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Contents

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Contents

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EDITORIAL

Anatomizing the "King of Neurosciences"

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Abstract

The human nucleus accumbens (NA), a major part of the ventral striatum, is the area of continuity between the putamen and head of the caudate nucleus. It consists of two parts, a shell laterally and a core medially. The first is mainly connected to the limbic system and the second to the extrapyramidal motor system. The NA, a major pleasure center of the human brain, acts as a limbic-motor interface and is involved in several cognitive, emotional and psychomotor functions. It has a modulating function in the amygdala-basal ganglia-prefrontal cortex circuit. It is considered as the neural interface between motivation and action. Further, it is a principal modulator of the reward circuits and supplies motor expression to emotional responses. Such a clinical significance could easily explain the intense work taking place in the respective field of basic research. Its exceptional clinical importance justifies the title of the "King of Neurosciences" for this nucleus. Purpose of this editorial is to review the "informational paths" left behind by the few researchers who tried to explore the architecture (gross anatomy) of this 'kingdom'. The first anatomical study focused on this nucleus came from Neto *et al*. The most extensive study of the NA gross, imaging, stereotactic and neurosurgical anatomy so far, came from the research efforts of Mavridis *et al*.

Key words: Gross anatomy; Neurosciences; Neurosurgical anatomy; Nucleus accumbens; Stereotactic anatomy

Core tip: The human nucleus accumbens (NA), a major pleasure center of the brain, is a limbic-motor interface involved in several neurological and psychiatric disorders. It became recently a deep brain stimulation target for selected patients. Its exceptional clinical significance justifies its title as the "King of Neurosciences". Purpose of this editorial is to review the few studies who explored the NA gross anatomy. The first anatomical study focused on this nucleus came from Neto *et al*. The most extensive study of the NA gross, imaging, stereotactic and neurosurgical anatomy came from the research of Mavridis *et al*.

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THE HUMAN NUCLEUS ACCUMBENS

The human nucleus accumbens (NA), a major part of the ventral striatum, is the area of continuity between the putamen and head of the caudate nucleus[1]. It consists of two parts, a shell laterally and a core medially. The first is mainly connected to the limbic system and the second to the extrapyramidal motor system (Figure 1). NA's afferent connections include: hippocampus, frontal cortex, entorhinal cortex, amygdala, cingulate gyrus and thalamus. Its efferent connections include: striatum, globus pallidus, hypothalamus, prefrontal cortex, ventral tegmental area and substantia nigra. The principal neurotransmitters in NA circuits are

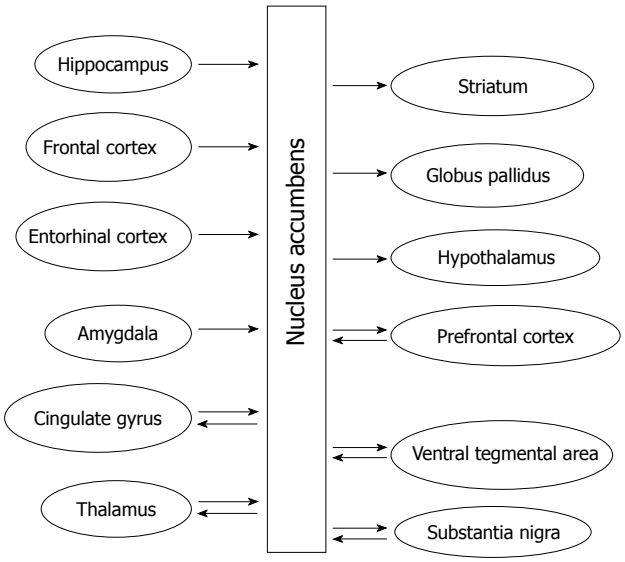

Figure 1 Nucleus accumbens connections. Schematic representation of the nucleus accumbens afferent and efferent connections within the human brain (modified from Mavridis[2]).

glutamic acid, dopamine and γ-aminobutyric acid (GABA)[2].

The NA, a major pleasure center of the human brain[2], acts as a limbic-motor interface and is involved in several cognitive, emotional and psychomotor functions[1]. It has a modulating function in the amygdala-basal ganglia-prefrontal cortex circuit. It is considered as the neural interface between motivation and action. Further, it is a principal modulator of the reward circuits and supplies motor expression to emotional responses[2]. The NA anatomical architecture and pathways, as well as the effect of different drugs on the NA have been studied on experimental animals.

"KING OF NEUROSCIENCES"

The human NA is involved in several neurological disorders including epilepsy, Parkinson's disease, Huntington's chorea, frontotemporal dementia, narcolepsy and spinocerebellar ataxia[2]. Given its great functional importance, it is not surprising that this nucleus is also involved in several psychiatric disorders such as obsessive-compulsive disorder, depression, Tourette syndrome, addiction, schizophrenia, bipolar disorder, attention-deficit/hyperactivity disorder, post-traumatic stress disorder and apathy[2]. Latest decade's advancements in Stereotactic Neurosurgery made the NA a deep brain stimulation target for selected patients mainly suffering from obsessive-compulsive disorder, depression and Tourette syndrome[2].

Such a clinical significance could easily explain the intense work taking place in the respective field of basic research. There are numerous neurochemical and neurobiological studies of the NA in the literature, usually focusing on neurons and neurotransmitters of this nucleus and its crucial connections. Moreover, there are several neuroimaging and some neuroanatomical studies of the human NA. The first are mainly magnetic resonance imaging (MRI) or functional MRI studies.

According to the above physiological and clinical data which aimed to light just the peak of the amazing iceberg, of the "Arctic Ocean of Neurosciences", called "human NA", I think that this exceptional nucleus rightfully deserves the crown of the "King of Neurosciences". Purpose of this editorial is to review the 'informational paths' left behind by the few researchers who tried to explore the architecture (gross anatomy) of this "kingdom".

GROSS ANATOMICAL STUDIES

Several animal studies have investigated the anatomy and physiology of the NA[1]. There are some studies that provided morphometric data of the human NA[1,3-7]. Methodologically, Yelnik *et al*[6] and Bardinet *et al*[7] used post-mortem brain MRIs (as well as dissections with cryomacrotome) for three-dimensional studying of the human basal ganglia. Xia *et al*[3] used T1-weighted high-resolution MRIs for studying the caudate nucleus (including findings about the NA). Ahsan *et al*[5] also used high-resolution MRIs for their volumetric study of the human basal ganglia and thalamus. Brabec *et al*[4] used anatomical dissections and MRIs for their volumetric study of the striatum. Neto *et al*[1] applied MRIs as well as coronal anatomical slices into cadaveric brains for their NA-focused study. Mavridis *et al*[8-11] used formalin-fixated cerebral hemispheres for studying NA stereotactic anatomy and morphometry and specific details of the NA deep brain stimulation (DBS) operative technique. They also used cerebral MRIs for studying NA stereotactic anatomy and morphometry[8,9], as well as MRIs from patients with Parkinson's disease[12].

Neto *et al*[1] studied the location, limits and size of the human NA and found the right NA to be wider than the left one. They reported that the precise limits of the NA were only possible to delimitate in the anatomical study and that the NA does not have a distinct signal intensity imaging, as well as no evidence of NA width or height variations along age and that this nucleus does not suffer any age-related atrophy as other brain structures. Brabec *et al*[4] reported absence of significant difference of the absolute volume of the caudate-accumbens complex between sides and gender. In contrast, Ahsan *et al*[5] found greater left NA.

Mavridis *et al*[9] found the definition of the NA limits with the caudate nucleus and putamen easier by MRI than by anatomical technique, specifically on T2-weighted MRIs due to the slightly more intense MR signal (remarkably similar to those of the cerebral cortex) that this nucleus presents compared to the caudate nucleus and putamen (and also compared to other nuclei such as the red or subthalamic nucleus). They also agreed with Neto *et al*[1] about the difficulty in establishing the rostral end of the NA relative to the caudate nucleus and putamen but found no such difficulty in transverse MRI sections.

They also found no statistically significant difference

among side regarding the NA stereotactic coordinates and dimensions[8,9] and that the human NA extended superiorly above the intercommissural plane[11] and was paradoxically longer in the elderly[9]. Further, its maximum transverse dimension was greater in individuals with putamen microcysts (dilated perivascular spaces)[9] and the absolute value of its y' coordinate was greater in males[8]. The NA was morphometrically correlated neither with the striatum[9] nor with its cortical connections. However, they found significant correlations of the thickness of NA cortical connections, specifically: the orbitofrontal with the entorhinal cortex, the cingulate with the orbitofrontal cortex, the piriform with the orbitofrontal and entorhinal cortices[2].

In addition, Mavridis *et al*[8] found stereotactically standard areas in the NA (*e.g.*, G, H, M). Standard area M (Mavridis' area), based on a combined study of anatomic specimens and MRIs, which is defined by coordinates x = 6.0 mm, x' = 9.0 mm, y = 2.0 mm, y' = 2.0 mm, z = -0.8 mm, z' = -2.0 mm and has a 3.6 mm^2 surface, always consisted a NA part regardless of side (right-left) or gender (male-female). They also found that the human NA is smaller in patients with advanced Parkinson's disease (Mavridis' atrophy). The mean percentage reduction of its size was 11.77%[12].

Finally, Mavridis *et al*[2] studied anatomical details of the NA DBS surgical technique on cadavers, they found that the today used electrode target point for NA DBS missed the target in 8% of cases[11] and they proposed a safe navigation model ('port' model) for NA DBS[10] as well as new surgical approaches and anatomic landmarks for NA surgery[2].

CONCLUSION

In conclusion, the human NA, a major pleasure center of the human brain, is a limbic-motor interface involved in several neurological and psychiatric disorders. During the last decade, this nucleus is also a DBS target for selected patients. Its exceptional clinical significance justifies the title of the "King of Neurosciences" for this nucleus. There are few researchers who tried to explore the gross anatomy of this nucleus. The first anatomical study focused on this nucleus came from Neto *et al*[1]. The most extensive study of the NA gross, imaging, stereotactic and neurosurgical anatomy so far, came from the research efforts of Mavridis *et al*[2,8-12].

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FIELD OF VISION

Nucleus accumbens stereotactic surgery: Achieving accuracy through area M

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Abstract

The nucleus accumbens (NA), a major pleasure center of the human brain, is a limbic-motor interface involved in several neurological and psychiatric disorders. During the last decade, this nucleus is also a deep brain stimulation target for selected patients. Purpose of this paper is to comment on the article entitled "Stereotactic anatomy of the human nucleus accumbens: from applied mathematics to microsurgical accuracy" which was recently published in "Surgical and Radiologic Anatomy" and is one of the latest articles on NA anatomy and surgery. The described results included a probability-based guide for *in vivo* (side-depended) stereotactic localization of the human NA and a standard for the NA, specific stereotactic zone of the human brain (which can be used in combination for an accurate stereotactic NA targeting). Furthermore, two specific stereotactically standard NA areas were found which could be used as abundant stereotactic guides for targeting of the anterior limb of the internal capsule, with electrode's contact 0 (lowest) placed in the vicinity of the NA. However, the most important finding of this paper was standard area M (Mavridis' area), which is the most reliable stereotactically standard area of the human NA, regardless of side or gender, useful for highly accurate stereotactic NA targeting.

Key words: Mavridis' area; Deep brain stimulation; Neuropsychiatric disorders; Nucleus accumbens; Stereotactic surgery; Surgical accuracy

Core tip: Nucleus accumbens (NA), a major pleasure center of the human brain, is a limbic-motor interface involved in several neurological and psychiatric disorders. It is also a deep brain stimulation target for selected patients. Purpose of this paper is to comment on the article entitled "Stereotactic anatomy of the human nucleus accumbens: from applied mathematics to microsurgical accuracy" which was recently published in "Surgical and Radiologic Anatomy". Its most important finding was standard area M (Mavridis' area), which is the most reliable stereotactically standard area of the human NA, regardless of side or gender, useful for highly accurate stereotactic NA targeting.

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COMMENTARY ON HOT TOPICS

Purpose of this paper is to comment on the recent article entitled "Stereotactic anatomy of the human nucleus accumbens: from applied mathematics to microsurgical accuracy"[1]. It is one of the latest articles on nucleus accumbens (NA) anatomy and surgery.

The NA, a major pleasure center of the human brain (Figure 1), is a limbic-motor interface involved in several neurological and psychiatric disorders[2]. During the last decade, this nucleus became also a deep brain stimulation

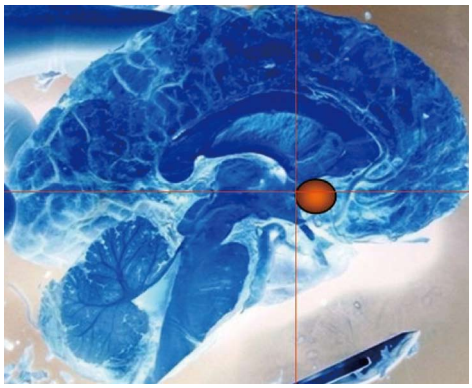

Figure 1 Nucleus accumbens location. Schematic representation of the nucleus accumbens contour on internal hemispheric surface (human brain, left hemisphere, lines represent stereotactic reference system) (modified from Mavridis[2]).

(DBS) target for selected patients mainly suffering from refractory major depression[3], obsessive-compulsive disorder[4] and Tourette syndrome[5].

According to the commended article, NA coordinates were measured at five different neurosurgically important three-dimensional levels, through two clinically oriented stereotactic studies, a magnetic resonance imaging and a gross anatomical (with totally 84 NAs studied). The study offered a stereotactic anatomic guide for some common targeting needs of the NA stereotactic surgery, resulted from detailed analysis and careful combination of the measured data[1].

The results included a probability-based guide for *in vivo* (side-depended) stereotactic localization of the human NA and a standard for the NA, specific stereotactic zone of the human brain (which can be used in combination for an accurate stereotactic NA targeting). Furthermore, two specific stereotactically standard NA areas were found which could be used as abundant stereotactic guides for targeting of the anterior limb of the internal capsule, with electrode's contact 0 (lowest) placed in the vicinity of the NA[1].

However, the most important finding of this paper was standard area M (Mavridis' area), which is the most reliable stereotactically standard area of the human NA, regardless of side or gender, useful for highly accurate stereotactic NA targeting. Standard area M is defined by coordinates (X, X', Y, Y', Z, Z') = (6, 9, 2, 2, -0.8, -2) and represents the most reliable standard part of the NA (of those revealed by the coordinates' analysis) within the human brain, regardless of side or gender. The surface of this area is 3.6 mm^2[1]. Area M consists a revolutionary finding because it is expected to be applicable in every adult human hemisphere. Additionally it offers a compass for neurosurgeons given the relative variety of NA target coordinates used in the past by several authors[3-16].

It is clear that the described study offered a necessary (considering the expanding dynamics of NA DBS) deep insight into the stereotactic anatomy of the human NA, missing from the literature[1]. Clinical research, more difficult of course, always requires a stable ground of basic research in order to bring successful treatment strategies as a result. Now that a safe anatomical basis for achieving surgical accuracy exists, problems that remain to be resolved are mainly related to NA DBS clinical application. Consequently, future research directions should focus on microelectrode recordings interpretation, establishing guidelines for stimulation parameters, minimizing complications and safely expanding respective therapeutic indications, if possible. Such efforts should always be made by multidisciplinary teams of experienced clinicians.

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CASE REPORT

Anterior communicating artery aneurysm associated with duplicated hypoplastic right A1 segment

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Abstract

Variations of the anterior cerebral artery (ACA)-anterior communicating artery (ACoA) complex are commonly observed when associated with a symptomatic intracranial aneurysm. We report an asymptomatic ACoA aneurysm associated with duplicated hypoplastic A1 segment of the right ACA, observed in a 70-year-old female cadaver. Furthermore, the aneurysm, practically substituting the ACoA, caused a remarkable depression on the internal surface of the right frontal lobe, anterior to the optic chiasm. Aneurysms and other anomalies of the ACA and ACoA are common and their microvascular surgical management requires sound knowledge of the normal and variant vascular anatomy. Persistence of some embryonic vessels that normally disappear, disappearance of vessels that would normally persist or sprouting of new vessels due to hemodynamic and genetic factors are the usual causes for such anomalies. The high incidence of coexisting vascular anomalies and aneurysm suggests that such abnormalities predispose to aneurysm formation due to changes in the regional blood flow. A1 segment duplication has been reported to occur in 4% of subjects in cadaveric studies and in up to 0.5%-9.7% of cases of ACoA aneurysm surgery. Angiographic hypoplasias and aplasias of the A1 segment have been also correlated with ACoA aneurysm patients.

Key words: Anterior cerebral artery; Anterior communicating artery; Aneurysm; Duplication; Hypoplasia

Core tip: Variations of the anterior cerebral artery (ACA)-anterior communicating artery (ACoA) complex are commonly observed when associated with a symptomatic intracranial aneurysm. We report an asymptomatic ACoA aneurysm associated with duplicated hypoplastic A1 segment of the right ACA, observed in a 70-year-old female. Furthermore, the aneurysm, practically substituting the ACoA, caused a remarkable depression on the internal surface of the right frontal lobe, antero-inferior to the anterior commissure and anterior to the optic chiasm. A literature review of similar cases and underlying mechanisms of such anomalies is presented.

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INTRODUCTION

Variations of the anterior cerebral artery (ACA)-anterior communicating artery (ACoA) complex are commonly observed when associated with a symptomatic intracranial aneurysm[1]. We report an asymptomatic ACoA aneurysm associated with duplicated hypoplastic A1 segment of the right ACA and causing a remarkable depression on the internal surface of the right frontal lobe. These anterior Willis circle anomalies were found during routine

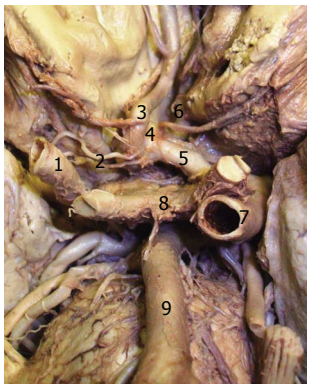

Figure 1 Duplicated hypoplastic A1 segment of the right anterior cerebral artery. 1: Right internal carotid artery (ICA); 2: Duplicated hypoplastic A1 segment of the right anterior cerebral artery (ACA); 3: A2 segment of the right ACA; 4: Anterior communicating artery (aneurysm); 5: A1 segment of the left ACA; 6: A2 segment of the left ACA; 7: Left ICA; 8: Optic chiasm; 9: Basilar artery.

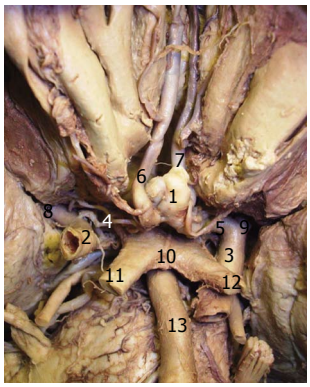

Figure 2 Duplicated hypoplastic A1 segment of the right anterior cerebral artery and anterior communicating artery aneurysm. 1: Anterior communicating artery aneurysm; 2: Right internal carotid artery (ICA); 3: Left ICA; 4: Duplicated hypoplastic A1 segment of the right anterior cerebral artery (ACA); 5: A1 segment of the left ACA; 6: A2 segment of the right ACA; 7: A2 segment of the left ACA; 8: Right middle cerebral artery (MCA); 9: Left MCA; 10: Optic chiasm; 11: Right optic nerve; 12: Left optic nerve; 13: Basilar artery.

dissection by chance. They were observed in a formalin-embalmed cadaver of a 70-year-old female who had died from heart disease. The details of this case as well as a relative literature-based discussion are presented below.

CASE REPORT

Dissecting the Willis circle arteries of this case's brain, it was observed no normal A1 (precommunicating) segment of the right ACA. Specifically, this segment was substituted by two hypoplastic branches (of about 1 mm in diameter) connecting the right internal carotid artery (ICA) with the A2 (postcommunicating) segment of the right ACA (Figures 1 and 2). Furthermore, an ACoA aneurysm (of about 10 mm in diameter), practically substituting the ACoA, was observed. Interestingly, it caused a remarkable depression on the internal surface of the right frontal lobe, antero-inferior to the anterior commissure and anterior (and slightly superior) to the optic chiasm (Figure 3).

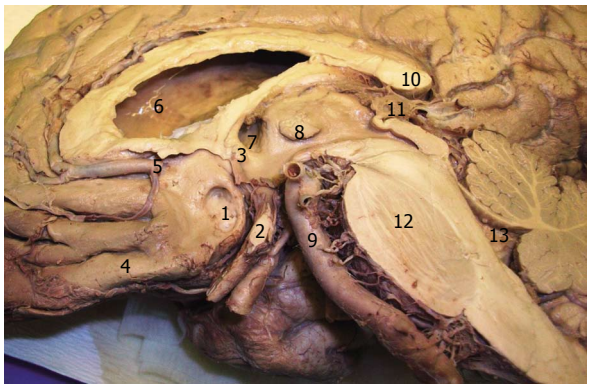

Figure 3 The depression on the internal surface of the right frontal lobe caused by anterior communicating artery aneurysm. 1: Cortical surface depression caused by aneurysm; 2: Optic chiasm; 3: Anterior commissure; 4: Gyrus rectus; 5: Right anterior cerebral artery; 6: Right lateral ventricle; 7: Right Monro foramen; 8: Massa intermedia; 9: Basilar artery; 10: Corpus callosum (splenium); 11: Pineal gland; 12: Pons (pontine nuclei); 13: Fourth ventricle.

DISCUSSION

Cases

More than half a century ago, Schuermann[2] discussed on unilateral ACA aplasia and surgical indication of ACoA aneurysm whereas Burmester *et al*[3] reported two cases of unilateral aplasia of the ICA in simultaneous aneurysm formation in the anterior area of the circle of Willis.

Matsumura *et al*[4] reported two patients with ruptured ACoA aneurysms associated with fenestration of the ACA. According to these authors, only few angiographic demonstrations of fenestration of the ACA have been reported in the literature. All fenestrations were limited to the distal half of the A1 portion, and approximately half of them were associated with aneurysms. The high incidence of coexisting fenestration and aneurysm suggests that congenital factors may play a role in the pathogenesis of cerebral aneurysm.

Kawakita *et al*[5] reported a case of a 25-year-old man with a ruptured saccular aneurysm in hypoplastic proximal ACA. He suffered a sudden onset of severe headache and vomiting due to subarachnoid hemorrhage. Cerebral angiography revealed this aneurysm in the hypoplastic A1 portion of the right ACA and no branch was present at the site of the aneurysmal neck.

Kim *et al*[6] reported a case of a 64-year-old female diagnosed with aneurysms of the proximal ACA and ACoA associated with middle cerebral artery (MCA) aplasia.

Weil *et al*[7] described a misleading case of a 70-year-old man with partially occluded A1 segment duplication that mimicked an ACoA aneurysm on computed tomography angiography and conventional angiography and led to surgical intervention. According to these authors, the location of such an anomaly at the ACoA on the side of least hemodynamic stress may provide a clue to recognizing this variant.

Anomalies of the ACA-ACoA-recurrent artery complex are frequently encountered, especially during ACoA

aneurysm surgery. Among these anatomic variations, duplication of the A1 segment of the ACA is infrequent. It has been reported to occur in 4% of subjects in cadaveric studies and in up to 0.5%-9.7% of cases of ACoA aneurysm surgery. Although A1 segment duplication can be identified on angiography, superimposition of vessels may render its identification difficult. Most clinically reported cases of A1 duplication are angiographically occult variations later identified during ACoA aneurysm surgery usually without consequences. Weil *et al*[7] concluded that A1 segment duplication with one arm occluded, can mimic an ACoA aneurysm on angiography and that the location of the anomaly at the ACoA on the side of least hemodynamic stress may provide a clue to suspect this variant.

Series

Kitami *et al*[8] analyzed angiographic features of the ACA and related vascular anomalies in a series of 704 aneurysm patients (mean age: 53 years). The total number of aneurysms was 866 with site distribution: ACoA 27%, MCA 31%, ICA 38%, ACA 6%, vertebrobasilar 5% and other arteries. More than one aneurysm was found out in 137 cases. Cases were divided into two groups, namely one who had the ACoA aneurysm and the other who had not. Angiographic calibers of A1 portion were compared statistically between these two groups. The ACoA aneurysm group showed significant asymmetry of A1 ($P < 0.005$) compared to the other cases. The left A1 portions were significantly dominant ($P < 0.05$) to the right in the ACoA aneurysm group. Angiographic hypoplasias and aplasias of A1 were found in the ACoA aneurysm group more frequently than in the other.

Karazincir *et al*[9] investigated the sites of intracranial aneurysms and incidence of associated congenital variations or anomalies. They retrospectively evaluated 190 cerebral angiography examinations that were positive for aneurysm. Fourteen cases with vasospasm were excluded and the remaining 176 patients were assessed for the location of the aneurysm and co-incidental vascular variations and/or anomalies. The most frequent locations of aneurysms were the supraclinoid ICA (32%), ACoA (30%) and MCA bifurcation (23%). Twenty-eight (17%) patients had multiple aneurysms. Ninety-one (52%) patients had a vascular anomaly or variation. Hypoplasia or agenesis of the A1 segment was found in 48 patients and an azygous ACA in one. The authors concluded that due to an increased hemodynamic stress, congenital anomalies of the intracranial arteries predispose to the formation of saccular aneurysms. Anomalies such as A1 hypoplasia or agenesis, azygous ACA, accessory MCA and persistent trigeminal artery are detected more frequently in patients with cerebral aneurysms compared to the normal population.

Aneurysms of the ACA and ACoA are common and their microvascular surgical management requires sound knowledge of the normal and variant vascular anatomy[10]. Saidi *et al*[10], from Kenya, evaluated ACA and ACoA variant anatomy by dissecting 36 adult brains. The ACA was observed to originate from the ipsilateral ICA in all cases. Unique variations observed include an accessory ACA from the ACoA, "bihemispheric pericallosal arteries", intertwining course of the A2 segments of the ACAs and crossing branches from one hemisphere to another. Variations of the ACoA were also observed including fenestration (26%) and duplication (13%). The majority of ACA bifurcations, in their study, were supracallosal suggesting the need for exploration of the interhemispheric fissure during surgical corrections of distal ACA aneurysms. ACoA fenestration was the most common variation raising concern as this has been shown to compromise collateral flow and predispose to aneurysm formation.

Kapoor *et al*[11] studied variations of the Willis circle using brains from 1000 medicolegal autopsy subjects of varying ages (Indian population). Out of 1000 specimens examined, 452 (45.2%) conformed to the typical pattern. In the rest of the specimens (54.8%) there were variations in the circulus arteriosus. The circle was deficient in 32 (3.2%). The ACA was absent in 0.4%, hypoplastic in 1.7%, duplicated in 2.6%, triple in 2.3% and single in 0.9%. The ACoA was absent in 1.8%, duplicate in 10%, triplicate in 1.2% and plexiform in 0.4%. Seventy-four brains (7.4%) had multiple variations. Intracranial saccular aneurysm was present in 10 (1%). Persistence of some embryonic vessel that normally disappear, disappearance of vessels that would normally persist or sprouting of new vessels due to hemodynamic and genetic factors are the usual causes for such anomalies.

Further, these authors reported that in four specimens (three male, one female) the proximal part of the ACA was absent on one side and larger than normal on the other side. Hypoplasticity of the proximal part of the ACA was present in 15 male specimens (10 right, 5 left) and two female specimens (one right, one left). But the distal part was normal in size. Loop formation in the proximal segment of the ACA was seen in 12 male specimens (seven right, five left) and 14 female specimens (six right, seven left, one on both sides). In each case the ACA divided into two components approximately 1 cm beyond its origin and rejoined to form a single artery. A loop was thus formed; no structure passed through this loop. The inside anteroposterior length of the loop varied from 2 to 12 mm. In one instance the loop extended 0.5 cm beyond ACoA, which joined the inner of the two constituent vessels of the loop. In 14 instances both the constituent vessels were apparently equal in caliber. In the remaining 12 instances one or the other artery of the loop was larger[11].

Finally, Kapoor *et al*[11] mentioned that hypoplasticity of the proximal part of the ACA is often described in the literature although a wide variation in the incidence, ranging from 4% to 44.3%, has been reported. Their study found hypoplasticity in only 17 specimens (1.70%). The wide variations in the incidence may be due to the fact that some workers have studied pathological or infarcted brains, while others based their studies on brains obtained from persons with mental disorder. Such structural

defects would resist the collateral blood flow. Duplication of a part of the ACA has been described by various authors under different names such as 'splitting' and 'island or loop formation'.

In conclusion, aneurysms and other anomalies of the ACA and ACoA are common and their microvascular surgical management requires sound knowledge of the normal and variant vascular anatomy. However, a case combining hypoplastic duplicated A1 segment, asymptomatic ACoA aneurysm and remarkable cortical surface depression is quite unusual. Persistence of some embryonic vessels that normally disappear, disappearance of vessels that would normally persist or sprouting of new vessels due to hemodynamic and genetic factors are the usual causes for such anomalies. The high incidence of coexisting vascular anomalies and aneurysms suggests that such abnormalities predispose to aneurysm formation due to changes in the regional blood flow.

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15 Morse SS. Factors in the emergence of infectious diseases. Emerg Infect Dis serial online, 1995-01-03, cited 1996-06-05; 1(1): 24 screens. Available from: URL: http://www.cdc.gov/ncidod/eid/index.htm

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