

The role of magnetic resonance tomography in assessing the effect of balloon atrioseptostomy on brain injuries in newborns with transposition of great arteries

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Introduction

Balloon atrioseptostomy (BAS) – is the chief instrument for correction of the critical condition in newborns with transposition of the great arteries (TGA) and intact ventricular septum. Before the definitive repair, i.e. the arterial switch operations (ASO) the atrioseptostomy remains the most effective palliative means to increase the oxygenation of arterial blood [9]. This endovascular surgery has both positive and negative aspects. According to the biggest retrospective research conducted by Mukherjee et al. that analyzed data on 8681 newborns with TGA, even though the BAS procedure does really decrease the number of death cases it also increases the risk of brain stroke. In newborns with TGA who underwent BAS the brain stroke occurred almost two times more often [10]. At the same time, Doshia H et al. pointed out that the research may lead to inaccurate conclusions [5]. Because such retrospective research didn't allow considering the age of patients during BAS and the time of brain stroke occurrence, it also made it impossible to correlate the degree of restriction at the level of atrium septum and the risk of brain strokes occurrence. The information in the two biggest foreign researches is controversial [1,10]. The research of Mukherjee et al. shows the interrelation between the CNS injuries and BAS however it does not state the exact reasons. Applegate et al. having analyzed the data on 2000 patients did not reveal the influence of BAS on the risk of brain stroke [1].

The only fact remains undisputable that the lesion of the interatrial septum results in subendocardial hemorrhage and fibrin accumulation towards the edge of the defect provoking clottage, when the

negative pressure in the introducer that is occurring at BAS doesn't allow eliminating the air aspiration and the risk of embolic complications.

Purpose. Based on MRI data to evaluate the risk of brain injury after BAS in newborns with TGA.

Material and methods

September 2009 through April 2012 a prospective brain MRI research was conducted involving 93 term newborns with TGA. In this research newborns were divided into groups based on performance of endovascular BAS procedure. Group A: 42 newborns with TGA who underwent brain MRI before BAS, with an average age at MRI - 3.6 ± 1.9 hours, mean age at ASO - 4 ± 2 hours. Group B: 51 newborns who underwent brain MRI after BAS, with mean age - 6.6 ± 4.0 days, mean age at BAS - 4.1 ± 3.4 days, and mean age at ASO - 8.1 ± 4.0 days. The scanning was performed with the use of 1,5 T MRI scanner (Magnetom Avanto, Siemens) in the presence of an anesthesiologist with the sedation of patients if necessary, and compulsory ECG, breathing and saturation rate monitoring. To reduce the time of the research the abbreviated protocol on neonate's brain MRI scanning based on priority of pulse patterns was used (Table 1).

Statistics data procession

The Relative Risk factor (RR) indicating the relationship between the influence and the disease was used to evaluate the interrelation between performance of BAS and the post-BAS outcome i.e. development of ischemic/hypoxic-ischemic

Table 1.
MRI protocol for neonate's brain examination based on priority of the MR sequences.

Priority level of MR sequences	MR sequences, axial	Time of examination (min.)	MR parameters
1	DWI	2:36	TR/TE=3600/112ms, FoV-230mm, slice thickness 4mm, gap=30%, matrix 192x192, 19 slice, NSA 4; b-factor 0, 500, 1000, 2000 sec/mm ² .
2	T1WI	5:45	TR/TE=574/12ms, FoV-160mm, slice thickness 3mm, gap=30%, matrix 256x256, 30 slice
3	SWI	5:50	TR/TE=49/40ms, FoV-230mm, slice thickness -1.6mm, gap=10%, matrix 320x320, 72 slice

brain injury. The bigger RR the more important its causation is. If RR=1, then the factor causes no influence, if RR<1, the factor has preventive effect.

The risk degree was evaluated based on the following:

1. Risk difference calculation (RD);
2. Relative risk indicator calculation (RR);
3. Calculation of 95% confidential interval (CI), i.e. for statistical significance p<0.05.

Results

The total number of patients exposed to the researched factor comprises 51. The total number of patients not exposed to the researched factor is 42. The portion of positive outcome among patients exposed to the researched factor is 62.7%. The portion of negative outcome among patients exposed to the researched factor is 37.3%. The portion of

negative outcome among patients not exposed to the researched factor is 100% (Table 2).

The number of patients with positive outcome is 32 (34.4%). The risk difference for the researched factor is 0.62. The Relative risk indicator for the researched factor is 2.7. There is the relationship between the outcome and the influence of the researched factor. 95% confidential interval ranking from 2.09279 to 3.49037.

Based on MRI data, 32 newborns within the group of patients who underwent BAS had brain lesions in the form of focal white matter injuries (WMI) and/or arterial ischemic brain stroke (fig.1-3). Clinical examination and neurosonography data at lacunar and cortical infarction and acute WMI were negative. Arterial ischemic stroke (fig.1,2) mainly caused by air embolism/ thromboembolism composed 46.8% (15/32) of all injuries that is 29.4% (15/51) within total patients' cohort. The risk difference for BAS and brain stroke composed 0.294118, relative risk

Table 2.
Results of statistical risk analysis.

Researches	Positive	Negative	Total
Exposed researches (after BAS)	32 (63%)	19 (37%)	51
Non-exposed researches (before/without BAS)	0	42 (100%)	42

indicator is 1.23, standard error for the relative risk indicator is 0.216053, 95% CI from 1.01 to 1.2. None of the patients before/without BAS had a brain stroke revealed. The mean age of newborns with arterial ischemic stroke at the moment of BAS was 6.7 ± 2.9 days and 2.5 ± 1.5 days without infarction.

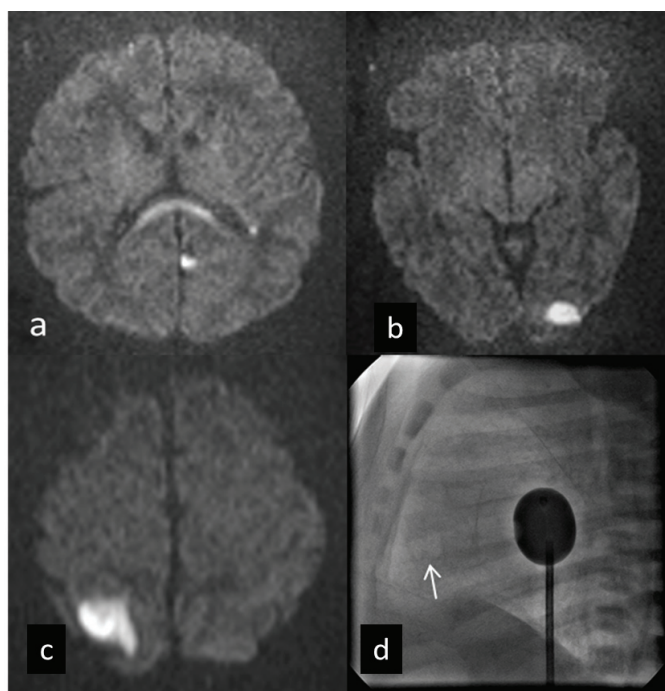


Fig. 1. 10-days-old newborn with TGA, underwent BAS at the age of 6 days old, brain MRI was performed before ASO. Axial DWI (a, b, c), $b=2000 \text{ sec/mm}^2$, shows multifocal arterial cortical stroke and hypoxic-ischemic WMI. On angiographic image in the projection of the right ventricle air bubbles (arrow) are visualized.

Discussion

The results of modern prospective studies and the retrospective evaluation of data registers do not presume final and complete approach to the choice of the harmless preoperative strategy in treatment of newborns with TGA in the meaning of neurological status [1,3,6-8,10-12].

Notwithstanding that our research shows high probability of brain injuries development after performing of BAS (RD - 0.62, RR-2.7, CI: 2.0-3.4) the intervention shall not be considered as the reason for WMI. This type of injuries is revealed both before and after BAS [10], and as shown by foreign studies, associated with the level and duration of systemic hypoxemia [11]. The white matter injury that occurred after BAS, as explained by Petit CJ et al. [11] is due to ineffective oxygenation restoration or additional reasons like low and unstable blood pressure or non-optimal ventilation parameters, etc.

We believe that BAS is the risk factor in the development of various arterial ischemic brain injuries like lacunar, cortical, or territorial (RD - 0.29, RR-1.2, CI: 1.0-1.2). In this regard, the risk of procedure in a greater degree increases at late BAS performance when the brain tissues have already been exposed to long-lasting postnatal systemic hypoxemia (mean age of newborns with brain stroke - 6.7 ± 2.9 days and 2.5 ± 1.5 days after BAS without injuries).

In earlier published foreign researches [3,6] the authors also attempted to explain the difference in the number of revealed brain injuries and uncertainty of their association with BAS (RD 63% vs 6%) by

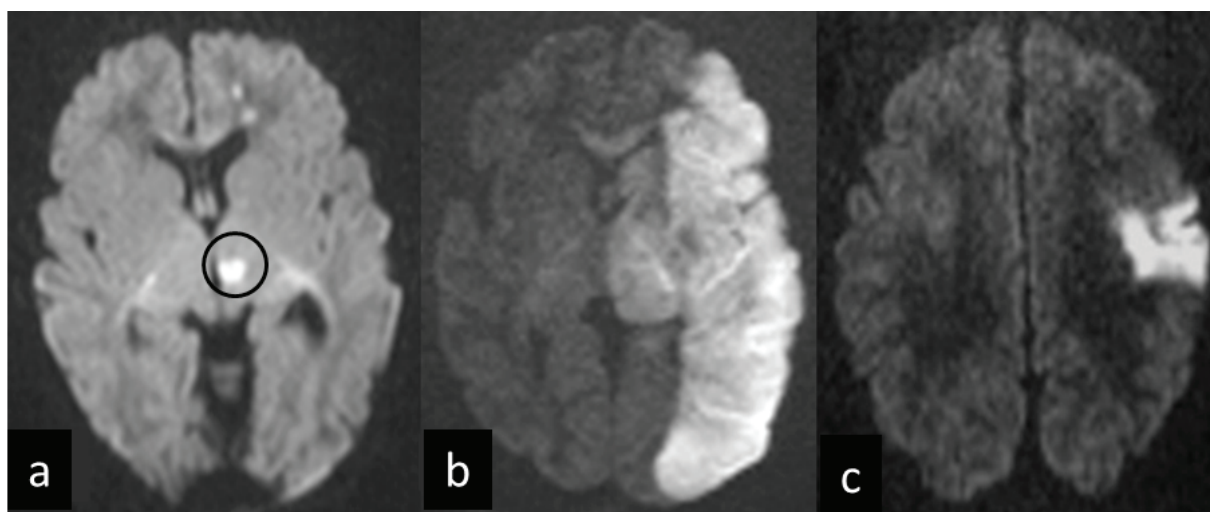


Fig. 2. Different types of preoperative brain stroke in newborns with TGA (a - lacunar stroke, b - territorial stroke, c - cortical stroke).

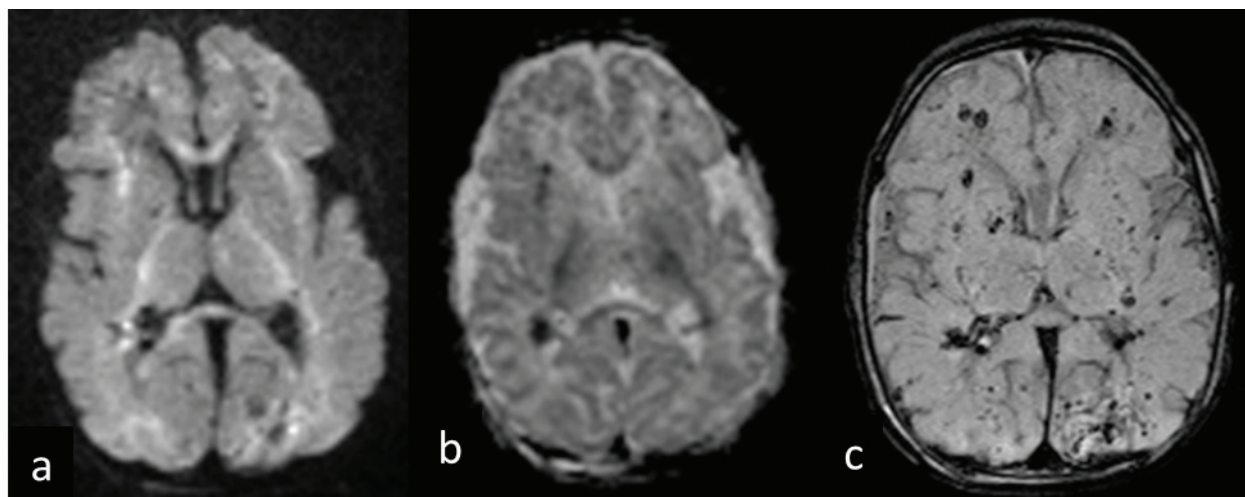


Fig. 3. 10-days-old newborn with TGA, underwent BAS at the age of 7 days, mean SaO₂ - 55%. Axial ADC-map (a, b), $b=2000 \text{ sec/mm}^2$, SWI (c). Multifocal bilateral WMI with multiple petechial hemorrhagic impregnation of brain lesions.

a different research structure and clinical condition of patients, and the peculiarities of radiological interpretation of a brain stroke. It would be incorrect to state that MRI produced false-negative results because the same MR- pulse sequences, sometimes even thinner scans (1-2mm), were used. Even that the timeframe from the moment of BAS to MRI in the research of John Beca et al. [3] is somewhat bigger though sufficient for a brain stroke imaging on DWI and T2-WI. The focal arterial ischemic stroke is a circumscribed area with decreased MR-signal intensity on ADC-maps or focal high MR-signal intensity on T2-WI in a defined arterial distribution [2]. This definition describes the type of MR imaging and the assumed physiological mechanism of the injury development. For newborns with TGA the combination of the earlier proposed radiological and pathophysiological definition of stroke may not work. Ischemia resulted in transcatheter procedures and use of intracardiac bypass, and due to the emboli “flow” may involve several arterial distributions. The most difficult to interpret are isolated punctate subcortical lesions associated with the diffusion decrease and bigger than typical WMI (1-2 sm). It is difficult to state whether these lesions are small stroke or represent separate, large focus of WMI. For instance, Block AJ et al. [4] describes single focus of injury $\leq 3 \text{ mm}$ as WMI and, at the same time, interprets bigger lesions as brain stroke. It is also possible that lacunar stroke in the context of major focal injuries of white matter were not distinguished as another additional model of the central nervous system injury.

Taking into consideration that not just BAS itself is the risk factor for brain injuries, also the repeal of the procedure may cause the WMI associated with the prolonged systemic hypoxemia. We believe, in case the ASO is impossible to perform within the first post natal hours or due to critical physical condition of a newborn at the time of admittance to clinic, the BAS intervention shall be considered as the necessary clinical option. In addition, the monitoring of the neurological status of a newborn by means of diffusion neuroimaging will be required.

Conclusion

Balloon atrioseptostomy is the risk factor for the development of brain arterial ischemic stroke in newborns with TGA, however the brain sensitivity to cardiac and embolic complications increases in the course of prolonged systemic hypoxemia.

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МАГНІТНО-РЕЗОНАНСНА ТОМОГРАФІЯ В ОЦІНЦІ ВПЛИВУ БАЛОННОЇ АТРИОСЕПТОСТОМІЇ НА РИЗИК УРАЖЕННЯ ГОЛОВНОГО МОЗКУ НОВОНАРОДЖЕНИХ З ТРАНСПОЗИЦІЄЮ МАГІСТРАЛЬНИХ АРТЕРІЙ

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Резюме. В статті проаналізовано результати власного проспективного дослідження 93 новонароджених з діагнозом ТМА, яким виконувалась МРТ головного мозку з ціллю визначення впливу БАС на ризик виникнення уражень ЦНС. Вік пацієнтів складав від 1,5 години до 14 днів. До БАС було обстежено немовлят перших годин життя, середній вік яких у подальшому на момент проведення операції артеріального переключення складав від 2 до 6 годин. Результати дослідження показали, що БАС є фактором ризику формування артеріальних ішемічних інфарктів головного мозку, при цьому чутливість мозку до кардіоеMBOLІЧНИХ ускладнень зростає на фоні тривалої системної гіпоксемії.

МАГНІТНО-РЕЗОНАНСНАЯ ТОМОГРАФИЯ В ОЦЕНКЕ ВЛИЯНИЯ БАЛОННОЙ АТРИОСЕПТОСТОМИИ НА РИСК ПОРАЖЕНИЯ ГОЛОВНОГО МОЗГА НОВОРОЖДЕННЫХ С ТРАНСПОЗИЦИЕЙ МАГИСТРАЛЬНЫХ АРТЕРИЙ

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Резюме. В статье проанализированы результаты собственного проспективного исследования 93 новорожденных с диагнозом ТМА, которым выполнялась МРТ головного мозга с целью определения влияния БАС на риска возникновения поражений ЦНС. Возраст пациентов варьировал от 1.5 часа до 14 дней. До БАС обследованы младенцы первых часов жизни, средний возраст которых в последующем на момент проведения операции артериального переключения варьировал от 2 до 6 часов. Результаты исследования показали, что БАС является фактором риска формирования артериальных ишемических инфарктов головного мозга, при этом чувствительность мозга к кардиоэмболическим осложнениям возрастает на фоне продолжительной системной гипоксемии.