Short Communication

Hypoperfusion of the Brainstem — A Possible Cause of the Sudden Infant Death Syndrome: Dopplersonographic Screening of the Blood Flow in the Basilar Artery in Dependency on Head and Body Position

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Abstract

Introduction: Hypoperfusion of the brainstem may be a cause of sudden infant death. With spectral Doppler sonography the flow in the basilar artery to the brainstem can be measured noninvasively. From the flow profile the flow velocities can be calculated.

Patients and methods: To prove the hypothesis of hypoperfusion of the brainstem as a cause of SIDS we performed Doppler sonographic flow measurements in the basilar artery of healthy newborns. We measured the peak and time average flow velocity in neutral position (infant supine and head in midline) and after rotation to the right and left. These measurements were performed either supine or prone. Possible alterations of the flow velocities during head rotation were compared with the intra individual normal values in neutral position. We interpreted our results as follows: If the flow during head rotation did not fall under 50% of the initial value in neutral position this was declared normal. If the flow velocities fell below 50% of the initial value this was declared abnormal. If a retrograde or biphasic flow could be shown during head rotation this was pathologic. In patients with abnormal or pathologic flow during head rotation the flow in both vertebral arteries was additionally measured.

Patients: From 1998 till 2016 we investigated 31,945 infants (15,521 girls and 16,424 boys). The mean gestational age was 38, 76 + 2, 13 weeks, the mean birth weight 3288 + 585 g. 4122 newborns without the voluntary screening program served as a control collective. We compared the incidence of SIDS in both groups.

Results: In 31,544 newborns (98, 74%) the flow in the basilar artery was independent on head and body position. 323 newborns (1, 01%) showed a reduction of the peak and/or time average flow velocity under 50% of the value in neutral position. In 78 patients (0, 24%) a pathologic retrograde or biphasic flow could be found. The flow alterations were more pronounced in prone than in supine position. Patients with pathologic flow were assumed to have a greater risk for SID. The parents were encouraged to avoid potentially dangerous head rotations. In all patients flow normalized within the first year of life. Normalization occurred earlier in supine than in prone position.

Occurrence of SIDS: None of our patients with abnormal or pathologic flow died of SIDS. 2 infants (0, 06 ‰) with normal Doppler sonographic screening died of SIDS. In the control group without Doppler sonographic screening 5 infants (1, 21‰) died of SIDS. Statistical analysis between both groups was significant.

Discussion: Pathologic flow occurred predominantly in infants with hypoplastic or aplastic vertebral artery if the leading contra lateral vertebral artery was compressed at the cranio cervical junction during head rotation. This may cause hypoperfusion of the brainstem. Repeated or longer lasting hypoperfusion episodes may cause lesions in the brainstem and lead to SIDS.

Conclusion: Doppler sonographic screening of position dependent blood flow in the basilar artery of healthy newborns may detect infants with increased risk of SIDS. Avoiding head rotations to the pathologic side may reduce the risk of SIDS.

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INTRODUCTION

The cause of sudden infant death (SID) is still unclear. We only know some risk factors which are associated with SID. An important risk factor is sleeping in prone position. More than 85% of SID victims are found lying on their stomach. In contrast to supine position the head is maximally turned to one side lying on the stomach. This may cause compression of the vertebral arteries at the cranio-cervical junction and cause hypoperfusion of the brainstem. Frequent or longer lasting hypoperfusion episodes of the brain stem may cause apnea and bradycardia and may be a cause of SID.

Brain stem gliosis, found in victims of SID, may be a consequence of frequent and longer lasting hypoperfusion episodes to the brainstem [1].

Hypoperfusion of the brainstem may be caused by compression of the vertebral arteries at the cranio-cervical junction during head rotation. The compression of the vertebral arteries could clearly be shown by pathologic anatomic investigations of SIDS victims by Pamphlett and coworkers [2]. They investigated SIDS victims and performed serial sections through the cranial cervical junction [2]. They showed that during head rotation the vertebral arteries can be significantly compressed between the transverse process of the atlas and the occipito-cervical membrane [2].

MATERIALS AND METHODS

Doppler sonographic screening of the flow in the basilar artery in neonatology

As long as the fontanelles are open the intracranial anatomic structures can excellently be displayed by 2d sonography [3,4]. With color Doppler all intracranial arteries especially the basilar artery and both vertebral arteries can be displayed within the 2d image [3,4]. With spectral Doppler the flow in these arteries can be measured. From the flow curve the peak systolic and time average flow velocities can be measured [3,4]. To evaluate a possible dependency of the flow in the basilar artery in different body positions and during head rotation the flow was measured in different head and body positions: Head in neutral position (supine – midline) vs head rotation to the right and left in supine and prone position.

We performed a voluntary Doppler sonographic screening program in healthy newborns since 1998. This program was offered to the parents of all newborns born in our department on a voluntary basis.

Our study was approved by the ethics commission of the University of Erlangen-Nuremberg.

After informed consent of the parents, blood flow in the basilar artery was measured in neutral position (infant supine with head in the midline). From the flow profile the peak systolic flow velocity and the time average flow velocities were measured. After rotation of the head to the right and left these flow velocities were additionally measured in supine and prone position. These flow velocities were compared with the values in neutral position. The values in neutral position were the intra individual normal value of the infant (100%).

We assumed that the flow velocities in the basilar arteries did not significantly change during head rotation. We estimated that they were independent on body position and head rotation. This was the case in the great majority of our newborns.

In dependency on possible flow alterations during head rotation we divided the infants in 3 groups:

- Infants in which the flow velocities didn’t fall under 50% of the flow velocities in neutral position during head rotation. This was the case in the great majority of our newborns. These infants were judged as normal.
- Infants with a fall of one or both flow velocities under 50% of the initial value in neutral position were judged as abnormal (Figure 1a,b). Inspite of the fall of the flow velocities still an ante grade flow could be found.
- Infants with a biphasic or retrograde flow during head rotation were judged as pathologic (Figure 2a,b). In these infants the time average flow velocity fell dramatically.

Patients

Study group: We started our study in the year 1998. Till 2016 we investigated 31,945 newborns, 15,521 girls and 16,424 boys. The mean gestational age of the infants was 38, 76 + 2, 13 week; mean birth weight was 3288 + 585 g. The infants were investigated in the newborn period with a mean actual age of 10, 3 + 13, 4 days.

Control group: 4122 parents did not make advantage of our voluntary screening offer. These infants served as a control group.

The occurrence of SID in both groups was compared with each other.

RESULTS AND DISCUSSION

Results

- In 31,544 newborns (98, 74%) the flow in the basilar artery was independent on head and body position. That means that the peak and time average flow velocity did not fall under 50% of the initial values during head rotation. There was no difference between rotations to either side.
- 323 newborns showed a reduction of the peak and/or the time average flow velocity under 50% of the value in neutral position. In these infants still a forward flow could be found (Figure 1a,b). Flow reductions occurred as well on the right and left side without favoring one side.
- In 78 infants a pathologic retrograde or biphasic flow could be found during head rotation (Figure 2a,b,c). In these patients a dramatic fall of the time average velocity could be found. That led to a dramatic fall of volume flow to the basilar artery supplying the brainstem.
- Abnormal or pathologic flow was caused by compression of the contra lateral vertebral artery at the cranio-cervical junction.
- The majority of patients with abnormal or pathologic flow
had a unilateral hypoplastic or aplastic vertebral artery
• If the normal sized, leading vertebral artery is compressed during head rotation the hypoplastic (or aplastic) contralateral vertebral artery can no longer supply enough blood flow to the brainstem.

**Summarizing our results:** The flow in the basilar artery is normally independent on head rotation and body position.

• In 98, 74% the flow in the basilar artery did not change during head rotation either in supine or prone position.
• In 1, 01% of the infants however flow fell below 50% of the initial value in neutral position during head rotation.
• Only 0, 24% of the infants showed a pathologic biphasic or retrograde flow during head rotation. In both situations the time average flow velocity fell dramatically. This causes a
Figure 2a Pathologic biphasic flow in the basilar artery during head rotation in prone position. The pathologic flow profile is caused by blockage of the contralateral vertebral artery at the cranio-cervical junction. During rotation a biphasic flow could be shown which leads to a dramatic fall of the time average velocity and may lead to hypoperfusion of the brainstem.

Figure 2b Pathologic retrograde flow in the basilar artery: No diastolic flow. The pathologic flow profile is caused by blockage of the contralateral vertebral artery at the cranio-cervical junction. As the time average flow velocity falls dramatically hypoperfusion of the brainstem may occur.

Drop of volume flow and perfusion of the brainstem.

The flow alterations were more pronounced in prone than in supine position.

The parents were encouraged to avoid potentially dangerous head rotations. All infants with pathologic flow got a home monitor which registered the heart rate and respiration. All parents were instructed in infant reanimation methods.

Repeated Doppler sonographic controls in intervals of 3 months showed gradual normalization of pathologic flow profiles and flow velocities during the first year of life. Normalization occurred earlier in supine than in prone position.

The occurrences of SID in the screening group and in the control group without screening were compared with each other.

Occurrence of SID: None of our newborns with abnormal or
Figure 2c Dynamic investigation of the blood flow in the basilar artery. During rotation gradual compression of the vertebral artery which leads to a continuous flow reduction in the basilar artery. Rotation of 80° causes a reduction of the flow velocities but still forward flow. Rotation of 85° causes a reverse of the flow profile with missing diastolic flow. The retrograde flow is caused by the blockage of the vertebral arteries during rotation. In these cases the basilar artery is perfused by the circle of Willis.

pathologic flow died of SID. This may be due to our treatment protocol, avoiding head rotations which were associated with abnormal or pathologic flow and monitoring the infants during sleep.

• On the other hand 2 infants (0, 06 ‰) with normal Doppler sonographic investigation died.

• In the control group without a Doppler sonographic screening program 5 infants (1, 21‰) died of SID.

The comparison between the two groups was statistically significant.

Discussion

Blood flow in the basilar artery normally is independent on head rotation and body position. In rare instances head rotations may cause a dramatic decrease of the flow velocities in the basilar artery. This may cause hypoperfusion of the brain stem and may lead to SID.

Our investigations showed that the pathologic flow in the basilar artery during head rotation is caused by a blockage of the vertebral artery contra lateral to the rotation side [5,6]. Especially if the other vertebral artery is hypoplastic, the not compressed hypoplastic artery can no longer supply enough blood to maintain a normal flow in the basilar artery. In the case of a unilateral aplastic vertebral artery blockage of the other vertebral artery may cause a dramatic fall of the flow in the basilar artery.

From the time average flow velocity (TAV) the volume flow (Q) in the basilar artery can theoretically be calculated according the following equation: Q = TAV x A (A is the cross sectional area of the artery). As A of the basilar artery is constant (the basilar artery is not compressed) volume flow Q is proportional to the TAV.

A dramatic fall of TAV causes a dramatic fall of the volume flow Q which may cause hypoperfusion of the brainstem. Repeated or longer lasting episodes of hypoperfusion may lead to ischemic injuries of the brainstem and cause bradycardia and apnea eventually leading to SIDS.

Our in vivo investigations are confirmed by pathologic anatomic investigations of Roger Pamphlett who investigated SIDS victims [2]. He demonstrated compression of the vertebral arteries at the craniovertebral junction during head rotation.

The reduction of the flow velocities in the basilar artery was more pronounced in prone than in supine position. In prone position the big head of the newborn baby is extremely turned to the side about 5° to 10° more than in supine position.

Repeated investigations during the first year of life showed gradual normalization. Normal flow occurred earlier in supine than in prone position. At birth the discrepancy between the large head and the small body is greatest. With advancing age this discrepancy gradually disappears. Improving neurodevelopment allow a better head control which prevents extreme head rotations especially in prone position. The risk for hypoperfusion of the brainstem during head rotation therefore gradually disappears.

The comparison of the SID incidence of the screening group with the infants without screening was statistically significant. In the control group the incidence of SID was similar to the incidence of SID during the last 20 years in Germany. The incidence in the screening group was much lower.
CONCLUSION

Our results show that blood flow in the basilar artery normally is independent on head rotation and body position

- In about 1% head rotation may cause a significant decrease of the flow velocities in the basilar artery leading to hypoperfusion of the brain stem
- The decrease is caused by a blockage of the contralateral (to the side of rotation) vertebral artery at the craniocervical junction during head rotation
- Our screening program demonstrates that hypoperfusion of the brain stem may be a cause of SID.
- Routine screening of the flow in the basilar artery may detect infants with a high risk of hypoperfusion of the brainstem.
- Avoiding head rotations which cause pathologic flow in the basilar artery may reduce the risk of SID.

REFERENCES