Sectional Anatomy of the Optic Pathways on the Coronal Plane

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Background: The purpose of this study was to provide practical data for the imaging diagnosis of the optic pathways.

Methods: Sectional anatomy of the optic pathways on the coronal plane was investigated on 15 sets of serial coronal sections of the head of Chinese adult cadavers and 6 sets of serial coronal magnetic resonance imaging of normal adults.

Results: On the coronal plane, we recognized the special structures of optic pathways by 5 key sections. (1) The midorbital optic nerve lay superomedially in the center of the adipose body of the orbit, surrounded by the subarachnoid space and the sheath of the optic nerve. (2) The optic chiasma was transverse between the optic and infundibular recesses of the portion of the floor of the third ventricle and it lay below the A1 segment of the anterior cerebral artery and above the tuber cinereum and the pituitary stalk, C2 or C3 segment of the internal carotid artery laterally. (3) The optic tract lay between the crus cerebri and the amygdaloid, the tail of the caudate nucleus laterally. The anterior choroidal artery inferiorly and downward M2 segment of the middle cerebral artery lay between the uncus and the crus cerebri. (4) The lateral geniculate body lay between the crus cerebri medially and the tail of the caudate nucleus laterally, the uncus and P2 segment of the posterior cerebral artery inferiorly. (5) The optic radiation formed the lateral wall of the lateral ventricle both in the temporal horn and in the occipital horn. The optic radiation was separated from the wall of the occipital horn by the tapetum, a thin layer of fibers derived from the splenium of the corpus callosum. Coronal sectional anatomy and magnetic resonance imaging of the optic pathways revealed similar results.

Conclusion: This study provides a good understanding of the structures of the optic pathways by correlation of coronal sections of the head of adult cadavers with the coronal magnetic resonance images of normal adults. [*J Chin Med Assoc* 2009;72(10):515–520]

Key Words: magnetic resonance imaging, optic pathways, sectional anatomy

Introduction

The optic pathways consist of the retina, optic nerve, optic chiasma, optic tract, lateral geniculate body, optic radiation and visual cortex. The optic pathways have complicated structures and important functions, the malformation of which can be produced by many diseases. Although the anatomy of the optic pathways,[1,2] the sectional anatomy and magnetic resonance imaging (MRI) of the optic pathways have been investigated abundantly,[3–5] serial coronal section studies of the optic pathways are insufficient despite the rapid development of modern imaging technology. In this study, we investigated markers, typical manifestations and adjacent relations of the optic pathways in coronal planes using brain sections taken from the cadavers of Chinese adults and compared them with the corresponding coronal MRI of healthy normal adults. This report aims to provide an anatomic basis for recognizing the crucial special structures and thus aid medical imaging diagnosis of diseases involving the optic pathways.

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Methods

Specimens of serial coronal sections of Chinese adult cadavers

Fifteen corpses of adult men and women (12 and 3, respectively) were collected. After regular embalmment and refrigeration, the heads of these bodies were cut into serial coronal sections using an electric ban saw, with the vertical line crossing the midpoint of the orbitomeatal line, which was the reference line. The width of the slices was 8 mm, and the width wasted by the saw was 1 mm. Running water was used to clean the sawdust. Images taken from the serial sections were used to track the optic pathways and their adjacent structures.

Coronal MRI of normal adults

Six healthy male adult volunteers with normal vision were enrolled, and the Siemens Sonata MR 1.5T (Siemens AG, Berlin, Germany) was used to obtain 6 sets of serial coronal MR images. The reference line was the same as for the sectional specimens of the cadavers. The imaging conditions were layer thickness 6 mm, SE sequence, T1-weighted 500/7.7 (TR/TE) and T2-weighted 6990/95 (TR/TE).

Results

On coronal planes of the sectional specimens, the optic nerve, optic chiasma, optic tract, lateral geniculate body, and optic radiation of the optic pathways could be displayed clearly. Six typical coronal sections were chosen to investigate markers, typical manifestations, adjacent structures and various disciplines of the optic pathways.

Coronal section through the intraorbital part of the optic nerve

The marker of this section was the crista galli, which stuck upward to the cerebral falx. The orbit was filled with the adipose body of the orbit, the optic nerve lay superomedially in the center of the adipose body of the orbit, and the subarachnoid space and the sheath surrounding the optic nerve could be clearly seen. The ophthalmic artery, superior ophthalmic vein and inferior ophthalmic vein lay around the optic nerve. The lacrimal gland and extrinsic eyeball muscles lay in the peripheral part of the orbit. The superior rectus and levator palpebrae superioris muscles were located superomedially, the inferior rectus was located inferior medially, the medial rectus lay medially, the superior obliques lay superomedially, the external rectus lay laterally, and the lacrimal gland lay superolaterally. The lacrimal vessels and lacrimal nerves were located at the mediosuperior aspect of the lacrimal gland. The infraorbital vessels and nerves lay in the infraorbital groove of the center of the infraorbital wall (Figure 1A).

Coronal section through the intracanicular part of the optic nerve passing through the anterior clinoid process

The marker of this section was the anterior clinoid process. The intracanicular part of the optic nerve was located at the medioinferior aspect of the anterior clinoid process, the medial side of which was adjacent to the wall of the sphenoid sinus. The subarachnoid space and sheath surrounding the optic nerve could be displayed clearly. The ophthalmic artery lay below the optic nerve vertically. At the lateroinferior aspect of the anterior clinoid process was located the greater wing of the sphenoid, and at the interior-inferior aspect of the anterior clinoid process was located the sphenoid body; the crack between them was the posteromedial part of the superior orbital fissure, which was filled with a lot of fat, connective tissue, the oculomotor nerve, trochlear nerve, abducent nerve and ophthalmic nerve. Beneath the anterior clinoid process was the greater wing of the sphenoid, on which the maxillary nerve penetrated the foramen rotundum; the lateral side of the greater wing of the sphenoid was the middle cranial fossa, where the temporal lobe and M2 section of the middle cerebral artery could be seen (Figure 1B).

Coronal section through the optic chiasma

The "⊥" was the marker of this section, which consists of the optic chiasma, infundibulum and hypophysis. The optic chiasma, which looks like the structure of "—", was located above the sulcus prechiasmaticus horizontally, separating the optic recess of the third ventricle above and the infundibular recess posteroinferiorly. A1 of the anterior cerebral artery running from the posterior-external to the anterior-interior was located above the optic chiasma. The middle of the posteroinferior aspect of the optic chiasma was the neighbor of the tuber cinereum and pituitary stalk, and the pituitary stalk went down through the foramen of the diaphragma to connect with the posterior lobe of the hypophysis; next to both sides were the initial parts of the lateral cerebral sulcus and the uncus, C1 or C2 of the internal carotid artery and M1 of the middle cerebral artery. On both sides of the sphenoid bone was the sinus cavernosus, inside of which was located C4 of the internal carotid artery.

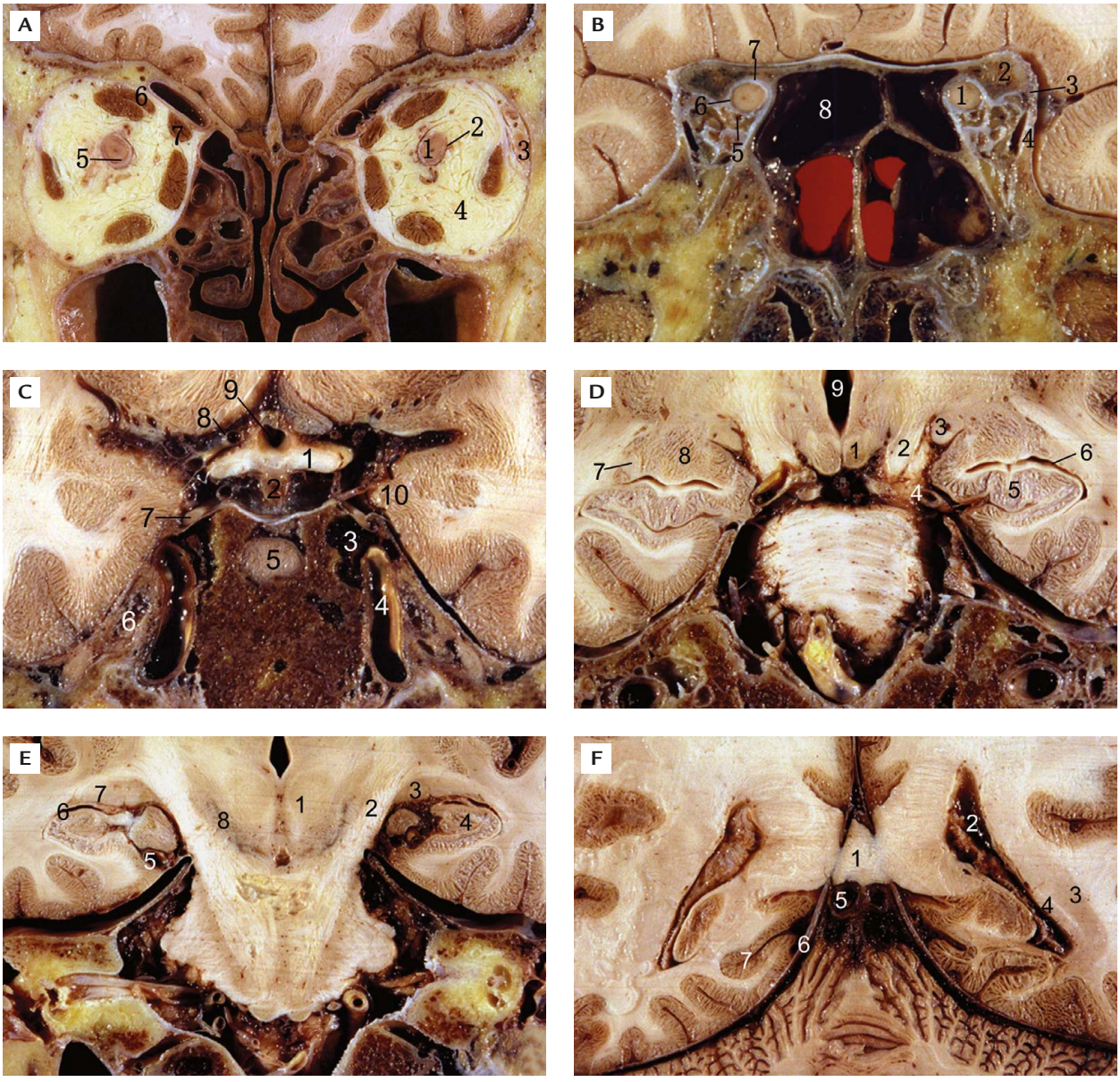

Figure 1. Serial sections of the brain taken from the cadavers of Chinese adults, showing the key structures, as well as their relations, of the optic pathways. (A) Coronal section through the middle orbital part: 1 = optic nerve; 2 = sheath of the optic nerve; 3 = lacrimal gland; 4 = fat of the orbit; 5 = subarachnoid space; 6 = levator palpebrae superior; 7 = superior oblique. (B) Coronal section through the optic canal: 1 = optic nerve; 2 = anterior clinoid process; 3 = superior orbital fissure; 4 = greater wing of the sphenoid; 5 = ophthalmic artery; 6 = subarachnoid space; 7 = sheath of the optic nerve; 8 = sphenoid sinus. (C) Coronal section through the optic chiasma: 1 = optic chiasma; 2 = pituitary stalk; 3 = sinus cavernosus; 4 = C4 of the internal carotid artery; 5 = posterior lobe of the hypophysis; 6 = trigeminal ganglion; 7 = oculomotor nerve; 8 = A1 of the anterior cerebral artery; 9 = optic recess of the third ventricle; 10 = uncus. (D) Coronal section through the middle optic tract: 1 = mamillary body; 2 = crus cerebri; 3 = optic tract; 4 = P2 of the posterior cerebral artery; 5 = hippocampus; 6 = inferior horn of the lateral ventricle; 7 = tail of the caudate nucleus; 8 = amygdaloid body; 9 = third ventricle. (E) Coronal section through the lateral geniculate body: 1 = red nucleus; 2 = crus cerebri; 3 = lateral geniculate body; 4 = hippocampus; 5 = P2 of the posterior cerebral artery; 6 = inferior horn of the lateral ventricle; 7 = tail of the caudate nucleus; 8 = substantia nigra. (F) Coronal section through the optic radiation: 1 = splenium of the corpus callosum; 2 = trigone of the lateral ventricle; 3 = optic radiation; 4 = tapetum; 5 = internal cerebral vein; 6 = tentorium of the cerebellum; 7 = anterior part of the calcarine sulcus.

On the lateral-superior aspect of the sphenoid bone was located the oculomotor nerve and trochlear nerve. On the lateroinferior aspect of the sphenoid bone was located the trigeminal ganglion, where the mandibular nerve passed through the foramen ovale (Figures 1C and 2A).

Coronal section through the part of the midoptic tract

The marker of this section was the mamillary body, above it was the third ventricle and below it was the interpeduncular fossa. The optic tract was located between the crus cerebri, the amygdaloid body and the tail of the caudate nucleus. Below the optic tract was the anterior choroidal artery, and below the anterior choroidal artery was P2 of the posterior cerebral artery, located between the uncus and crus cerebri. The amygdaloid and the lateral tail of the caudate nucleus were located inside the gyrus semilunaris, below which was the inferior horn of the lateral ventricle, hippocampus, hippocampus groove and parahippocampal gyrus in sequence. Between the 2 sides of the uncus was the interpeduncular fossa with the oculomotor nerve passing through, and above the interpeduncular fossa were the mamillary body, third ventricle and dorsal thalamus in sequence, the internal capsule and the fibers formed the crus cerebri located outside the dorsal thalamus (Figure 1D).

Coronal section through the lateral geniculate body

The markers of this section were the red nucleus and the substantia nigra. The lateral geniculate body lay next to the crus cerebri. Outside of the lateral geniculate body was the tail of the caudate nucleus. Above the lateral geniculate body was the optic radiation. Below the lateral geniculate body was P2 of the posterior cerebral artery, the inferior horn of the lateral ventricle, hippocampus and gyrus parahippocampalis in sequence (Figure 1E).

Coronal section through the optic radiation

The marker of this section was the splenium of the corpus callosum and the trigone of the lateral ventricle. The optic radiation formed the lateral wall of the posterior horn of the lateral ventricle, in the middle of which ran the thin tapetum of the splenium of the corpus callosum. The splenium of the corpus callosum transversed in the triangle constructed by both the tentorium of the cerebellum and cerebral falx, below which was the last part of the internal cerebral vein. There were 3 sulci above the tentorium of the cerebellum from mediosuperior to lateroinferior, including the anterior part of the calcarine sulcus, collateral sulcus and occipitotemporal sulcus in sequence. Between the gyrus parahippocampalis and the tentorium of the cerebellum ran P2 of the posterior cerebral artery (Figures 1F and 2B).

Discussion

Based on the results above, we discuss the markers, typical manifestations, adjacent structures and various disciplines of the optic nerve, optic chiasma, optic tract, lateral geniculate body, and optic radiation on serial coronal sections and serial coronal MRI of the head.

Optic nerve

The optic nerve derived from the optic disc was separated into 4 sections, including an intrabulbar part,

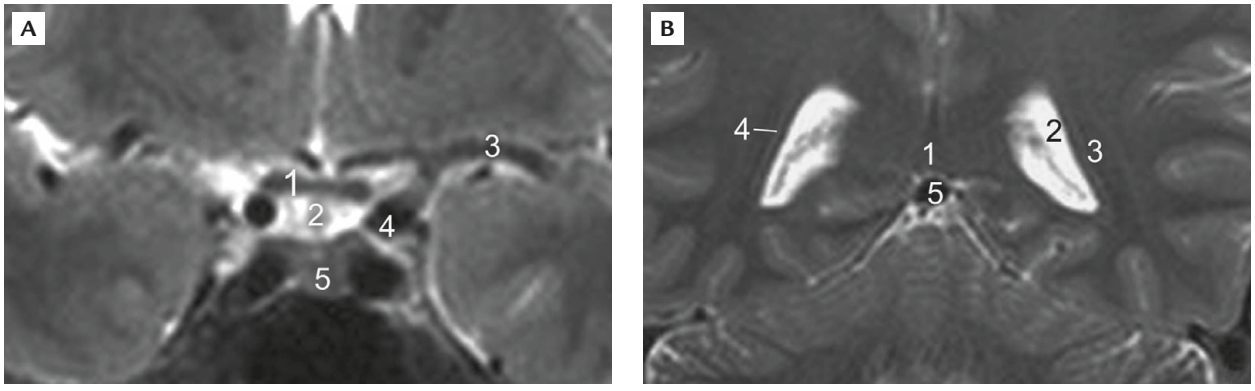

Figure 2. Coronal T2-weighted magnetic resonance imaging of healthy Chinese adult volunteers, showing the related key structures of the optic pathway correlating with Figures 1C and 1F. (A) Level through the optic chiasma: 1 = optic chiasma; 2 = pituitary stalk; 3 = M2 of the middle cerebral artery; 4 = C1 of the internal carotid artery; 5 = posterior lobe of the hypophysis. (B) Level through the optic radiation: 1 = splenium of the corpus callosum; 2 = trigone of the lateral ventricle; 3 = optic radiation; 4 = tapetum; 5 = great cerebral vein.

intraorbital part, intracanicular part and intracranial part. The intrabulbar part was very short, so it was difficult to see.[6] The intraorbital part of the optic nerve could be clearly seen. The sheath and subarachnoid space of the optic nerve could also be clearly seen. The optic nerve was protected by the adipose body of the orbit. Extrinsic eyeball muscles lay around the orbit. The ophthalmic artery, and superior and inferior ophthalmic veins surrounded the optic nerve. In contrast to the adipose body of the orbit, extrinsic eyeball muscles, ophthalmic vessels and subarachnoid space around the optic nerve, the tiny focus of the intracanicular part of the optic nerve could be demonstrated easily by MRI. The intracanicular part of the optic nerve was 10 mm from the orbital entrance to the cranial entrance; the subarachnoid space around this section was smaller, so it was hard to be shown on T2-weighted MRI; the ophthalmic artery running along this section of the optic nerve lateroinferiorly got through the optic canal to reach the orbital apex. The common tendinous ring at the origin of the superior rectus and medial rectus connected with the sheath of the optic nerve tightly; the superior and inferior branches of the oculomotor, nasociliary and abducent nerves were between the origin of the external rectus and optic nerve.[4] This special structure causes the pain of retrobulbar neuritis. The intracranial part of the optic nerve lay near the optic chiasma.

Optic chiasma

The optic chiasma lay in the saddle, with many adjacent structures. The intracranial part of the optic nerve and the initial part of the optic tract (it was defined from the beginning to the anterior margin of the crus cerebri) were adjacent to the optic chiasma, so we discuss the 3 parts as a whole body. This study investigated the structure of the intracranial part of the optic nerve, the optic chiasma and the initial part of the optic tract on 3–7 sections of 15 sets of serial coronal sections of the head of Chinese adult cadavers and 6 sets of serial coronal MR images of normal adults. The optic chiasma lay centrally, which linked the intracranial part of the optic nerve anterolaterally and turned out to be the beginning section of the optic tract posterolaterally. The intracranial part of the optic nerve started from the cranial opening of the intracanicular part of the optic nerve and ran along both sides of the sulcus prechiasmaticus, and then turned out to be the optic chiasma. The optic tract after the optic chiasma ran posterolaterally between the tuber cinereum and anterior perforated substance in the interpeduncular cistern, and then ran into the space between the crus cerebri and uncus. The intracranial part of the optic nerve lay at the medial side of the anterior clinoid process, above the C3 of the internal carotid artery and below the olfactory sulcus, olfactory tract and gyrus rectus, which turned out to be the optic chiasma posteromedially. Above the optic chiasma was the A1 of the anterior cerebral artery, below the optic chiasma was the pituitary stalk, which passed through the foramen of the diaphragma and connected with the posterior lobe of the hypophysis;[5,7] it is the structure of "⊥" on MRI. On the inner side of the cavernous sinus were located C4 of the internal carotid artery and abducent nerve, and on the lateral side of the cavernous sinus were located several nerves, including the oculomotor nerve, trochlear nerve, ophthalmic nerve and maxillary nerve from up to down. The structures of the intracranial part of the optic nerve, the optic chiasma and the initial part of the optic tract and their adjacent relations in the saddle are complicated, but in contrast to the suprasellar cistern and the internal carotid artery and its branches including the anterior and middle cerebral arteries, little tiny focus of the intracranial part of the optic nerve, the optic chiasma and the initial part of the optic tract could be recognized clearly on MRI.

Optic tract

The optic tract originating from the optic chiasma ran posterolaterally between the tuber cinereum and anterior perforated substance in the interpeduncular cistern and then went into the gap between the crus cerebri and uncus. This section was the cistern part of the optic tract,[8] which ran around the posterosuperior direction of the crus cerebri and dorsal thalamus and ended at the lateral geniculate body of the metathalamus. On the coronal sectional specimens, the optic tract lay between the crus cerebri and the cortex of the gyrus semilunaris. Below the optic tract was the anterior choroidal artery, below which was P2 of the posterior cerebral artery between the uncus and gyrus parahippocampalis, below which were the inferior horn of the lateral ventricle, hippocampus, hippocampus groove and gyrus parahippocampalis. On high-resolution MRI, in contrast to the structures of the posterior cerebral artery, anterior choroidal artery and gyrus parahippocampalis groove, the optic tract next to the crus cerebri could be recognized.

Lateral geniculate body

The lateral geniculate body was an oval eminence on the metathalamus, located at the ventrolateral part of the medial geniculate body and adhering closely to the top of the lateral cerebral peduncle. On the coronal sectional specimens, the lateral geniculate body

could be seen clearly, adhering closely to the crus cerebri. At the lateral side of the lateral geniculate body was the tail of the caudate nucleus, at the top of the lateral geniculate body was the optic radiation, below the lateral geniculate body was the posterior cerebral artery. On MRI, the lateral geniculate body could not be shown clearly in contrast to the surrounding structures; it could only be recognized on proton density-weighted MRI.[9,10]

Optic radiation

The optic radiation derived from the lateral geniculate body was separated into 2 parts, 1 of which ran posterolaterally directly in the parietal lobe forming the superior wall of the middle part of the lateral ventricle; the other part of the optic radiation (also named Meyer's loop) ran in the temporal lobe, forming the lateral wall of the front part of the inferior horn of the lateral ventricle, and then ran posterior-horizontally, forming the lateral wall of the inferior horn and the posterior horn of the lateral ventricle. The 2 parts of the optic radiation were separated by the tapetum and then reached the cortex on both sides of the calcarine sulcus together.[7,11] On high-resolution MRI, in contrast to the posterior horn of the lateral ventricle and the occipital lobe cortex, the thin tapetum forming the lateral wall of the posterior horn of the lateral ventricle and the optic radiation next to the tapetum could be recognized.

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