

Fetal-Type Variant of the Posterior Cerebral Artery and Concurrent Bilateral Cerebral Infarctions in a Korean Male Cadaver

Variante de Tipo Fetal de la Arteria Cerebral Posterior e Infartos Cerebrales Bilaterales Concurrentes en un Cadáver Masculino Coreano

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SUMMARY: Fetal-type variant of the posterior cerebral artery is a relatively common variant of the cerebral arterial circle (circle of Willis), but concurrent cerebral pathologies have not been well reported. We describe a case of fetal-type variant of the posterior cerebral artery and concurrent bilateral cerebral infarctions in the territories of the middle cerebral artery in a 78-year-old Korean male cadaver. Fetal-type variant of the posterior cerebral artery was found the right cerebral arterial circle, arose from the internal carotid artery with larger diameter than the pre-communicating segment from the basilar artery. Histopathological examination revealed that left supramarginal gyrus and right infraparietal lobule showed characteristic cerebral infarctions with chronological changes, respectively. Knowledge on the variation in the posterior cerebral artery combined with clinical features including cerebral infarction plays a pivotal role to anatomists and clinicians.

KEY WORDS: Cerebral arterial circle (Circle of Willis); Fetal-type variant; Cerebral infarction; Cadaver.

INTRODUCTION

Since Thomas Willis described the cerebral arterial circle “*circulus arteriosus cerebri*” (circle of Willis) in 1662, numerous anatomical variations have been reported. Padgett (1948) suggested the cerebral arterial circle and the permanent origins of its branches are fully formed at 6 to 7 weeks of estimated gestational age. However, variations in the diameter of the component vessels may occur, of which the size of the posterior communicating artery relative to the posterior cerebral artery is one of the main differences between the fetal and adult forms of the cerebral arterial circle (Seydel, 1964).

Basically in adults three configurations of the posterior bifurcation of the posterior communicating artery can be distinguished as follows (van Overbeeke *et al.*, 1991): 1) the normal posterior part of the cerebral arterial circle in which the pre-communicating part of the posterior cerebral artery (PCA) from the basilar artery (P1) has a diameter larger than the PCA (the adult-type); 2) the PCA and P1 have the same diameter and make an approximately

equal contribution to the PCA distal to the cerebral arterial circle (a transitional-type), and 3) the diameter of the P1 is smaller than the diameter of the PCA and the blood supply to the occipital lobes is mainly from the internal carotid artery (a fetal- or embryonic-type). During fetal and infant stage, a transitional-type is found up to 73 % before 20th week after conception. The frequencies of the adult- and fetal- (higher percentage up to 35 %) types gradually increase at the expense of the transitional-type. The frequency of fetal-type variant of the PCA is reported 5.8 – 40 % of adult cerebral arterial circle (van Overbeeke *et al.*, 1991).

Hypoplastic segments (including P1) have a high rate of association with aneurysms of the cerebral arterial circle (Milenkovic *et al.*, 1985; Vasovic *et al.*, 2013), but there were no significant relationships between a presence of different cerebral arterial circle types in cases with the cerebral cause of death and a presence of aneurysms (Vasovic *et al.*, 2013). In addition, the association of the

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cerebral arterial circle abnormalities and neurodegenerative pathologies did not show any significance also (Wijesinghe *et al.*, 2020). However, fetal-type variant of the PCA might be a feasible risk factor for rupture (Xu *et al.*, 2019), recurrence (Lee *et al.*, 2021) or recanalization (Choi *et al.*, 2020) of posterior communicating artery aneurysms.

Interestingly, a significant association was reported between microscopic infarcts in deep white matter and hypoplasia in communicating arteries (Wijesinghe *et al.*, 2020). Herein, we report a case of concurrent bilateral cerebral infarctions in the setting of a unilateral fetal-type variant of the PCA.

MATERIAL AND METHOD

During routine educational dissection, the fetal-type variant of the PCA and concurrent bilateral cerebral infarctions were observed in a 78-year-old Korean male cadaver whose cause of death was cardiac arrest. This study was approved by the Institutional Review Board of Jeju National University.

All the vessels consisting cerebral arterial circle were examined and the external caliber of the arteries was measured by digital caliper. The brain tissues were excised and then processed for paraffin embedding (ASP300S, Leica Biosystems, Wetzlar, Germany). The paraffin-embedded tissue blocks were cut into 4 μm -thick slices and stained with hematoxylin and eosin (H/E) using an autostainer (Tissue-Tek Prisma, Sakura Finetek, Tokyo, Japan).

RESULTS

On the right side of the cerebral arterial circle, fetal-type variant of the PCA (2.8 mm in external caliber) was found which was arose from the internal carotid artery (4.6 mm in external caliber) with larger diameter than the P1 (1.2 mm in external caliber) from the basilar artery (4.2 mm in external caliber). The left PCA and posterior communicating artery showed 2.5mm and 1.5mm in external caliber, respectively. No additional vascular variations including aneurysms in the cerebral arterial circle and its first bifurcation sites were found.

The surface of the left brain was discolored and depressed around the supramarginal gyrus (Fig. 2A). On section, the lesion brain parenchyme was diffusely

softened. Microscopically, the brain parenchymal structure was destructed and surrounded by acute hemorrhage in the cortical surface (Fig. 2B and 2C). The destructed area of the brain parenchyme was replaced by numerous foamy histiocytes (Fig. 2D). Also observed were some red neurons scattered in the surrounding brain tissue (Fig. 2E).

The right brain had two foci of wedge-shaped defects in the inferior parietal lobule near the intraparietal sulcus. Grossly, the cortical architecture was disrupted on the cut surface (Fig. 3A and 3B). Under the microscope, the brain tissue was edematous and showed a few irregular cystic spaces (Fig. 3C). Some foamy histiocytes and a few hemosiderin-laden macrophages were scattered in the edematous areas and along the parenchymal surface (Fig. 3D). Remaining brain parenchyme revealed proliferation of reactive glial cells including some gemistocytic astrocytes and fibrillary gliosis in the background (Fig. 3E).

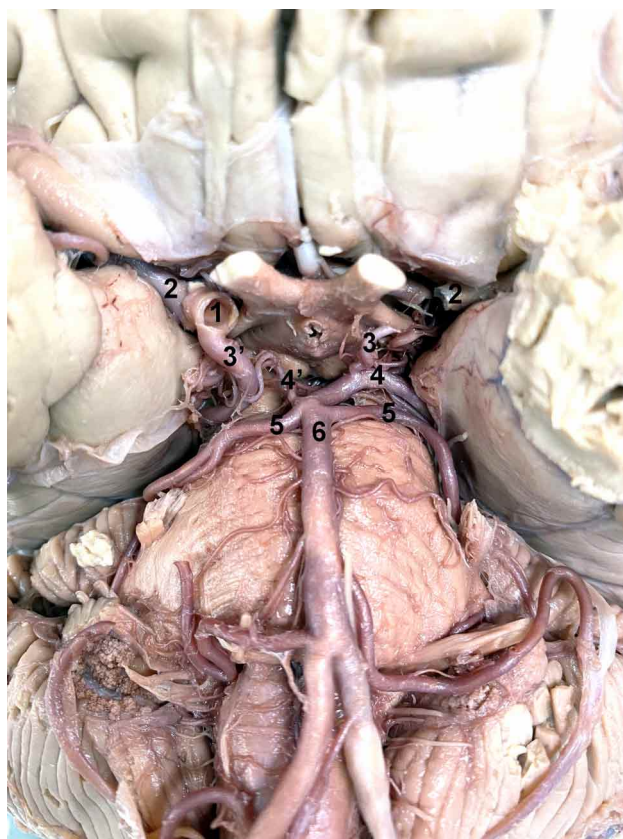


Fig. 1. Photograph of fetal-type variant of the posterior cerebral artery (right). 1, internal carotid artery; 2, middle cerebral artery; 3, posterior communicating artery; 4, posterior cerebral artery; 5, superior cerebellar artery; 6, basilar artery; 3', fetal-type variant of the posterior cerebral artery; 4', pre-communicating segment (P1) of the posterior cerebral artery

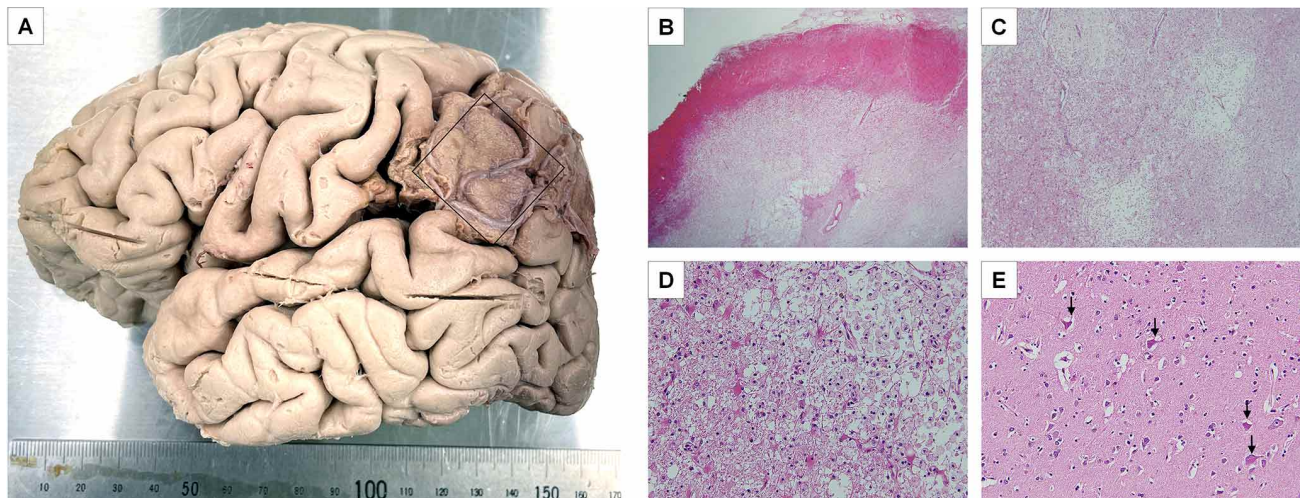


Fig. 2. Photomicrographs of left brain. A. Gross appearance of the discolored and depressed cortical lesion. Rectangle was further examined by H/E stain. Micrographs of B. loss of parenchymal tissue and associated acute hemorrhage (magnification x 10), C. dismantled cortical tissue (magnification x 40), D. numerous foamy histiocytes (magnification x 200), and E. red neurons (arrows) scattered in the surrounding parenchyme (magnification x 200).

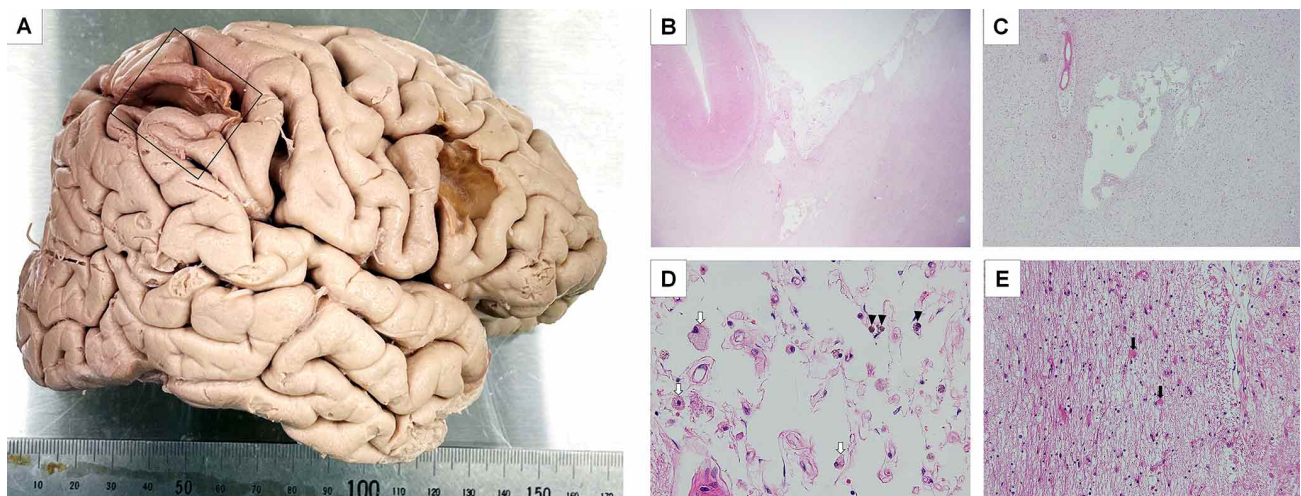


Fig. 3. Photomicrographs of right brain. A. Gross appearance of two parenchymal defects. Rectangle was further examined by H/E stain. Micrographs of B. a wedge-shaped empty cavity (magnification x 10), C. irregular cystic spaces surrounded by edematous brain tissue (magnification x 40), D. a few hemosiderin-laden macrophages (arrowheads) and foamy histiocytes (white arrows) (magnification x 400), and E. gemistocytic astrocytes (arrows) and fibrillary gliosis (magnification x 200).

DISCUSSION

At a gestational age of about 5 weeks (from the 4-mm to 12-mm embryo stage), the cerebral arterial circle formed by the carotid system and followed by the posterior circulation (Luh *et al.*, 1999). As the posterior cerebrum, cerebellum and brainstem grow, the posterior circulation develops from the primitive arterial mesh, longitudinal neural arteries (Lambert *et al.*, 2016; Roman-Filip *et al.*, 2021). Although the caudal internal carotid artery regresses becoming the posterior communicating artery in typical cerebral arterial circle, it might continue

to be dominant and becomes the fetal-type variant of the PCA. Therefore, the P1 regresses or may disappear, and furthermore two PCAs may emerge, one is derived from the internal carotid artery and the other is a classic PCA from the basilar artery.

As a result, fetal-type variant of the PCA including this report has been considered as a common anatomic variation. The frequency of fetal-type variant of the PCA is reported up to 40 % of adult cerebral arterial circle (van

Overbeeke *et al.*, 1991), which was reported 12.9 % (12/93 cadavers) (Chung *et al.*, 1980) to 18.2 % (63/347 cadavers) (Chun & Kwun, 1985) in Koreans. The fetal-type variant of the PCA in adults was more observed on the right than on the left as observed in this report. Bergman *et al.* (2022) summarized the frequency as 5.5 % on the right side, 4.5 % on the left side, and 2 % on both sides. In Koreans (Chung *et al.*, 1980; Chun & Kwun, 1985), the frequency was 8.2 % on the right side, 5.2 % on the left side, and 3.6 % on both sides. In addition, unilateral fetal-type variant of the PCA was significantly more frequent on the right (15 %) than on the left side (8 %) in an angiography study (Frid *et al.*, 2022).

Fetal-type variant of the PCA recently deserves more clinical attention, especially combined with cerebral infarctions. Almost all cerebral infarctions are caused by local vascular occlusions and can even occur without obstructions as in margin zone infarctions or when there is a reduction in perfusion pressure combined with a severe atherosclerotic stenosis. Histopathological changes by infarction go through ischemic change, liquefaction necrosis, phagocytic absorption, tissue loss, and empty space (Mena *et al.*, 2004; Kumar *et al.*, 2021). In this report, the histopathological features are compatible with cerebral infarction associated with secondary hemorrhage in the left brain, and the defect of the right brain might be the result of previous infarction and following liquefaction necrosis, phagocytic absorption, and resultant empty cavitory spaces.

Only a few cases of concurrent manifestation of cerebral infarction and fetal-type variant of the PCA have been reported. Fetal-type variant of the PCA was concurrently observed with ipsilateral multiple (middle cerebral artery and PCA) infarctions with stenotic internal carotid artery without known etiology (Kolukisa *et al.*, 2015), with ipsilateral multiple (anterior cerebral artery, middle cerebral artery, and PCA) infarctions or with contralateral multiple (middle cerebral artery and PCA) infarctions (Lambert *et al.*, 2016), and with thalamic infarction (Roman-Filip *et al.*, 2021).

Yang *et al.* (2007) reported that the fetal-type variant of the PCA was more frequently found in the ipsilateral hemisphere of patients with an infarction than in the control group (44.4 % vs 18.5 %) by both diffusion-weighted magnetic resonance imaging (DWI) and cerebral angiography (1388 patients), of which large artery atherosclerosis of the carotid artery was very common in patients with infarction. Recently, Frid *et al.* (2022) reported that the prevalence of any fetal-type variant of the PCA was similar in ischemic stroke patients (31 %

and unselected patients (32 %) with DWI and computed tomography angiography diagnosed with 1953 ischemic stroke patients.

Fetal-type variant of the PCA may positively affect clinical outcome in patients with ischemic stroke such as protection of a reserve blood flow capacity as well as negative effect on clinical outcome such as certain atypical pathological manifestations (Kolukisa *et al.*, 2015). Therefore, by being aware that a fetal-type variant of the PCA exists, clinicians can plan their approach or endovascular procedure to minimize the risk of perioperative complications (Lambert *et al.*, 2016). Interestingly, Klimek-Piotrowska *et al.* (2013) mentioned that comparison with imaging-based and cadaveric studies revealed noticeable difference on the cerebral arterial circle variations. The frequency of entire circle closed occurred almost 3 times more often in the cadaveric study. The posterior communicating artery was considered 'absence' in imaging-based studies, while considered 'hypoplasia' in cadaveric studies. The variable features such as the technical and ethnical factors should be considered, because a significant association was reported between microscopic infarcts in deep white matter and hypoplasia in communicating arteries (Wijesinghe *et al.*, 2020).

Taken together, we clearly showed a fetal-type variant of the PCA and concurrent bilateral cerebral infarctions. Although the variant is not uncommon based on embryological development, concurrent cerebral infarctions recently deserves clinical attention. This case report underscores the variable anatomy, clinical significance, and embryological origins of fetal-type variant of the PCA.

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RESUMEN: La variante de tipo fetal de la arteria cerebral posterior es una variante relativamente común del círculo arterial cerebral (polígono de Willis) de la arteria cerebral, pero las patologías cerebrales concurrentes no han sido bien informadas. Describimos un caso de variante de tipo fetal de la arteria cerebral posterior e infartos cerebrales bilaterales concurrentes en los territorios de la arteria cerebral media en un cadáver masculino coreano de 78 años.

La variante de tipo fetal de la arteria cerebral posterior se encontró en la parte de derecha del círculo arterial cerebral, surgido de la arteria carótida interna con mayor diámetro que el segmento precomunicante de la arteria basilar. El examen histopatológico reveló que el giro supramarginal izquierdo y el lóbulo infraparietal derecho mostraban infartos cerebrales característicos con cambios cronológicos, respectivamente. El conocimiento sobre la variación en la arteria cerebral posterior combinado con las características clínicas, incluido el infarto cerebral es fundamental para los anatomistas y los médicos.

PALABRAS CLAVE: Círculo de Willis; Variante de tipo fetal; Infarto cerebral; Cadáver.

REFERENCES

- Bergman, R. A.; Afifi, A. K. & Miyauchi, R. *Illustrated encyclopedia of human anatomic variation: Opus II: Cardiovascular system: Arteries: Head, Neck, and Thorax-Posterior Communicating Artery*, 2022. Available from: <https://www.anatomyatlases.org/AnatomicVariants/Cardiovascular/Text/Arteries/CommunicatingPosterior.shtml>
- Choi, H. H.; Cho, Y. D.; Yoo, D. H.; Lee, H. S.; Kim, S. H.; Jang, D.; Lee, S. H.; Cho, W. S.; Kang, H. S. & Kim, J. E. Impact of fetal-type posterior cerebral artery on recanalization of posterior communicating artery aneurysms after coil embolization: matched-pair case-control study. *J. Neurointerv. Surg.*, 12(8):783-7, 2020.
- Chun, M. H. & Kwun, H. S. Anatomical observation on the arteries of the brain in Korean adults. I. Circulus arteriosus cerebri. *J. Cathol. Med. Coll.*, 38(2):441-61, 1985.
- Chung, I. H.; Kim, H. J.; Han, Y. P. & Chang, J. H. The morphologic study of Willisian circle. *J. Korean Neurosurg. Soc.*, 9(2):345-56, 1980.
- Frid, P.; Wasselius, J.; Drake, M.; Wu, O.; Petersson, J.; Rost, N. S.; Lindgren, A. & MRI-GENIE study, the ISGC. Fetal posterior cerebral artery configurations in an ischemic stroke versus an unselected hospital population. *Acta Neurol. Scand.*, 145(3):297-304, 2022.
- Klimek-Piotrowska, W.; Kopec, M.; Kochana, M.; Krzyzewski, R. M.; Tomaszewski, K. A.; Brzegowy, P. & Walocha, J. Configurations of the circle of Willis: a computed tomography angiography based study on a Polish population. *Folia Morphol. (Warsz.)*, 72(4):293-9, 2013.
- Kolukisa, M.; Gürsoy, A. E.; Kocaman, G.; Dürüyen, H.; Toprak, H. & Asil, T. Carotid endarterectomy in a patient with posterior cerebral artery infarction: influence of fetal type PCA on atypical clinical course. *Case Rep. Neurol. Med.*, 2015:191202, 2015.
- Kumar, V.; Abbas, A. K. & Aster, J. C. *Robbins and Cotran's Pathologic Basis of Disease*. 10th ed. Philadelphia, Elsevier/Saunders, 2021. pp.1253-5.
- Lambert, S. L.; Williams, F. J.; Oganisyan, Z. Z.; Branch, L. A. & Mader Jr., E. C. Fetal-type variants of the posterior cerebral artery and concurrent infarction in the major arterial territories of the cerebral hemisphere. *J. Investig. Med. High Impact Case Rep.*, 4(3):2324709616665409, 2016.
- Lee, H. J.; Choi, J. H.; Shin, Y. S.; Lee, K. S. & Kim, B. S. Risk factors for the recurrence of posterior communicating artery aneurysm: the significance of fetal-type posterior cerebral artery. *J. Stroke Cerebrovasc. Dis.*, 30(7):105821, 2021.
- Luh, G. Y.; Dean, B. L.; Tomsick, T. A. & Wallace, R. C. The persistent fetal carotid-vertebrobasilar anastomoses. *AJR Am. J. Roentgenol.*, 172(5):1427-32, 1999.
- Mena, H.; Cadavid, D. & Rushing, E. J. Human cerebral infarct: a proposed histopathologic classification based on 137 cases. *Acta Neuropathol.*, 108(6):524-30, 2004.
- Milenkovic, Z.; Vucetic, R. & Puzic, M. Asymmetry and anomalies of the circle of Willis in fetal brain. Microsurgical study and functional remarks. *Surg. Neurol.*, 24(5):563-70, 1985.
- Padget, D.H. The development of the cranial arteries in the human embryo. *Contrib. Embryol.*, 32:205-61, 1948.
- Roman-Filip, C. C.; Stîngaciu, A. R.; Catana, M. G.; Dan, A. A.; Balas, A. F.; Juravle, C. & Grosu, F. Atypical posterior circulation strokes: a case-based review of rare anatomical variations involved. *Rom. J. Morphol. Embryol.*, 62(1):289-93, 2021.
- Seydel, H. G. The diameters of the cerebral arteries of the human fetus. *Anat. Rec.*, 150:79-88, 1964.
- Van Overbeeke, J. J.; Hillen, B. & Tulleken, C. A. A comparative study of the circle of Willis in fetal and adult life. The configuration of the posterior bifurcation of the posterior communicating artery. *J. Anat.*, 176:45-54, 1991.
- Vasovic, L.; Trandafilovic, M.; Jovanovic, I.; Ugrenovic, S.; Vlajkovic, S.; Milic, M. & Dordevic, G. Morphology of the cerebral arterial circle in the prenatal and postnatal period of Serbian population. *Childs Nerv. Syst.*, 29(12):2249-61, 2013.
- Wijesinghe, P.; Steinbusch, H. W. M.; Shankar, S. K.; Yasha, T. C. & De Silva, K. R. D. Circle of Willis abnormalities and their clinical importance in ageing brains: A cadaveric anatomical and pathological study. *J. Chem. Neuroanat.*, 106:101772, 2020.
- Xu, Z.; Kim, B. S.; Lee, K. S.; Choi, J. H. & Shin, Y. S. Morphological and clinical risk factors for the rupture of posterior communicating artery aneurysms: significance of fetal-type posterior cerebral artery. *Neurol. Sci.*, 40(11):2377-82, 2019.
- Yang, J. H.; Choi, H. Y.; Nam, H. S.; Kim, S. H.; Han, S. W. & Heo, J. H. Mechanism of infarction involving ipsilateral carotid and posterior cerebral artery territories. *Cerebrovasc. Dis.*, 24(5):445-51, 2007.

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