripheral oxygen saturation
NIRS	near infrared spectroscopy
TOI	tissue oxygenation index
$\triangle HbO_2$	oxygenated hemoglobin
$\triangle$HHb	deoxygenated hemoglobin
$\triangle$tHb	total hemoglobin
$\triangle$CBV	cerebral blood volume
$\triangle$HbD	difference between $\triangle HbO_2$ and $\triangle$HHb
Hb	hemoglobin
HR	heart rate
RR	respiratory rate
MABP	mean systemic arterial blood pressure
$TcPCO_2$	trans-cutaneous carbon dioxide pressure
HIBD	hypoxic-ischemic brain damage
IVH	Intraventricular hemorrhage
MV	mechanical ventilation
PS	pulmonary surfactant
EEG	electroencephalography
CBF	cerebral blood flow
CBFV	cerebral blood flow velocity
RI	resistance index
CO	cardiac output

Figures

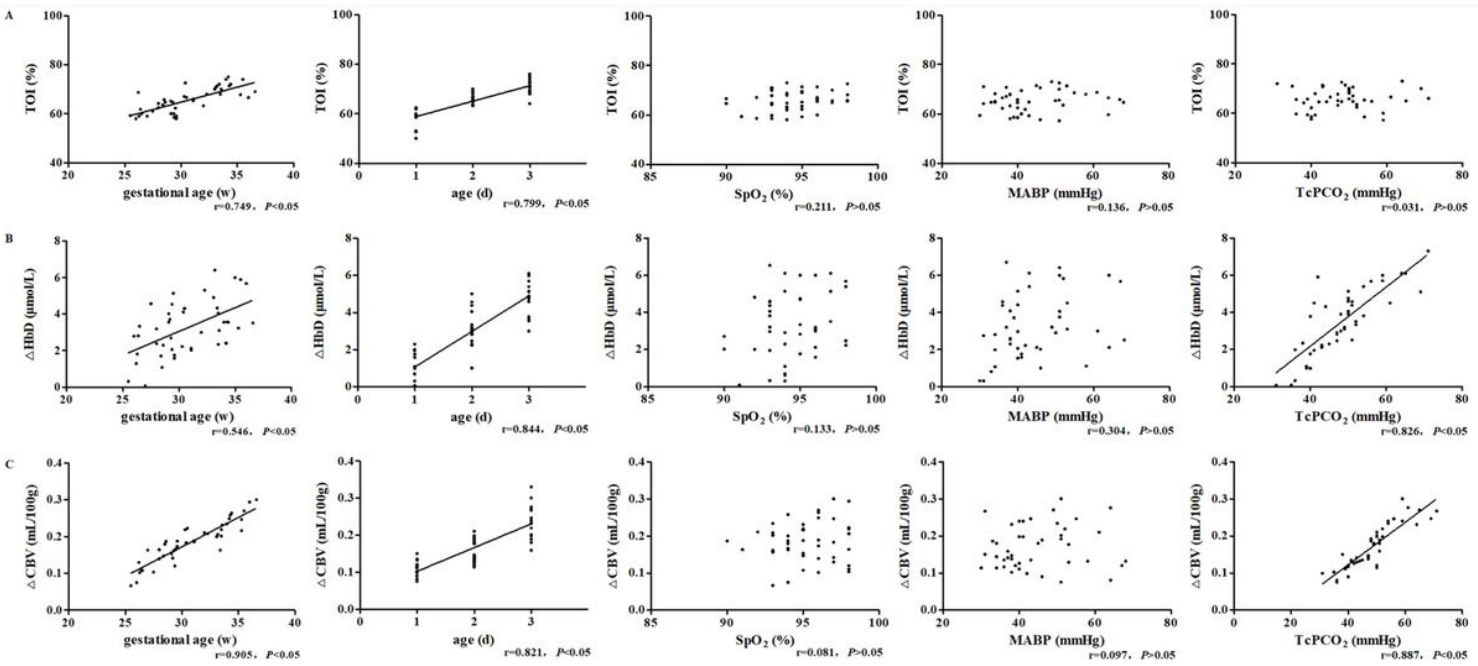

Figure 1

Related factors analysis of cerebral hemodynamics (A) TOI was significantly positive correlated with GA (r=0.749, P<0.05) and postnatal age (r=0.799, P<0.05); there were no significant correlation between TOI with SpO2 (r=0.211, P>0.05), MABP (r=0.136, P>0.05) and TcPCO2 (r=0.031, P>0.05). (B) △HbD was significantly positive correlated with GA (r=0.546, P<0.05), postnatal age (r=0.844, P<0.05) and TcPCO2 (r=0.826, P<0.05); there were no significant correlation between △HbD with SpO2 (r=0.133, P>0.05) and MABP (r=0.304, P>0.05). (C) △CBV was significantly positive correlated with GA (r=0.905, P<0.05), postnatal age (r=0.821, P<0.05) and TcPCO2 (r=0.887, P<0.05); there were no significant correlation between △CBV with SpO2 (r=0.081, P>0.05) and MABP (r=0.097, P>0.05).

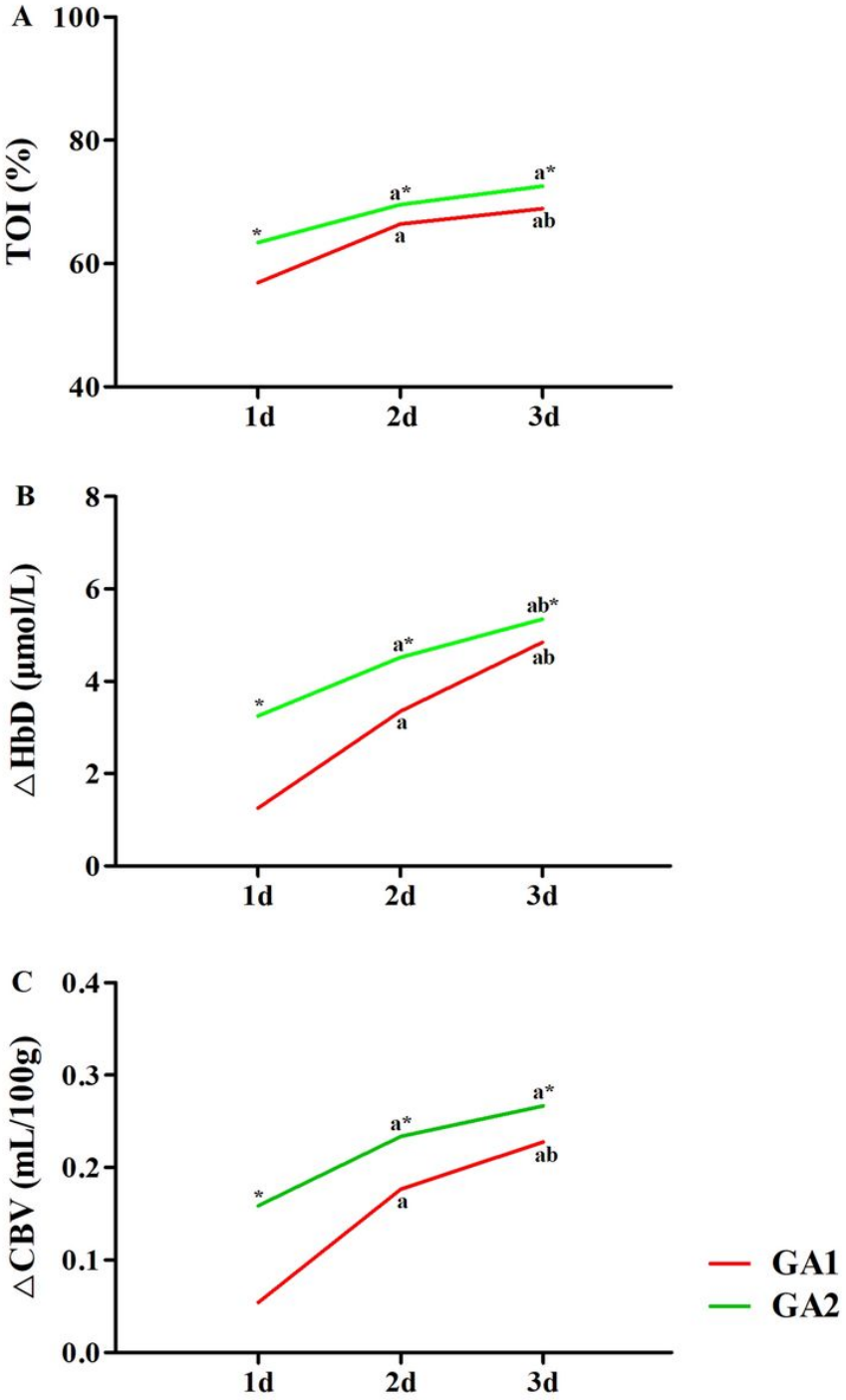

Figure 2

Effects of GA and postnatal age on cerebral hemodynamics (A) TOI of GA2 group were all significant higher than that of GA1 group at the same postnatal age (*P<0.05). In GA1 group, TOI of two days group and three days group were both significant higher than one day group (aP<0.05); TOI of three days group was significant higher than two days group (bP<0.05). In GA2 group, TOI of two days group and three days group were both significant higher than one day group (aP<0.05). (B) △HbD of GA2 group were all significant higher than that of GA1 group at the same postnatal age (*P<0.05). In GA1 group and GA2 group, △HbD of two days group and three days group were both significant higher than one day group (aP<0.05); △HbD of three days group was significant higher than two days group (bP<0.05). (C) △CBV of GA2 group were all significant higher than that of GA1 group at the same postnatal age (*P<0.05). In GA1 group, △CBV of two days group and three days group were both significant higher than one

day group (aP<0.05); △CBV of three days group was significant higher than two days group (bP<0.05). In GA2 group, △CBV of two days group and three days group were both significant higher than one day group (aP<0.05).

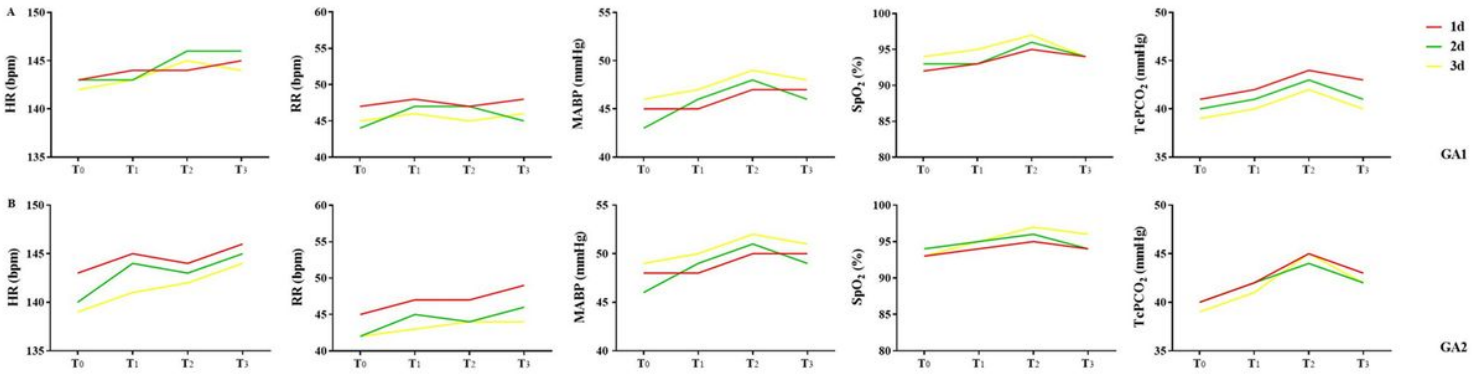

Figure 3

Effects of different nCPAP pressure levels on the life signs, SpO2 and TcPCO2 (A) In GA1 group, PEEP of 4-8 cmH2O had no significant influence on the HR, RR, MABP, SpO2, and TcPCO2 (P>0.05). (B) In GA2 group, PEEP of 4-8 cmH2O had no significant influence on the HR, RR, MABP, SpO2, and TcPCO2 (P>0.05). T0: PEEP is 4 cmH2O; T1: PEEP is 6 cmH2O; T2: PEEP is 8 cmH2O; T3: PEEP is 4 cmH2O.

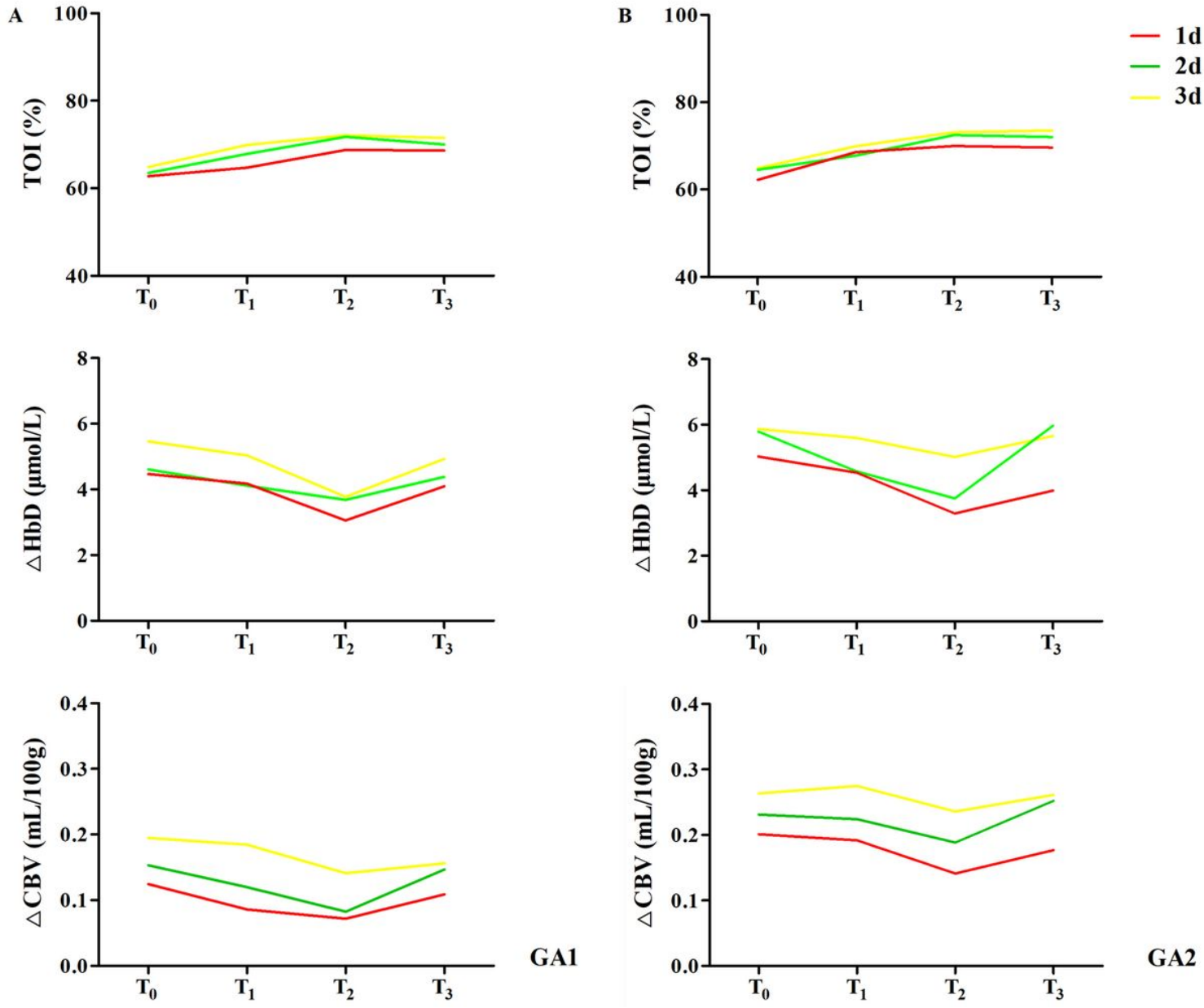

Figure 4

Effects of different nCPAP pressure levels on the cerebral hemodynamics (A) In GA1 group, PEEP of 4-8 cmH2O had no significant influence on the TOI, △HbD and △CBV (P>0.05). (B) In GA2 group, PEEP of 4-8 cmH2O had no significant influence on the TOI, △HbD and △CBV (P>0.05). T0: PEEP is 4 cmH2O; T1: PEEP is 6 cmH2O; T2: PEEP is 8 cmH2O; T3: PEEP is 4 cmH2O.