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Research Article – Embryology

How does Adamkiewicz artery influence blood supply to the fetal spinal cord?

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Abstract

Adamkiewicz artery became important in clinical practice since it was noticed that its damage during aorta aneurysm repair surgery can sometimes lead to distal spinal cord ischemia. The complexity of anatomical variations can be related to the development of spinal cord arteries. The aim was to describe topography of Adamkiewicz artery and its relations to the anterior spinal artery in fetuses. The study was carried on 4 Batson's resin corrosion casts and 24 formalin-fixed fetuses injected with dyed gelatin or latex aged 15-24 weeks gestational age. In fixed specimens vertebral canals were dissected, the anterior spinal artery was traced and Adamkiewicz artery localized. Arteries were photographed and digitally measured. Data were afterwards statistically analyzed. Anterior spinal artery was duplicated in 3/28 cases. There were from 1 to 3 Adamkiewicz arteries per specimen, mean 1.71. No relation was found between the number of Adamkiewicz artery and age. In 37/48 cases Adamkiewicz artery emptied into the anterior spinal artery on the left side. Mean degree of narrowing in anterior spinal artery (diameter of the anterior spinal artery above junction with Adamkiewicz artery divided by its diameter under that junction) was 76.74%. The diameter of Adamkiewicz artery was also correlated linearly with the degree of narrowing of anterior spinal artery ($r=0.68$; $p<0.05$). The arteries of the anterior aspect of thoracolumbar spinal cord in the 2nd trimester of pregnancy represent the adult pattern. A potentially great impact of Adamkiewicz artery on the distal spinal cord circulation may be postulated on the basis of these morphological data.

Key words

Spinal cord vascularization, anterior spinal artery, great radicular artery.

Introduction

The importance of the great radicular artery (great anterior segmental medullary artery, latin: arteria radicularis magna) described first by Adamkiewicz in 1882, has been undisputable since surgical treatment of the aneurysms of aorta became a routine procedure. This vessel is widely known as the Adamkiewicz artery. The recommendations to preserve or reconstruct blood supply to the cord by this vessel during surgery are still discussed. It is mainly related to multiple variations of thoracolumbar spinal cord vascularization, these manifest in different clinical outcomes in the studies that have been held.

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Adamkiewicz artery is said to be the largest segmental aortic branch supplying the anterior spinal artery in its thoracic or lumbar portion. It normally originates as intercostal or lumbar artery; it varies in the level of origin and the side (Adamkiewicz, 1882; Charles, 2011). But, as Lazorthes et al. (1971) emphasized, the existence of a couple of smaller radiculomedullary arteries in thoracic and lumbar regions also plays a role in the vascularization of the spinal cord. The anterior spinal artery, into which Adamkiewicz artery always empties, is the largest, unpaired arterial vessel running on the anterior aspect of the spinal cord: it begins at the brain stem level as the connection of two branches from the right and left vertebral arteries.

It is well known that a classical definition of Adamkiewicz artery as the only important vessel supplying the thoracolumbar portion of the spinal cord is at least "incomplete". The number of possible variations is directly related to the development of the spinal cord vascularization. Only a few articles treat this subject, thus we decided to study the fetal anatomy of the spinal cord arteries in the second trimester of pregnancy and to focus on the role of Adamkiewicz artery in particular.

Materials and Methods

This study was performed on 28 fetal specimens from spontaneous miscarriages, aged 15 to 24 weeks of gestation, from the collection of the Department of Descriptive and Clinical Anatomy, Medical University of Warsaw. In all cases parental consent was received. None of the fetuses presented with morphological malformations.

Four specimens were infused with Batson resin and then put in a natrium hydroxide solution, which effectively gave arterio-venous corrosion casts.

Twenty-four specimens were injected with dyed gelatin or latex and then fixed in 10% formalin solution for at least two weeks. After fixation, we visualized the anterior surface of the vertebral column and afterwards, using a SMZ 1500 microscope (Nikon, Tokyo, Japan) and microsurgical technique, we removed all the vertebral bodies and opened the vertebral canal from T3 to S1. Dura mater was dissected in order to allow the exposure of the anterior surface of the spinal cord.

Each specimen was labeled and described, all findings were documented using photographs taken with a DS-Fil camera and NIS-Elements software (Nikon); in 21 cases we also digitally measured Adamkiewicz artery diameter and anterior spinal artery diameter above and under the junction to Adamkiewicz artery. In all cases we counted the number of eventual multiple Adamkiewicz arteries and assessed lateralization, level of derivation from intercostal or lumbar arteries and level of junction to anterior spinal artery, always in regard to the vertebral bodies and arches. Adamkiewicz artery was defined as the largest spinal branch or, if there were more, two or three approximate branches (Figs. 1-2).

The obtained data is presented as mean values with standard deviations (SD). We performed statistical analysis of correlation; Pearson's correlation factor was calculated and likehood ratio presented as p-value. We used Statistica 10.0 software (StatSoft, Inc., Tulsa, OK, USA). p-value smaller than 0.05 was considered as statistically significant. All values were rounded to two decimal places.

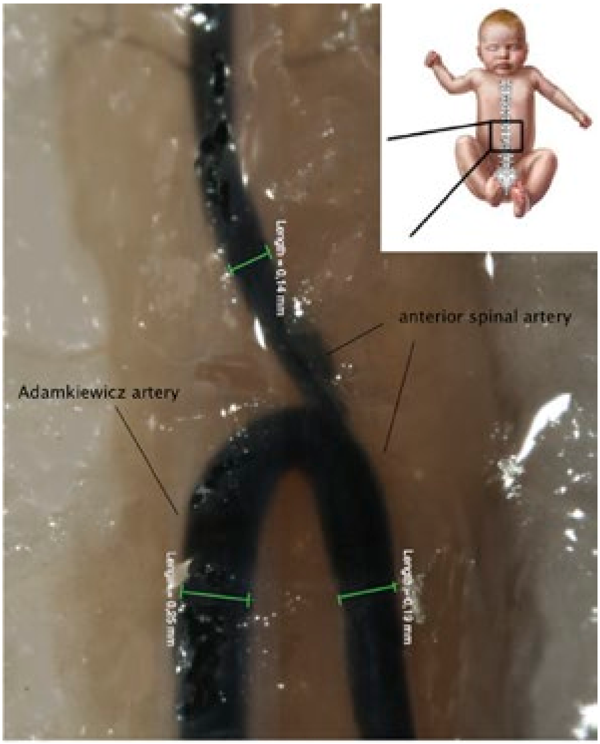

Figure 1 – Anterior spinal artery with Adamkiewicz artery injected with black latex in a 22 week old formalin fixed fetus.

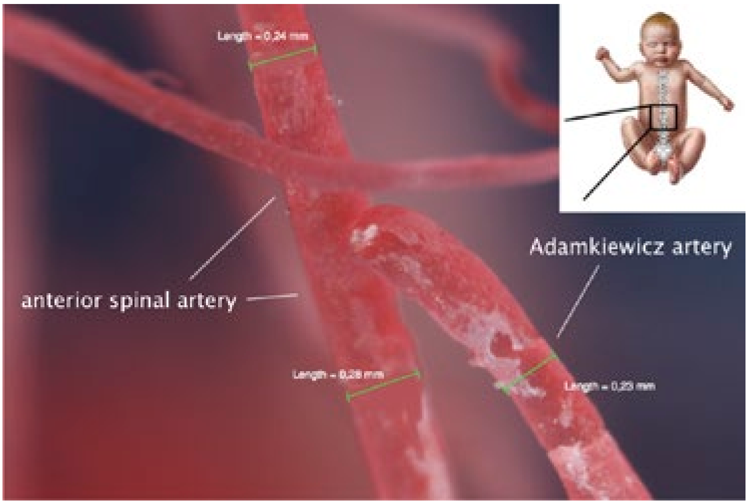

Figure 2 – Anterior apinal artery and Adamkiewicz artery in an arterial corosion cast specimen of 21 week old fetus.

Results

The anterior spinal artery was well visualized throughout its course (from T3 to S1) in each of the specimens; in 3 cases a bifurcation of anterior spinal artery was observed (in 2 cases from L2 downwards, i.e. on the surface of cauda equina, and in 1 case from T11 to L1).

The number of Adamkiewicz arteries varied from 1 to 3 (mean 1.71, SD 0.66). In 14 out of 28 examined cases (50%) there were 2 Adamkiewicz arteries, in 3 cases (10.71%) 3 Adamkiewicz arteries were found.

There was no correlation between the number of Adamkiewicz arteries and fetal age (r=0.08, p=0.69).

In 37/48 cases (77.08%) Adamkiewicz artery reached the anterior spinal artery from the left side. In cases with a single vessel identified as Adamkiewicz artery, 6/11 were on the left side. When there were two Adamkiewicz arteries, they were both on the left side in 11/14 cases and bilateral in the remaining 3/14 cases. In all three cases where three Adamkiewicz arteries were observed two were on the left and one on the right side. Details on number and side of Adamkiewicz arteries per specimen are presented in Figure 3.

Adamkiewicz artery originated from an intercostal or a lumbar artery at a level between T6/T7 intervertebral foramen (6th intercostal artery) to L3/L4 intervertebral foramen (3rd lumbar artery). Forty-four cases (91.67%) originated between T8/T9 and L2/L3. In case of double Adamkiewicz artery the arteries derived usually within a distance of 3 to 4 intervertebral foramina. More detailed description of all double Adamkiewicz artery cases is shown in Figure 4.

Adamkiewicz artery emptied into the anterior spinal artery at the level between T5 to L2; in 83.33% cases the level of the junction was located between T7 and T12.

The degree of narrowing of anterior spinal artery was expressed as the relation of the diameter of anterior spinal artery above the connection with Adamkiewicz artery

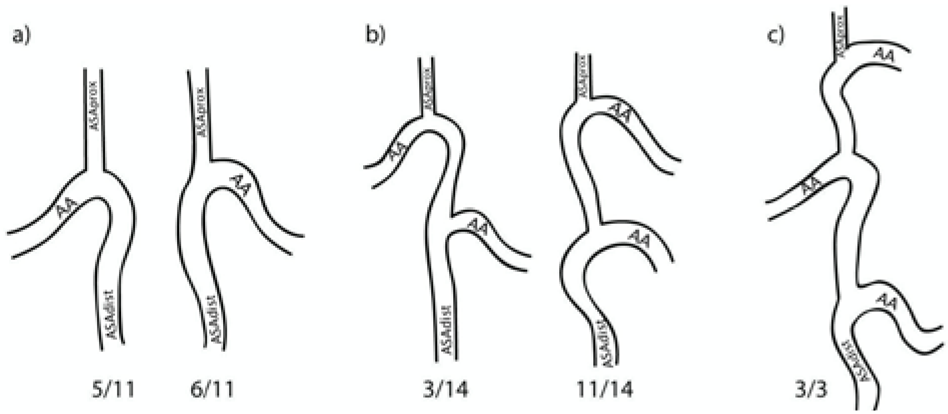

Figure 3 – Adamkiewicz artery side of origin (arteries are presented in random order); a) cases with one Adamkiewicz artery; b) cases with two Adamkiewicz arteries; c) cases with three Adamkiewicz arteries. AA: Adamkiewicz artery; ASAprox: proximal portion of the anterior spinal artery; ASAdist: distal portion of the anterior spianl artery.

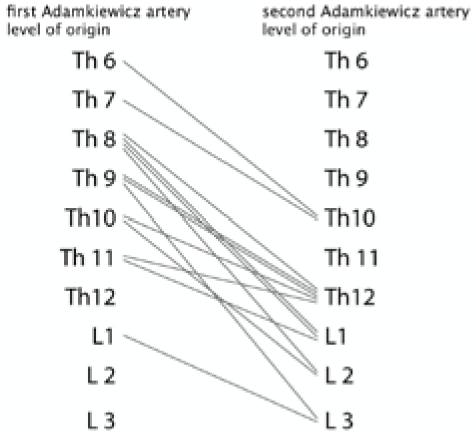

Figure 4 – Level of origin of Adamkiewicz artery in the cases where two Adamkiewicz arteries were found. The lines connect the levels of the two Adamkiewicz arteries of each case.

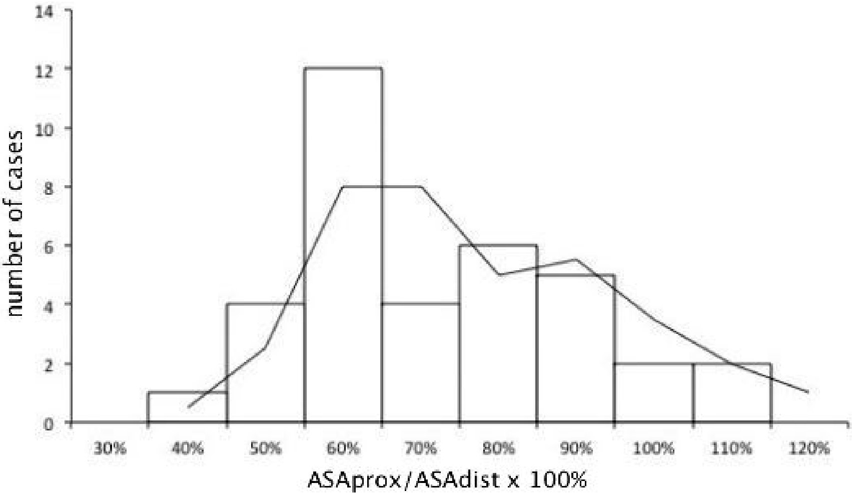

Figure 5 – Degrees of narrowing of anterior spinal artery (ASAprox/ASAdist). ASAprox: proximal portion of the anterior spinal artery; ASAdist: distal portion of the anterior spianl artery.

(ASAprox) to its diameter under the connection (ASAdist). The mean value was 76.74%, SD 17.53. The distribution of the degree of narrowing of anterior spinal artery is shown in Figure 5.

To determine the role of Adamkiewicz artery in spinal cord circulation, relation of the diameter of Adamkiewicz artery to the diameter of anterior spinal artery above the junction (ASAprox) was calculated – mean 1.21, SD 0.40. Obtained values were then compared to the degree of narrowing of anterior spinal artery and

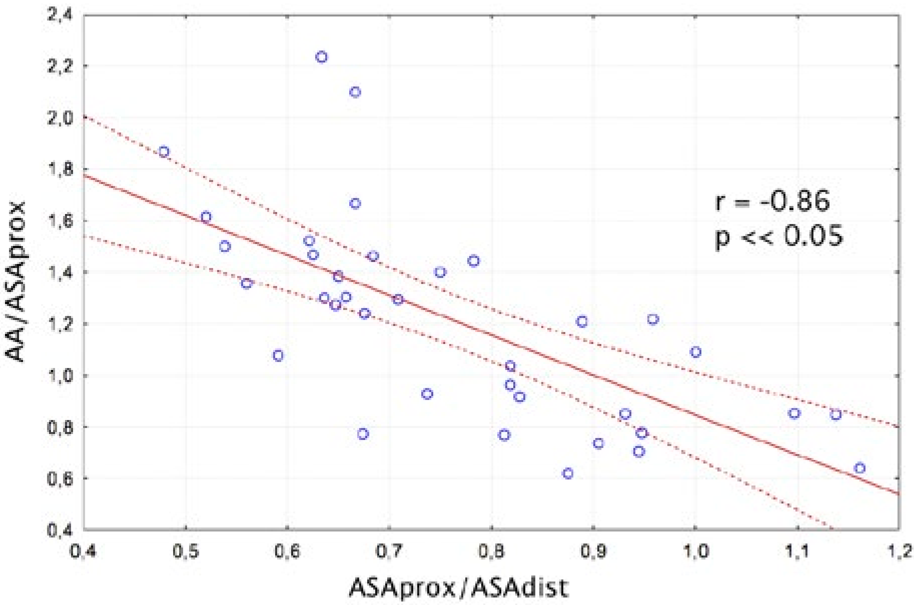

Figure 6 – Correlation between the degree of narrowing of the anterior apinal artery (AA/ASAprox) and the Adamkiewicz-artery-to-proximal-anterior-spinal-artery (ASAprox/ASAdist) diameter ratio. The dotted lines indicate 95% confidence interval. AA: Adamkiewicz artery; ASAprox: proximal portion of the anterior spinal artery; ASAdist: distal portion of the anterior spianl artery.

a strong negative linear correlation was observed – $r=0.68$, $p<<0.05$. This relation is presented in Figure 6.

Discussion

It is good to start with a short description of classic arterial anatomy of the anterior surface of thoracolumbar spinal cord in adults. The anterior spinal artery, the main arterial vessel of the spinal cord, is supplied by 1) a couple of smaller segmental branches in high thoracic region, 2) Adamkiewicz artery in thoracolumbar region and 3) radiculo-spinal arteries (of different importance) in sacral region (Charles et al., 2011; Melissano et al., 2010). The branches on left side are dominant (Melissano et al., 2010).

Our description of arteries of the fetal spinal cord (between 15 and 24 weeks of gestational age) is not significantly different from that presented above. Zawilinski et al. (2001) already reported the bifurcation of the anterior spinal artery, it was found in our study in 3 cases; the previous description, however, regarded the cervical portion of this vessel (Zawilinski et al., 2001). This bifurcation may be a developmental stage, representing many contributories from left and right side that would eventually create the anterior spinal artery. This pattern of spinal cord arteries can be observed to adulthood on the posterior cord surface, as two independent posterior spinal arteries (Zawilinski et al, 2001).

The mean number of Adamkiewicz arteries per case found here (1.71) is similar to the data reported by Koshino et al. (1999) and Nojiri et al. (2007) in studies on adult populations (1.3-1.4). The slightly higher mean number per case in our study may be explained by a different identification of a vessel as an Adamkiewicz artery, an issue raised by Koshino et al. (1999). To date, there exists no comprehensive definition of Adamkiewicz artery, which seems to be the most significant limitation of current and the majority of previous studies. Furthermore, Koshino et al. (1999) suggested that the number of Adamkiewicz arteries may be related to the ethnic group. The lateralization of Adamkiewicz artery leaves no doubts: the domination on the left side was similar to what reported from other studies (Charles et al., 2011; Koshino et al., 1999; Nojiri et al., 2007; Morishita et al., 2003).

The level of origin of Adamkiewicz artery from an intercostal or lumbar artery (in a range of six vertebrae for over 90% of studied group) corresponds to the data presented by Charles et al. (2011) and Koshino et al. (1999). The distance between two Adamkiewicz arteries in the majority of cases extends between 3 and 4 vertebral bodies, but it may vary from 1 to 6 vertebral levels, similar to what reported by Koshino et al. (1999).

Although statistical data suggest the existence of some dominant patterns, in daily clinical practice the great number of variations of Adamkiewicz artery needs to be held in mind. Dommisse (1974) in his work presented multiple cases of spinal cord vascularization and did not classify them into types. Neither we present any dominant pattern.

Our study shows that there is no significant change in the number of Adamkiewicz arteries per case with time of gestation. The findings agree with those of Zawilinski at al. (2001) who found similar results in fetuses aged between 19-28 weeks of gestational age as in adults.

The influence of Adamkiewicz artery to the blood supply of the distal spinal cord needed to be determined. We used a similar method as Morishita et al. (2003), who were the first to measure the degree of narrowing of the anterior spinal artery (ASAprox/ASAdist*100%) and that of Adamkiewicz artery (AA) to the proximal anterior spinal artery (AA/ASAprox). The observed statistically significant negative correlation between these parameters suggests a great role of Adamkiewicz artery for the distal spinal cord circulation in fetal period, which may continue all life long. The narrowing of the anterior spinal artery itself was reported by Dommisse (1974) to be sometimes a critical determinant for distal cord circulation. This parameter was at least as important in our studied population as in adults.

The results presented above can be brought to daily clinical practice by emphasizing that all the procedures that potentially compromise arterial blood flow to spinal cord in newborns and infants, for example catheterization of big systemic arterial vessels, open thoraco-abdominal aorta surgery or spine and spinal cord surgery, have a similar-to-adult-population probability of causing distal spinal cord ischemia, which eventually leads to paraplegia and distal spine syndromes, as reported by Lin et al. (2009). There is great number of potential variations causing complications and no predefined risk factors

Acknowledgment

In all cases of fetal specimens the Department of Descriptive and Clinical Anatomy obtained a written parental consent to pursue academic research.

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