The Dentate Nucleus and Its Projection System in the Human Cerebellum: The Dentate Nucleus Microsurgical Anatomical Study

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BACKGROUND: Neurosurgical management of cerebellar lesions remains challenging. Thus, it is important to have sound knowledge of the microsurgical anatomy of the cerebellum and dentate nucleus (DN) and to define different types of exposure in a variety of surgical interventions.

OBJECTIVE: To examine the anatomy of the DN from a neurosurgical viewpoint using fiber tracking techniques.

METHODS: Ten formalin-fixed human hemispheres were dissected with the Ludwig and Klingler fiber dissection technique under $\times 6$ to $\times 40$ magnification. Anatomic images were created with 3-dimensional diffusion tensor imaging. The relationships of the DN to tentorium and suboccipital and lateral surfaces of the cerebellum and its spatial positioning relative to different surgical approaches in the cerebellum and fourth ventricle were examined. The fiber tracts terminating at and surrounding the DN were defined.

RESULTS: The DN is at greater risk of being injured in the transvermian and supratonsillar approaches to the cerebellum and fourth ventricle, with lesser risk in the telovelar and subtonsillar approaches. Superior approaches are safer compared with other approaches.

CONCLUSION: The DN represents an important anatomic structure in surgical interventions involving the posterior fossa, particularly in the elderly because of the common occurrence of atrophy-related problems in this age group. Functionally and anatomically, the DN is closely related to the superior and middle cerebellar peduncles. The inferior cerebellar peduncle poses positional risks because it follows an anterior and superior course relative to the DN. The telovelar approach is a safer procedure for interventions involving the pathological lesions of the fourth ventricle floor.

KEY WORDS: Approaches to cerebellum, Dentate nucleus, Fiber dissection, White matter tracts

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The dentate nucleus (DN), the largest of the deep cerebellar nuclei, is buried within the cerebellar white matter adjacent to the fourth ventricular roof and vermis.[1,2] DN may be subject to injury during surgical interventions involving the cerebellum, brainstem, cerebellar peduncles, and fourth ventricle.[3-6]

The DN has a grayish-yellow lamina and functions in planning, initiating, and controlling the volitional movements and in cognition. It receives afferent fibers from the premotor cortex and the supplementary motor cortex (via the corticocerebellar and pontocerebellar systems). It also receives fibers from the spinocerebellar tract that ascend in the inferior cerebellar peduncle and play a major role in equilibrium, balance, and posture. Its major efferent fibers, referred to as the dentatothalamic or dentatorubrothalamic tract, ascend in the superior cerebellar peduncle and have a role in the timing and arrangement of voluntary movements.[7-9] Recent studies have also revealed the presence of connections between the DN and oculomotor, prefrontal, and posterior parietal regions of the cerebral cortex.[10,11]

The aim of the present study is to examine the position of the DN and its related fiber tracts in relation to different surgical approaches to the cerebellum and fourth ventricle.

ABBREVIATIONS: DN, dentate nucleus; **DTI,** diffusion tensor imaging

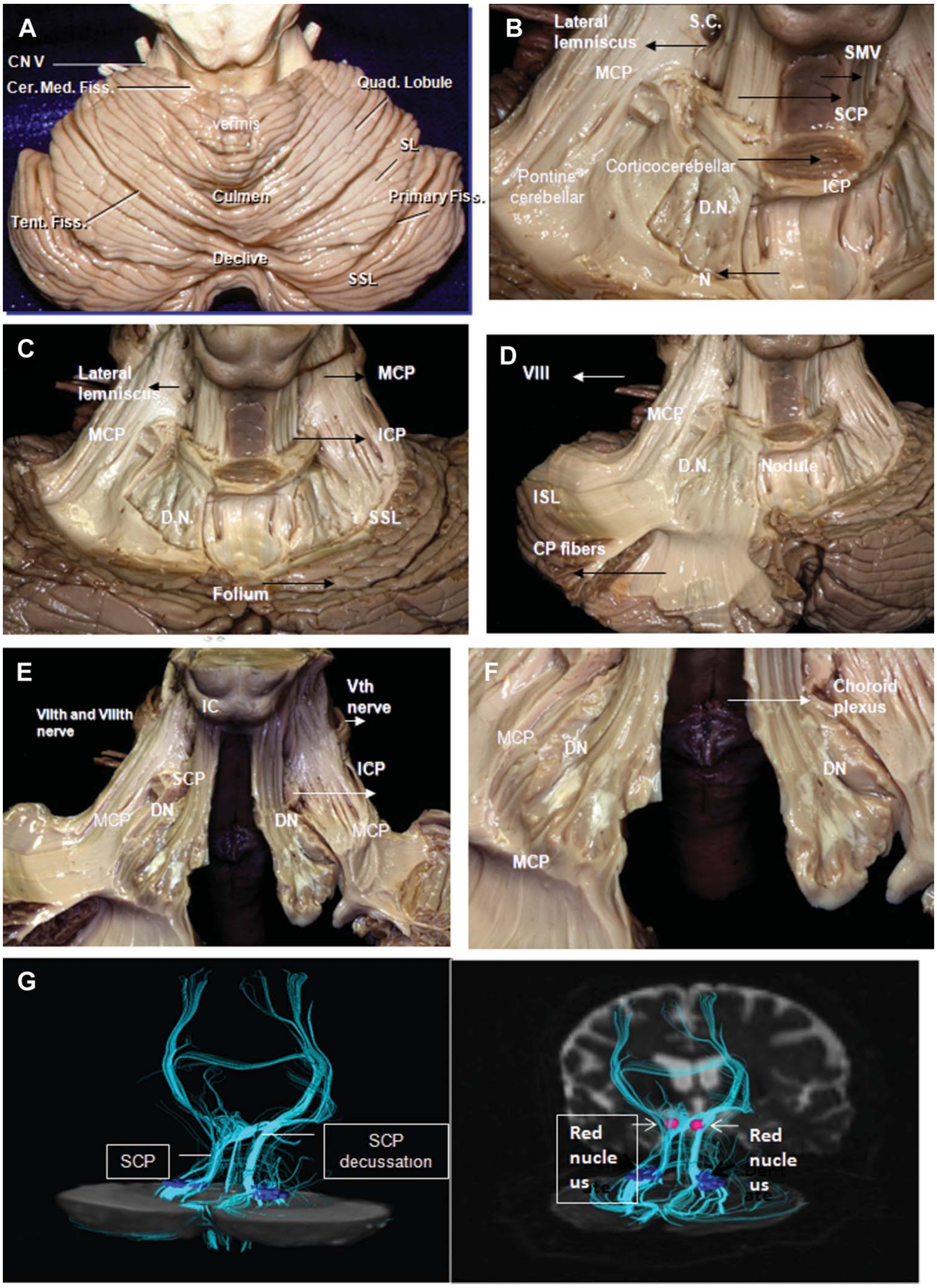
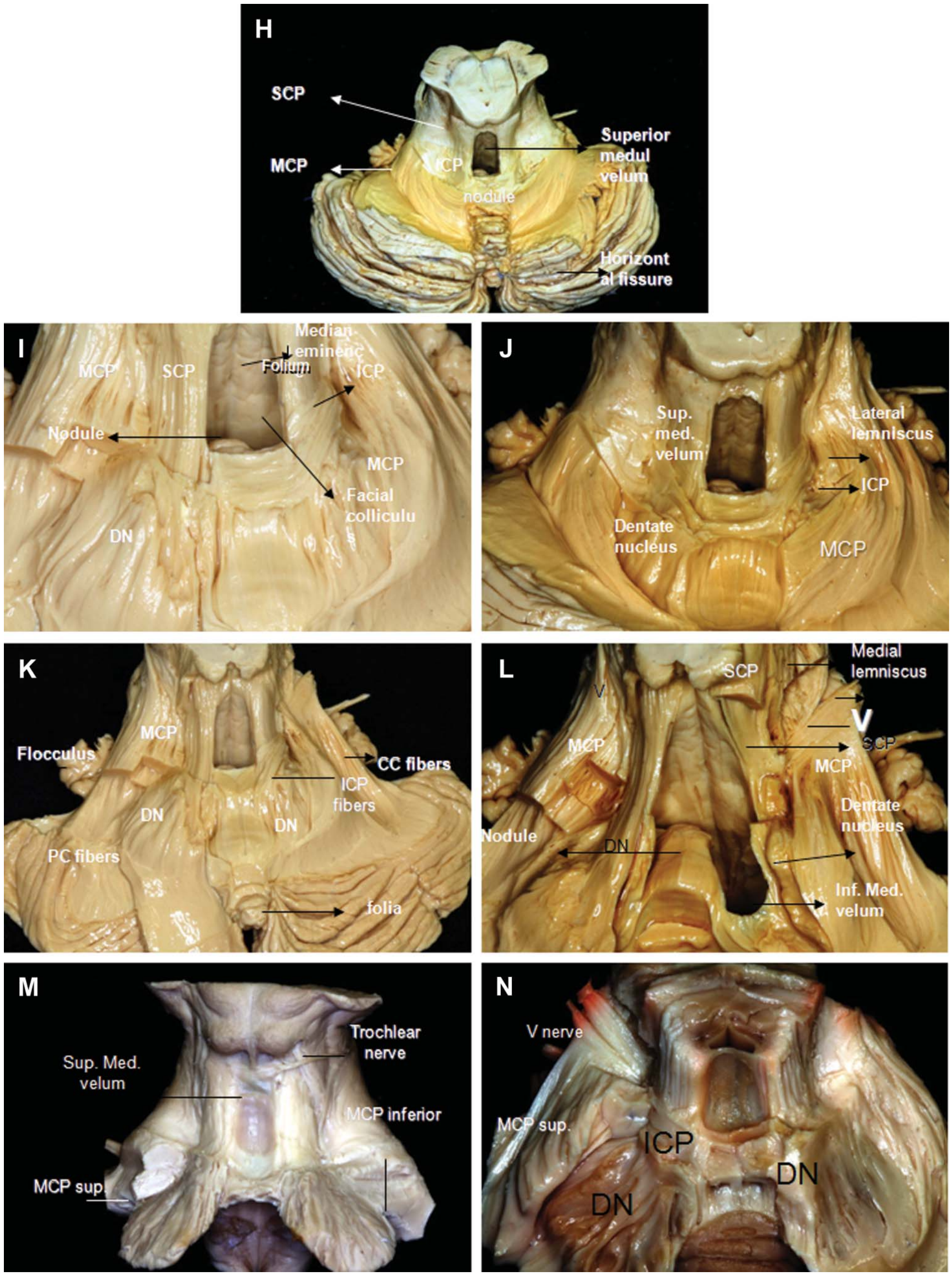


FIGURE 1. *Continues.*



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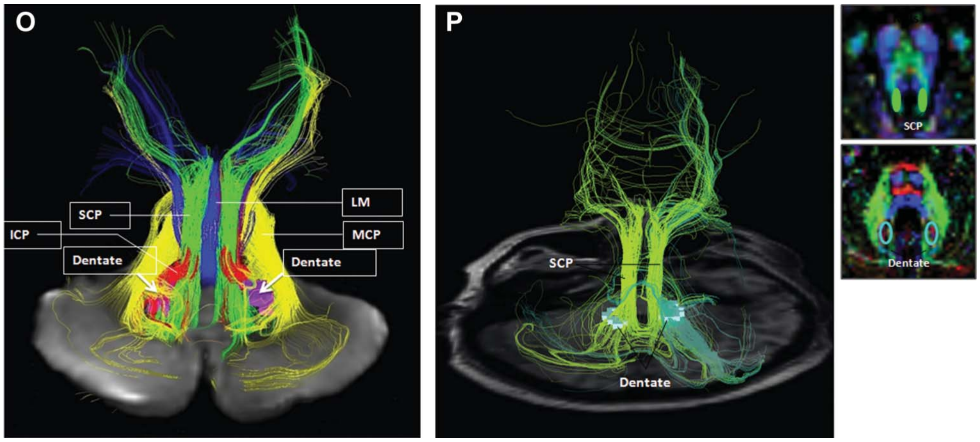

FIGURE 1. **A**, *the tentorial surface of the cerebellum faces the tentorium. This surface slopes downward to its posterior and lateral margins. The culmen and quadrangular (quad) lobules correspond to the anterior part of the tentorial surface, and the declive, simple lobules (SL), and part of the superior semilunar lobules correspond to the posterior part of the tentorial surface.* **B**, *the simple and quadrangular lobules have been removed. The nodule area is located at the medial side of both the dentate nucleus (DN) and superior medullar velum (SMV) with parts of the central lobe preserved. These structures are located superior, anterior, and medial to the DN. Superior cerebellar peduncle fibers emerge from the hilus of the DN and project rostrally into the upper pons, where they form a compact bundle along the dorsolateral wall of the fourth ventricle. Inferior cerebellar peduncle fibers enter the cerebellum from the lateral part of the pons and form the dorsal part of the fourth ventricle roof. They ascend perpendicular to the fourth floor and pass from the anterosuperior margin of the DN. They carry the spinocerebellar, cuneocerebellar, olivocerebellar, and vestibulocerebellar fibers. The middle cerebellar peduncle fibers course along from the lateral side of the DN, and some curve over and around the DN and some project in parallel. This peduncle carries the corticocerebellar (CC) and pontinocerebellar fibers.* **C**, *the simple and quadrangular lobules with vermian have been dissected bilaterally. Superior and middle cerebellar peduncle fibers have been dissected bilaterally. After dissection of the curved middle cerebellar peduncle fibers, the DN with large gray matter is observed. Superior cerebellar peduncle (SCP) fibers ascend symmetrically and are separated by the superior medullar velum, which is shown with part of the lingula.* **D**, *the left superior semilunar lobule (SSL) up to the horizontal fissure has been dissected. Middle cerebellar peduncle fibers project to the posterior part of the cerebellum, and the DN has an anatomic relationship to these fibers. Inferior cerebellar peduncle fibers that course lateral to the nodule area are seen.* **E**, *all gray and white matter around the DN has been dissected. Superior cerebellar peduncle fibers are seen bilaterally passing under the superior and inferior colliculi up to the red nucleus. Some middle cerebellar peduncle fibers project parallel to the DN, and curved fibers around the DN have been dissected. These fibers terminate in the superior and inferior semilunar lobule (ISL) areas.* **F**, *larger view of* **E**. *Superior cerebellar peduncle receives fibers from the DN. The hilus is at the same anatomic level as the choroid plexus. The hilus of the DN has been dissected. Middle cerebellar peduncle fibers follow a course superior and posterior to the DN.* **G**, *tractography showing a posterior oblique view of bilateral DN connectivity. The DN is shown in purple and the dentatorubrothalamic tract is shown in blue. DN fibers connect to the red nucleus. The cursor in the diffusion tensor images points to the right red nucleus.* **H**, *the tentorial surface of the cerebellum in another specimen. Corticocerebellar fibers curve over the DN and terminate at the vermian area. Middle cerebellar peduncle fibers are seen bilaterally; some of them connect to unite at the vermian area, making a curve.* **I**, *the superior cerebellar peduncle is lateral to the nodule (N). Inferior cerebellar peduncle fibers cross to the contralateral side of the cerebellum. The inferior cerebellar peduncle is anterior and superior to the DN.* **J**, *middle cerebellar peduncle fibers cover the DN. The lateral lemniscus (LM) is tracked laterally and superiorly to the DN and ascends into the inferior colliculus by crossing the superior cerebellar peduncle. The middle cerebellar peduncle is formed mainly by 2 groups of fibers: the corticocerebellar and pontinocerebellar (PC) fibers. Corticocerebellar peduncle fibers project from lateral to medial; PC fibers project laterally. The superior half of the roof is formed medially by the superior medullary velum and laterally by the inner surfaces of the superior cerebellar peduncles.* **K**, *some inferior cerebellar peduncle fibers pass to the contralateral side; some fibers track to the posterior ipsilaterally.* **L**, *view after deeper dissection of the superior medullary velum and superior cerebellar peduncle. Superior cerebellar peduncle fibers radiate into the DN. The inferior medullary velum blends into the nodule medially. On the right side, middle cerebellar peduncle fibers at the level of the triangle with the inferior and superior cerebellar peduncles were dissected, and the trigeminal nerve was exposed.* **M** *and* **N**, *superior aspect of the cerebellum after all the gray matter around the DN was removed in another specimen. The DN is located posterior to the inferior cerebellar peduncle. The nucleus of the trigeminal nerve area is anterior, superior, and lateral to the DN.* **O**, *tractographic reconstruction showing a posterior view of the cerebellum and cerebellar peduncles with the DN (arrows). The DN is in the middle of the triangle formed by the inferior cerebellar peduncle (ICP) anterior (red), middle cerebellar peduncle (MCP) lateral (yellow), and superior cerebellar peduncle medial (green) bilaterally. The medial lemniscus (ML) is shown in blue.* **P**, *posterior view of bilateral superior cerebellar peduncle tractogram (light green) and right DN connectivity (dark green). DN areas are also shown. Note that few connections shown in tractograms are crossed. Detailed regions of interest are shown above on the right. CC, corticocerebellar.*

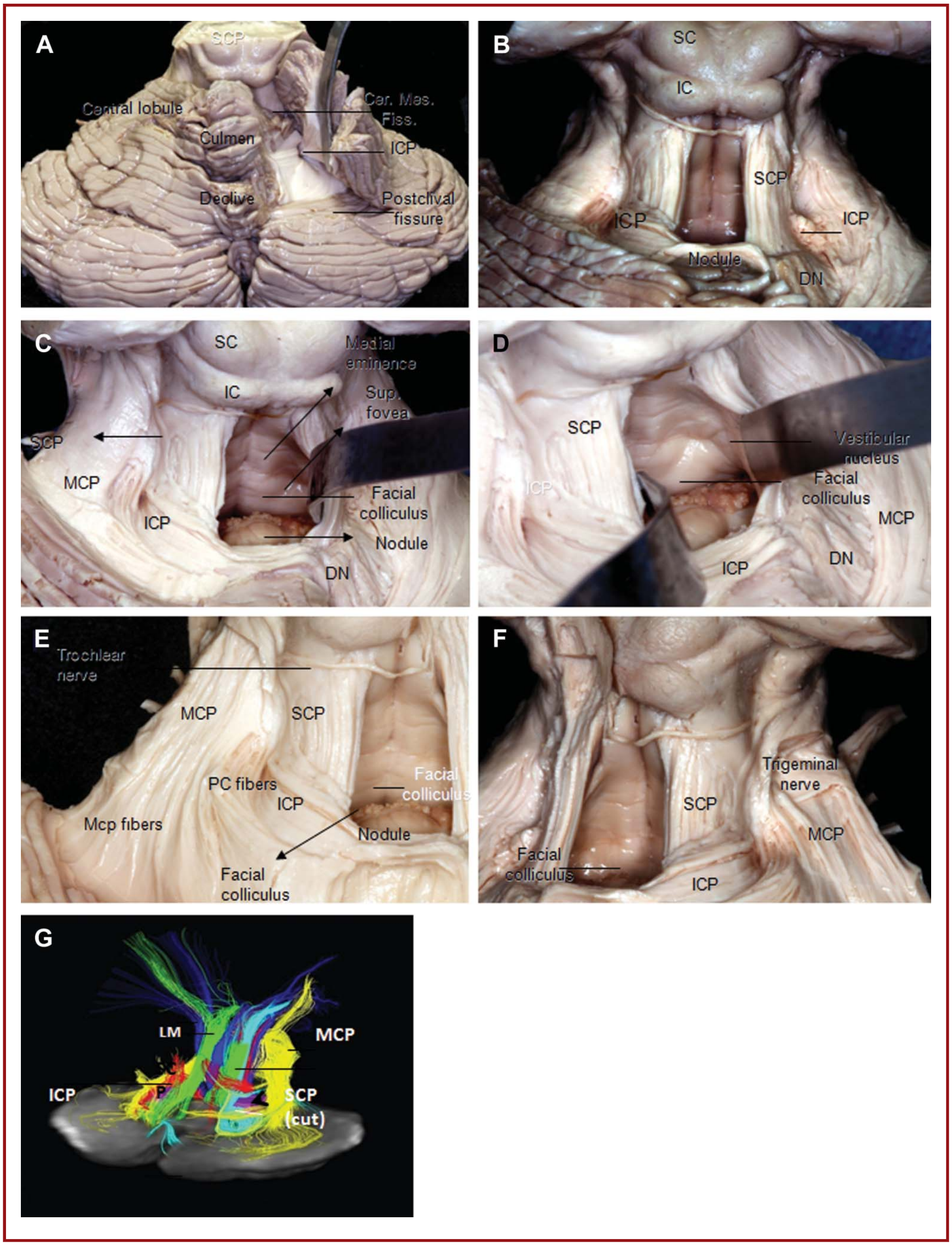
A
SCP
Central lobule
Culmen
Cer. Mes. Fiss.
ICP
Declive
Postclival fissure
B
SC
IC
SCP
ICP
ICP
Nodule
DN
C
SC
IC
Medial eminence
Sup. fovea
SCP
MCP
ICP
Facial colliculus
Nodule
DN
D
SCP
ICP
Vestibular nucleus
Facial colliculus
MCP
ICP
DN
E
Trochlear nerve
MCP
SCP
PC fibers
ICP
Facial colliculus
Mcp fibers
Nodule
Facial colliculus
F
Trigeminal nerve
SCP
MCP
Facial colliculus
ICP
G
LM
MCP
ICP
SCP (cut)

FIGURE 2. **A**, *on the tentorial surface, the primary fissure is located in the dentate nucleus (DN) area. The simple and quadrangular (quad) lobules have been retracted to expose the lateral part of the central lobule. The culmen is medial to and above the DN from the tentorial surface. Its posteroinferior attachment area is approximately the beginning of the DN from the tentorial surface. If dissection begins from the primary fissure, after retraction of the simple and quadrangular lobules laterally, inferior cerebellar peduncle fibers can be followed from lateral to medial.* **B**, *inferior cerebellar peduncle (ICP) has fibers crossing to the contralateral side of the cerebellum that pass anterior and inferior to the nodule (N). The hilus of the DN is approximately at this level.* **C**, *superolateral side of the cerebellum after removal of the quadrangular lobule on both sides. The superior medullary velum (SMV) is dissected. After retraction of the superior cerebellar triangle laterally, the superolateral side of the choroid plexus and the fourth ventricle floor is observed with the facial colliculus and median eminence.* **D**, *closure view of* **C** *with retraction of the superior cerebellar peduncle (SCP). Some middle cerebellar peduncle fibers have been removed to expose the border of the DN.* **E**, *simple and quadrangular lobules have been dissected up to the superior semilunar lobule (SSL). The middle and inferior cerebellar peduncles can be followed over the nodule while passing the contralateral side of the cerebellum. Facial colliculus is deep to the nodule, positioned anterior to the inferior cerebellar peduncle.* **F**, *the trochlear nerve crosses behind the superior cerebellar peduncle. Inferior cerebellar peduncle fibers arise between the superior and middle cerebellar peduncle and along the edge of the fastigium. The fourth ventricle floor with facial colliculus is shown after dissection of superior medullary velum.* **G**, *tractographic reconstruction shows an oblique view of cerebellar peduncles and the medial lemniscus (ML; blue). Fibers of the middle cerebellar peduncle (MCP; yellow) are lateral to the inferior cerebellar peduncle (red) and superior cerebellar peduncle (green). CC, corticocerebellar; ISL, inferior semilunar lobule; LM, lateral lemniscus; ML, medial lemniscus; PC, pontinocerebellar; SL, simple lobule.*

MATERIALS AND METHODS

A total of 10 fresh formalin-fixed and frozen cerebellum specimens were examined with the Ludwig and Klingler[12] fiber dissection technique and a novel modified method designed specifically by our team for this part of the nervous system. Microscope magnifications of ×6 to ×40 were used for the enhancement of both techniques. The arachnoid was removed microsurgically, and fibers were dissected with the use of a wood spatula as described by Ludwig and Klingler.

However, during the course of our study, the Ludwig and Klingler technique proved inadequate for the dissection in the white matter zone because of the very small caliber of the fibers and decussation; therefore, a gentler technique suitable for dissection in cerebellum and brainstem was designed. In this novel technique, readily available cotton swabs and Rhoton microsurgical instruments with very small dimensions were used. To achieve better delineation of the borders of the DN, a cotton-wrapped low-speed drill (10 000 rpm) was used. Before drilling, the tip was dampened with alcohol to obtain a working area that was not too soft. In this way, a tiny, slippery instrument mainly targeting the nucleus could be designed. The speed of this drill was set at the lowest level, and the drill was kept wet. The main idea behind this novel approach was that fiber dissection in such a narrow area requires the use of a fine instrument. All techniques were used at the highest possible magnification level.

Compared with the Ludwig and Klingler method, in which some fibers of tracts are wasted with the wooden spatula, this novel technique allowed the preservation of more fibers. In addition, it required less time and could localize the decussation and shifting of the tracts. Although the Ludwig and Klingler technique can detect only parallel large fibers, the new technique could pinpoint the nuclei and their margins, which were exposed through drilling the white matter around the nucleus, thus allowing the detection of the exact margins and size of the DN.

Diffusion tensor imaging (DTI) was performed on 15 healthy volunteers with a 3-T Magnetom Trio magnetic resonance imaging (MRI) device (Siemens, Erlangen, Germany). For the DN, a high-resolution MRI 3-dimensional T1 sequence (Neuronavigator) was carried out as follows: 3-dimensional magnetization-prepared rapid-acquisition gradient echo T1 (repetition time/echo time, 19/4.9 milliseconds; field of view, 250 × 250 mm; matrix, 256 × 256; contiguous sagittal slices, 160; thickness, 1 mm; and voxel, 1 × 0.98 × 0.98 mm) with preintravenous and postintravenous injection of paramagnetic contrast (gadopentetate dimeglumine). A DTI sequence was performed with a single-shot spin echo planar imaging (repetition time/echo time, 10.100/102 milliseconds; field of view, 250 mm; in-plane resolution, 2 × 2 mm; slice thickness, 2.0 mm; average, 2; matrix, 128 × 128; contiguous axial slices, 70; and voxel: 1.95 × 1.95 × 2 mm). The images were acquired in 30 nonlinear directions (b = 1000 s/mm^2) and in 1 acquisition without diffusion encoding (b = 0 s/mm^2). Tractographies of the DN and peduncles, traced in both the anterograde and retrograde directions, were acquired with the use of the DTV.II SR toolbox (UT Radiology/Image Computing and Analysis Laboratory, Department of Radiology, University of Tokyo Hospital; an extension of Volume-One package software [http://www.volume-one.org/]). Fractional anisotropy value in all cases was < 0.10.[13]

RESULTS

Despite previous conventional MRI studies on details of the cerebellar anatomy,[7,14,15] to the best of our knowledge, no studies to date have been carried out that combine DTI of cerebellar white matter and fiber dissection. High-resolution DTI color mapping and tractography have improved our understanding of normal human brain white matter anatomy, and in the present study, these techniques were applied to white matter fibers associated with the cerebellum. The primary goal of obtaining DTI images was to provide a demonstrative contribution to our dissections, which was the principal technique of our study.

Lobes of the Cerebellum in Relation to the DN

The cerebellum consists of 3 anatomic parts: a median vermis and 2 lateral hemispheres. The central vermis is elevated above the level of the hemispheres on the upper surface of the cerebellum, contrary to its deep depression on the suboccipital surface. The vermis is located adjacent to the DN bilaterally, and it is closer to the suboccipital surface of the cerebellum than to the tentorial surface.

The cerebellum has fissures that divide the organ into a series of layers or leaves. The largest and deepest fissure is the horizontal

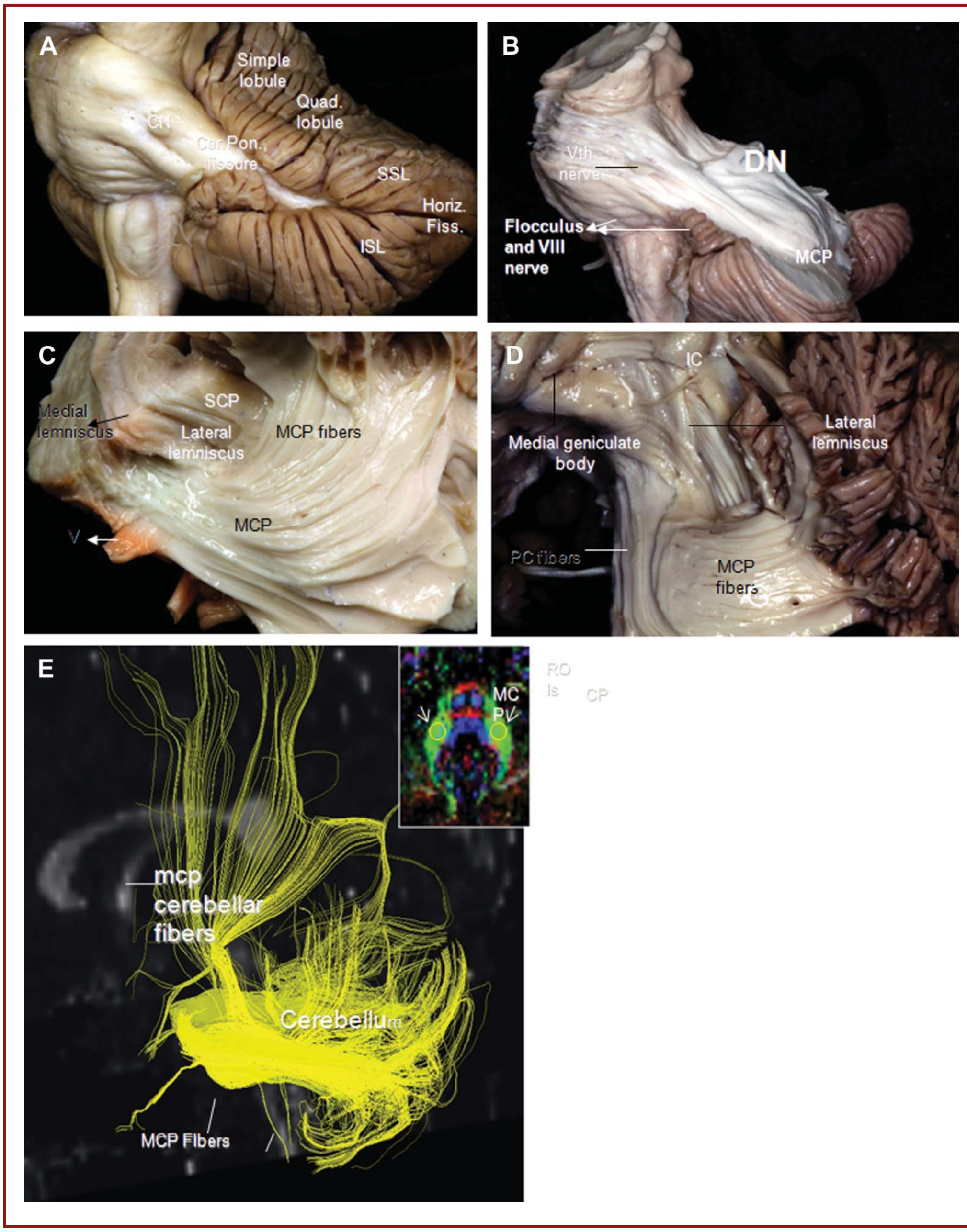
A
Simple lobule
Quad. lobule
CN
Cer.Pon. fissure
SSL
Horiz. Fiss.
ISL
B
Vth nerve
DN
Flocculus and VIII nerve
MCP
C
Medial lemniscus
SCP
Lateral lemniscus
MCP fibers
MCP
V
D
IC
Medial geniculate body
Lateral lemniscus
PC fibers
MCP fibers
E
MC P
mcp cerebellar fibers
Cerebellum
MCP Fibers

FIGURE 3. **A**, *lateral aspect of the left cerebellum and brainstem. Cerebellopontine fissure is located between the tentorial surface and suboccipital surface of the cerebellum. The superior part is formed by the quadrangular (quad), simple, and a small part of the superior semilunar lobules (SSL). The inferior part is formed by the inferior semilunar and biventral lobules and the tonsil. The cerebellopontine fissures are V-shaped fissures formed where the cerebellum wraps around the pons and the middle cerebellar peduncles (MCP). These fissures have a superior and an inferior limb, which meet at a lateral apex.* **B**, *the middle cerebellar peduncle has been dissected. It covers the dentate nucleus (DN) superiorly and inferiorly (shown also in suboccipital dissections). The trigeminal nerve zone is located between the middle cerebellar peduncle fibers.* **C**, *superolateral aspect of the cerebellum. The trigeminal nerve is seen between the middle cerebellar peduncle fibers, and corticocerebellar (CC) fibers are mainly superior to the trigeminal nerve. The medial lemniscus (ML) is anterior to the superior cerebellar peduncle (SCP) fibers and medial to the lateral lemniscus.* **D**, *lateral lemniscus (LL) located lateral to the superior cerebellar peduncle fibers. These fibers pass into the inferior colliculus and then project to the medial geniculate body. The lateral lemniscus arises between the superior and middle cerebellar peduncle fibers and forms the lateral mesencephalic fissure of the midbrain. Middle cerebellar peduncle fibers cover the DN, making a curve.* **E**, *diffusion tensor image of the middle cerebellar peduncle. The middle cerebellar peduncle projects posteriorly, inferiorly, and medially inside the cerebellum. The small image shows the region of interest of the diffusion tensor image. Cer. Pon., cerebellopontine; Fiss, fissure; Horiz, horizontal; ICP, inferior cerebellar peduncle; Inf, inferior; ISL, inferior semilunar lobule; N, nodule; Pet, petrosal; PC, pontinocerebellar; Post., posterior; SL, simple lobule; SMV, superior medullary velum.*

sulcus. The horizontal sulcus divides the semilunar lobule into inferior and superior semilunar lobules. These lobules receive fibers bilaterally from the middle cerebellar peduncle, as shown in Figures 1 and 2.

The vermis, positioned between the 2 hemispheres, is an important structure in the transvermian approach because it connects both hemispheres. The culmen represents the most apical part of the vermis at the tentorial surface. The distance between the tip of the culmen and the DN is 9.6 mm (Figures 1 and 2). From posterior to anterior, the subdivisions of superior vermis are represented by the lingula, central lobule, monticulus, and folium vermis. The DN is located 5 mm lateral to the vermis. The posterior lobe of the cerebellum, located between the primary and posterolateral fissures, represents the largest subdivision of the cerebellum. Vermal parts of the posterior lobe are, in the following order, the declive, folium, tuber, pyramid, and uvula. The pyramid has an attachment to the cerebellum bilaterally and is the beginning of the medial part of the DN (Figure 3). This attachment area of the pyramid is a landmark for the DN in cadaveric dissections.

The lobus centralis is a small square lobule situated in the anterior cerebellar notch. The hilus of the DN is approximately 9.1 mm posterior to the lobus centralis, and this distance is important in dissection of the DN at the tentorial surface in cadaveric specimens (Figures 1 and 2).

After removing the quadrangular lobules, inferior cerebellar peduncle fibers can be observed passing anteriorly to the DN (Figures 1 and 3) and projecting to the contralateral side through anterior DN (Figure 4).

The folium vermis is a short, narrow, concealed bandlike structure at the posterior extremity of the vermis. Laterally, it expands in either hemispheres into a sizeable lobule, the superior semilunar lobule, which occupies the posterior third of the upper surface of the hemisphere and is connected below by the horizontal sulcus. The superior semilunar lobule receives fibers mainly from middle cerebellar peduncles that are referred to as pontinocerebellar and corticocerebellar fibers (Figures 1 and 2).

Superior Cerebellar Peduncle in Relation to the DN

On sagittal dissections, the superior cerebellar peduncle, located approximately 5 mm from the midline, can be identified lateral to the superior medullary velum, tracting obliquely from the cerebellum to the midbrain. The superior cerebellar peduncle is the largest cerebellar efferent bundle, which is a group of fibers that emerge from the hilus of the DN. These fibers pass rostrally into the upper fourth ventricle.

The superior cerebellar peduncles emerge from the upper and medial part of the white substance of the hemispheres. They project in parallel and are placed under cover of the superior and inferior colliculi. They connect the DN to the red nucleus, forming the dentatorubrothalamic tract. They are joined by the superior medullary velum, can be followed up to the inferior colliculi, and disappear in the red nucleus (Figures 1 and 2).

The superior cerebellar peduncle is the largest efferent group of fibers of the DN. They form the upper lateral boundaries of the fourth ventricle, but as they ascend, they converge on the dorsal aspect of the ventricle and thus assist in the formation of its roof (Figure 4). The dentatorubrothalamic tract (dentatothalamic tract) is the major tract of the superior cerebellar peduncle. It ascends to the red nucleus, decussates, and projects to the ventrolateral side of the thalamus.

The superior medullary velum is of particular importance for approaches to the fourth ventricle in anatomic dissections. After exposure of the superior medullary velum, the nuclei of the abducens and the vestibular and cochlear nerves can readily be seen in the fourth ventricle floor in anatomic specimens. After retraction of the superior medullary velum laterally, tuberance of the DN is observed at the lateral recess of the fourth ventricle floor (Figure 2).

Middle Cerebellar Peduncle in Relation to the DN

The DN is located posteroinferiorly in the middle cerebellar peduncle fibers. There are 2 groups of middle cerebellar peduncle fibers passing over the DN. The first group of fibers are parallel to the midline and are essentially called the corticocerebellar fibers.

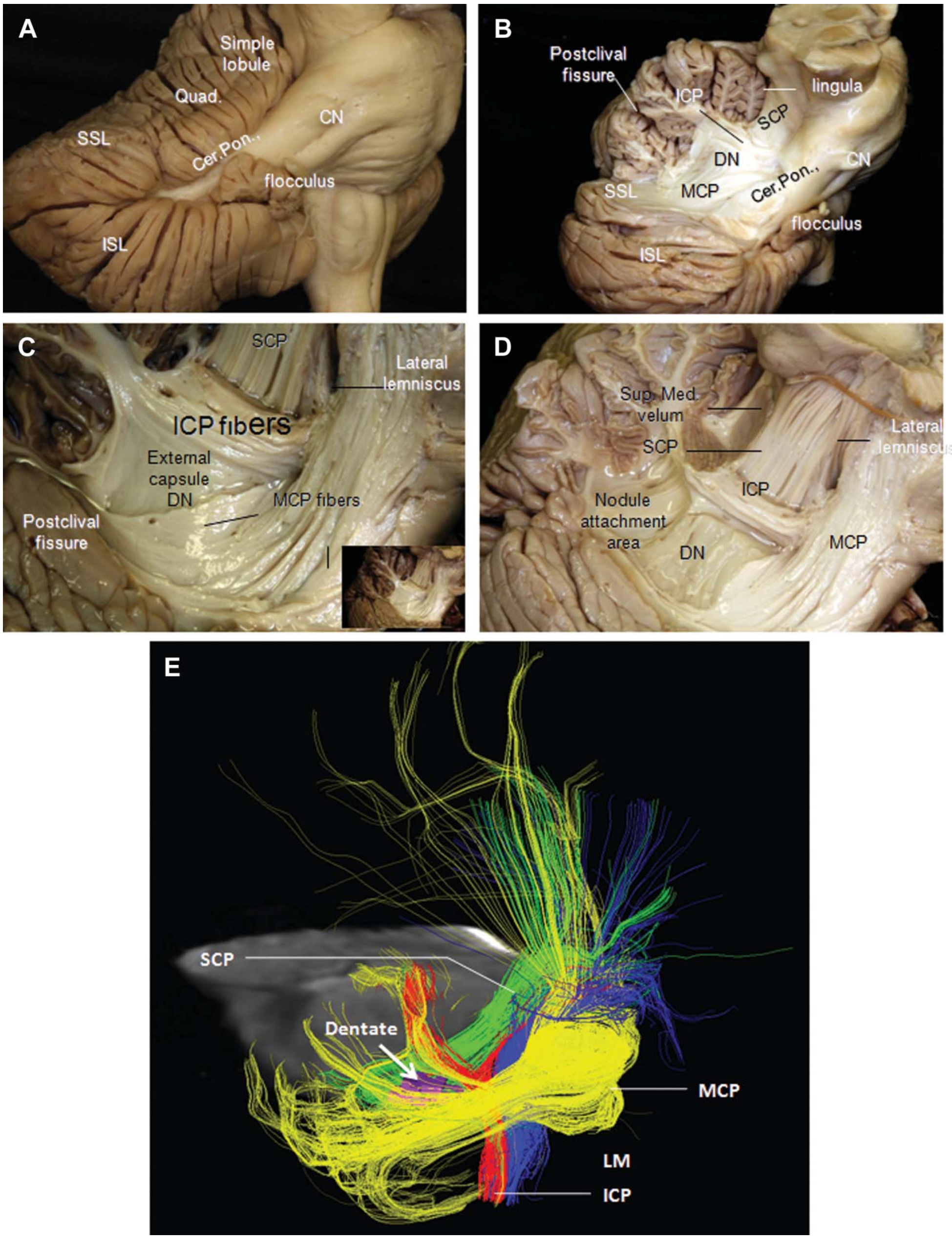
A
Simple lobule
Quad.
SSL
Cer.Pon.,
CN
flocculus
ISL
B
Postclival fissure
ICP
lingula
SCP
DN
CN
SSL
MCP
Cer.Pon.,
flocculus
ISL
C
SCP
Lateral lemniscus
ICP fibers
External capsule DN
MCP fibers
Postclival fissure
D
Sup. Med velum
SCP
Lateral lemniscus
ICP
Nodule attachment area
DN
MCP
E
SCP
Dentate
MCP
LM
ICP

FIGURE 4. **A**, *lateral aspect of the right cerebellum.* **B**, *the dentate nucleus (DN) is located lateral to the vermis, particularly in the culmen area. The lingula has a very close relationship with superior cerebellar peduncle (SCP) fibers that include efferent fibers to the DN. Inferior cerebellar peduncle (ICP) fibers enter the cerebellum from the lateral part of the pons and form the dorsal part of the lower roof of the fourth ventricle. They ascend parallel to the fourth floor and pass from the anterior and superior margin of the DN. The DN is located posterior to inferior cerebellar fibers. Inferior cerebellar fibers pass to the other side of the cerebellum over the nodule (N). Middle cerebellar peduncle fibers pass from the lateral side of the DN and curve over and around the DN.* **C**, *middle cerebellar fibers have been dissected, and the external capsule of the DN is located just superior to the DN. Middle cerebellar peduncle (MCP) fibers, which are mainly corticocerebellar (CC), curve around the DN. Postclival fissure is located posterior to the DN.* **D**, *the inferior cerebellar peduncle enters the cerebellum and extends to the other side of the cerebellum superior to the nodule area. The inferior cerebellar peduncle is located between the DN and superior cerebellar peduncle. The lateral lemniscus (LM) passes through the triangle formed by the inferior cerebellar peduncle, middle cerebellar peduncle, and superior medullary velum (SCP). The nodule area is located medial to the DN.* **E**, *selective fiber tracking of the inferior cerebellar peduncle and superior medullary velum in the lateral view. The area of interest selected for inferior cerebellar peduncle on diffusion tensor imaging is the posterolateral part of the medulla in axial section. This peduncle is rather difficult to get with selective tracking, and images were often better with 2 b values. The area of interest to get a tracking of superior medullary velum is easy to trace on lateral diffusion tensor imaging. In normal cases, the 2 superior medullary velum are symmetrical. They can be followed to the level of internal capsule and corona radiata. Dtn, level of projection of the dentate nucleus; ISL, inferior semilunar lobule; Med, medula level; Ml, medial lemniscus projection; PC, pontinocerebellar; Pnt, pontine level; SL, simple lobule; SSL, superior semilunar lobule.*

The other group of fibers project parallel to the DN, toward the posterior cerebellum, to reach the superior and inferior semilunar lobules. This group is known as pontocerebellar fibers. Middle cerebellar peduncles radiate to all the cerebellar locations. Superior fibers of the middle cerebellar peduncle make a curve around the DN. These fibers cover the DN from the medial to lateral direction. Middle cerebellar peduncle fibers wrap the DN superiorly and inferiorly. Fibers on the inferior side, called

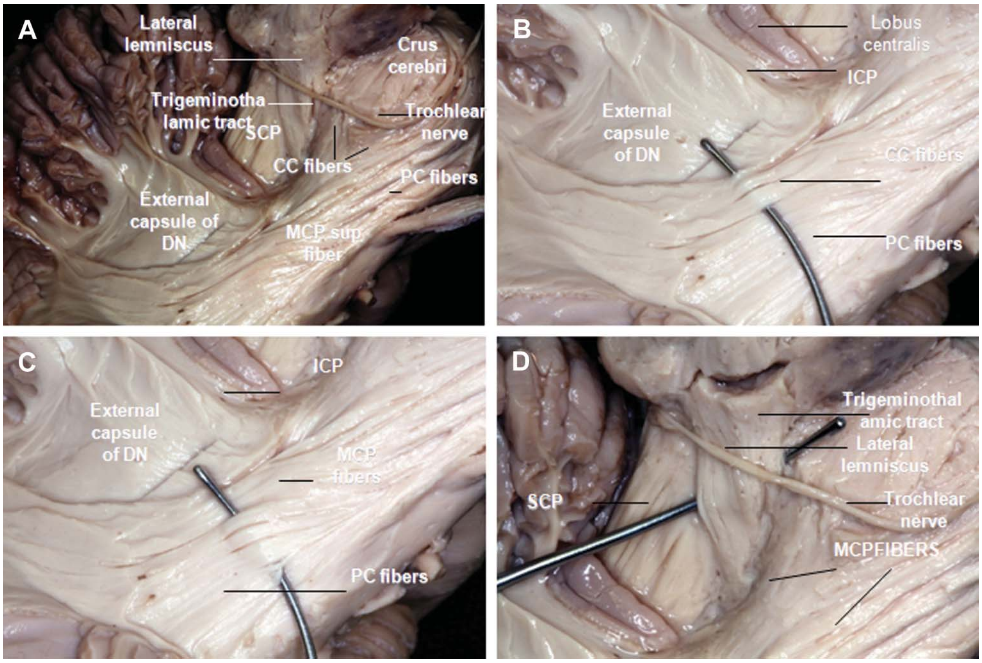

FIGURE 5. **A**, *superior (SCP) and middle cerebellar peduncle (MCP) fibers have been dissected on the right side of cerebellum. Lateral lemniscus (LM) tracts between the superior and middle cerebellar peduncles and trochlear nerve project anteriorly. The middle cerebellar peduncle has been dissected, and the external capsule is observed over the dentate nucleus (DN). The trochlear nerve wraps around the crus cerebri.* **B**, *middle cerebellar peduncle and its fibers that cross the midline over the DN are clearly shown. The DN is outlined and can be traced with the surrounding fibers.* **C**, *middle cerebellar peduncle fibers are dissected. Usually pontinocerebellar fibers track laterally and corticocerebellar fibers track medially.* **D**, *same specimen as* **C** *showing closure, and the superior view, lateral lemniscus, and trigeminothalamic tract are demonstrated over the dissector. The trochlear nerve crosses over the lateral lemniscus. The superior cerebellar peduncle is located medial and inferior to the lateral lemniscus. ICP, inferior cerebellar peduncle; ISL, inferior semilunar lobule; N, nodule; quad, quadrangular; SL, simple lobule; SMV, superior medullary velum; SSL, superior semilunar lobule.*

the middle cerebellar inferior fibers, project to the posterior cerebellum, passing superiorly over the tonsils. These fibers constitute the pontinocerebellar fibers. Fibers located superiorly are referred to as the middle cerebellar superior fibers, and some of those fibers project mainly ipsilaterally whereas others project contralaterally. Middle cerebellar peduncle fibers curve over the DN and project to the contralateral side from the posterior of the nodule (Figures 1, 2 and 5).

Inferior Cerebellar Peduncle in Relation to the DN

The inferior cerebellar peduncle ascends from the medulla to cerebellum, conveying a number of fiber systems to the cerebellum (Table 1). Inferior cerebellar peduncle fibers ascend to the cerebellum from the lateral pons and pass dorsally from the roof of the fourth ventricle. They ascend perpendicular to the fourth floor and pass from the anterior and superior margins of the DN. The DN is located posterior to the inferior cerebellar peduncle fibers. The inferior cerebellar peduncle fibers cross to the contralateral side of the cerebellum over the nodule; however, some fibers follow an ipsilateral course from the lateral border of the nodule. They carry mainly the spinocerebellar, cuneocerebellar, olivocerebellar, and vestibulocerebellar pathways.

The nodule or anterior part of the inferior vermis is located between the 2 DNs. It has a semilunar shape, and its convex border is continuous with the white substance of the cerebellum, extending on either side up to the flocculus. On either side of the nodule, a thin layer of a white substance exists, which is referred to as the inferior medullary velum. It also has a semilunar form, and its convex border is continuous with the white substance of the cerebellum. Inferior cerebellar peduncle fibers cross to the contralateral side superior to the nodule, and some ipsilateral fibers project posteriorly through the superolateral side of the nodule. The attachment of the inferior medullary velum to the cerebellum at the lateral border is approximately 2.6 mm away from the lateral border of the DN. The closest part of the inferior medullary velum to the DN at the lateral recess is called the DN tuberance (Figures 1 and 2).

Dorsal spinocerebellar fibers are major fibers of the inferior cerebellar peduncle that cross over to the contralateral hemisphere of the cerebellum (Figure 4). Although some of these fibers pass from the anterior surface of the DN projecting from the lateral direction to the medial direction, others follow a parallel course to the nodule and dorsally to the fourth ventricle roof. Dorsal spinocerebellar fibers ascend ipsilaterally in a tract that is located at the edge of the spinal cord and terminate ipsilaterally. The inferior cerebellar peduncle also carries the olivocerebellar pathway. This pathway is distributed to all parts of the cerebellum at the ipsilateral and contralateral sides. The cuneocerebellar tract conveys fibers from the ipsilateral accessory

TABLE 1. Measurements of Important Structures in the Cerebellum According to the Position of the Dentate Nucleus

	Right, mm	Range, mm	Left, mm	Range, mm
Postnodular fissure	7.7	7.1-8.2	7.91	7.0-8.2
Tonsillar attachment	0.69	0.5-0.9	0.65	0.5-0.7
Inferior semilunar lobule	15.2	14.6-15.3	15.48	14.1-15.6
Trigeminal nerve exit point	4.30	3.2-4.7	4.90	3.5-5.1
Primary fissure	13.32	12.1-14.3	13.21	12.3-14.2
Prepyramidal fissure	7.73	7.2-8.6	7.68	7.2-8.3
Cerebellomesencephalic fissure	8.62	8.1-9.4	8.69	8.6-9.1
Flocculonodular lobule	12.2	12.1-13.4	12.14	11.9-12.7
Cerebellopontine fissure	17.4	17.1-17.9	17.14	17.1-17.4
Cerebellomedullar fissure	2.25	1.1-2.4	2.22	1.0-2.3
Trigeminal nerve entrance	8.59	7.2-8.9	9.14	7.7-9.3
Simple lobe	11.30	11.2-11.5	10.94	10.2-11.5
Quadrangular lobe	13.25	13.1-13.4	12.98	12.1-13.3
Trigeminal nerve entrance to the middle cerebellar peduncle	8.82	8.6-8.9	8.26	8.0-8.8
Uvula	2.16	2.1-2.9	2.03	0.6-2.3
Pyramid attachment area	1.8	1.1-2.4	1.77	1.3-2.1
Inferior medullary velum	2.6	0.3-3.7	2.57	0.2-3.8
Tuber vermis	1.41	1.2-1.7	1.44	1.3-1.7
Superior semilunar lobule	17.1	16.9-17.5	17.52	16.8-17.9
Tip of the tonsil	10.9	10.8-11.2	10.85	10.5-11.3
Nodule	5.0	5.2-5.6	4.78	4.2-5.3
Postpyramidal fissure	5.8	5.1-7.4	5.78	5.2-6.1
Midline end of dentate nucleus	7.95	7.5-8.4	7.75	7.2-8.4
Trochlear nerve	17.49	17.2-17.7	17.44	17.1-17.6
Lobus centralis	9.4	9.2-9.5	9.20	9.1-9.5
Culmen	9.61	9.2-10.5	9.60	9.1-10.3
Declive	8.73	8.5-9.2	9.04	8.7-9.1

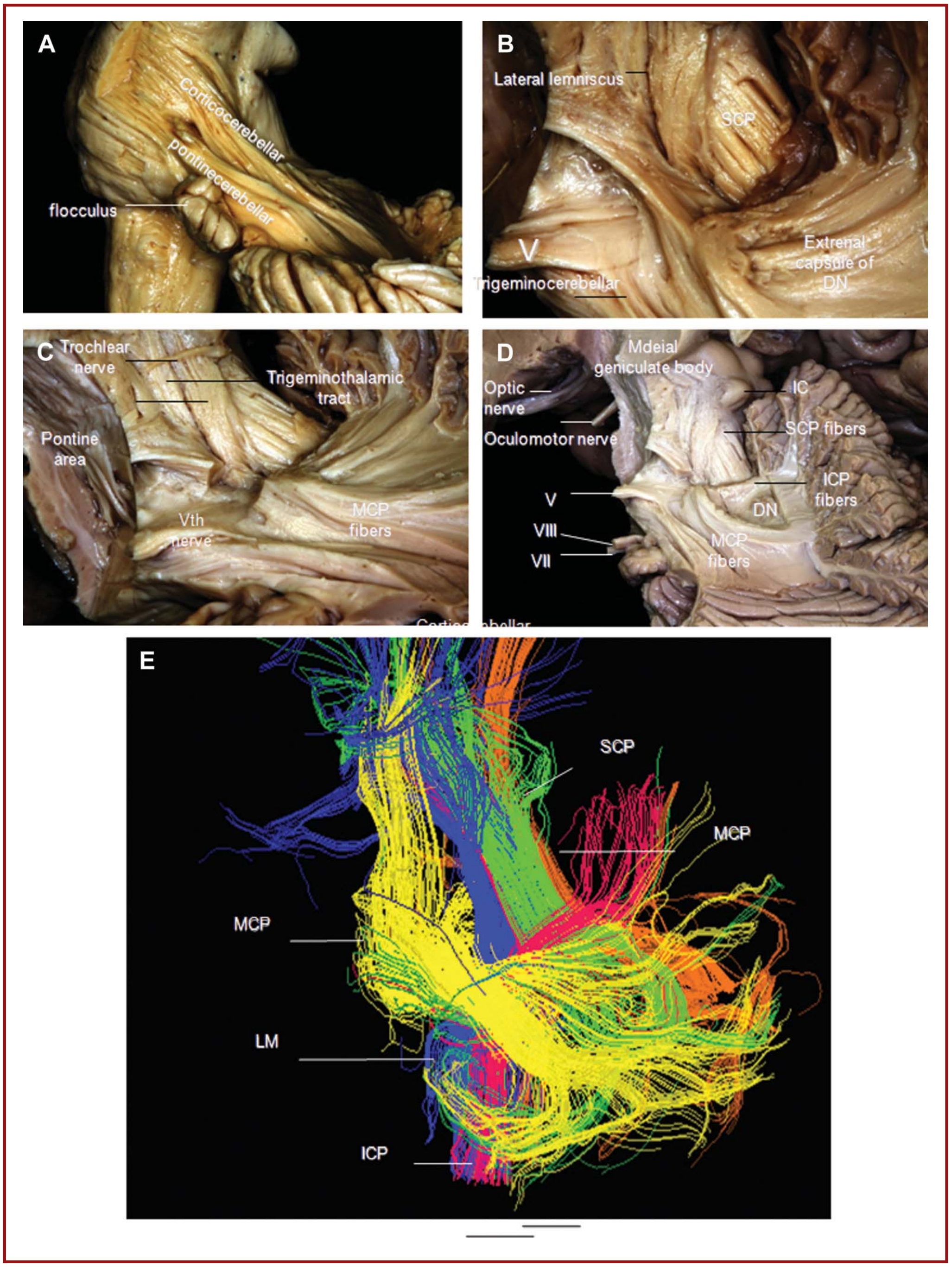
A
Corticocerebellar
pontinecerebellar
flocculus
B
Lateral lemniscus
SCP
V
Trigeminocerebellar
Extrenal capsule of DN
C
Trochlear nerve
Trigeminothalamic tract
Pontine area
Vth nerve
MCP fibers
D
Mdeial geniculate body
Optic nerve
Oculomotor nerve
IC
SCP fibers
ICP fibers
DN
V
VIII
VII
MCP fibers
E
SCP
MCP
MCP
LM
ICP

FIGURE 6. **A**, *lateral view of the left side of the cerebellum. The trigeminal nerve zone arises between the middle cerebellar peduncle (MCP) fibers. Flocculus is just lateral to the middle cerebellar peduncle fibers. Middle cerebellar peduncle fibers pass superior to the dentate nucleus (DN). The middle cerebellar peduncle also has fibers that pass inferior to the DN and the trigeminal nerve.* **B**, *the middle cerebellar peduncle has been dissected over the trigeminal nerve. The motor part of the trigeminal nerve is located superiorly and medially to the sensory nerve fibers. The lateral lemniscus (LM) is located between the superior (SCP) and middle cerebellar peduncle fibers.* **C**, *pons is dissected with the pyramidal tract, and the lateral lemniscus is separated from the trigeminothalamic tract. Trigeminal nerve fibers can be followed up to the lateral recess where the nucleus is localized. The trigeminal nucleus is located lateral to the superior cerebellar peduncle.* **D**, *general view of the same specimen with the exposure of optic, trigeminal, vestibular, and facial nerves in relation to the DN.* **E**, *diffusion tensor images of the lateral view of the cerebellum. Images are correlated with the above dissections. ICP, inferior cerebellar peduncle; ISL, inferior semilunar lobule; N, nodule; quad, quadrangular; SL, simple lobule; SMV, superior medullary velum; SSL, superior semilunar lobule.*

cuneate nucleus to the cerebellum. Cuneocerebellar fibers project ipsilaterally to the hemisphere of the cerebellum over the nodule. Nomenclature of fibers in the contralateral or ipsilateral hemispheres and information on their physiology and histology can be found in textbooks (eg, *The Cerebellum: Brain for an Implicit Self*, Neuroscience; 2nd edition; 2001).

Position of the DN in Relation to Cerebellar Surfaces

Tentorial Surface

The tentorial surface faces the tentorium and is retracted in the supracerebellar approach. The anteromedial part of the tentorial surface, the apex, formed by the anterior vermis, is the highest point on the cerebellum. This part is approximately 17.1 mm away from the lateral border of the DN. Its surface slopes downward from its anteromedial to its posterolateral edge. The tentorial surface carries the inferior and middle cerebellar peduncle fibers from the superior anterior to posterior inferior direction (Figure 2). The hemispheric part of the tentorial surface includes the quadrangular, simple, and superior semilunar lobules, and the vermian division includes the culmen, declive and folium.

The lateral side of the DN is, on average, 11.1 mm away from the tip of the simple lobes and 11 mm away from the lateral part of the quadrangular lobe. This lobe receives corticocerebellar and pontinocerebellar fibers from the middle cerebellar peduncle. Anterior and medial to these fibers lay the inferior cerebellar peduncle fibers (Figure 3).

The tentorial surface is divided into anterior and posterior sections by its major fissure, the tentorial fissure. This fissure, located between the quadrangular and the simple lobules on the hemisphere and the culmen and declive on the vermis, has also been called the primary fissure. It is just above and approximately 13.2 mm away from the DN. The postclival fissure separates the simple and the superior semilunar lobules. The fissure is at the posterior part of the cerebellum, and the DN is 12.6 mm away from the tip of the fissure (Figure 4).

Dissection of the tentorial surface from the simple lobe to the superior semilunar lobule is shown in Figures 1-3. The superior cerebellar peduncle and lateral lemniscus can be seen after dissection of the simple and quadrangular lobules. The inferior cerebellar peduncle fibers and superior cerebellar peduncle fibers can be observed after removal of the simple and quadrangular lobules. Dissection is continued until the superior semilunar lobule is reached, as shown in Figure 1. Some fibers of the inferior cerebellar peduncle are observed projecting to the contralateral side; other fibers are observed ipsilaterally. At this location, identifying different fiber groups is highly challenging. In physiology literature, olivocerebellar and vestibulocerebellar fibers are described as crossing to the contralateral side and lateral to the nodule; these are referred to as cuneocerebellar and spinocerebellar fibers, which project ipsilaterally. Some middle cerebellar peduncular fibers project laterally and some others medially. Corticocerebellar fibers make a curve around the DN, and pontinocerebellar fibers go parallel to the DN to the posterior cerebellum (Figures 4 and 5). After dissection of middle cerebellar peduncle fibers, a very thin external capsule is observed superior to the DN (Figure 5). If dissection is extended into the white matter of the cerebellum, the DN can be distinguished laterally and posteriorly.

Lateral Surface in Relation to the DN

The lateral recesses are narrow, curved pouches formed by the union of the roof and the floor. The rostral wall of each lateral recess is formed by the caudal margin of the cerebellar peduncles. The inferior cerebellar peduncle courses upward in the floor ventral to the lateral recess and turns posteriorly at the lower part of the pons to form the ventricular surface of the rostral wall. The inferior cerebellar peduncle ascends superomedially to the DN and courses between the superior and middle cerebellar peduncles. The biventral lobule that is inferomedial to the DN is dorsal to the lateral recess (Figures 3, 4, and 6).

The lateral lemniscus courses lateral and superior to the DN and just lateral to the inferior cerebellar peduncle. It crosses the superior cerebellar peduncle (Figures 1 and 2).

The trigeminal nerve exit point is at the middle cerebellar peduncle and is 8.6 mm from the DN. The trigeminothalamic tract passes lateral to the lateral lemniscus and reaches the ventral posteromedial nucleus of the thalamus ipsilaterally. It arises from the sensory trigeminal nucleus, which is located lateral to the locus cereus and vestibular fibers that join the medial longitudinal fasciculus (Figures 1-3).

Suboccipital Surface

Operative approaches to the fourth ventricle and to most cerebellar tumors commonly involve this surface and its close

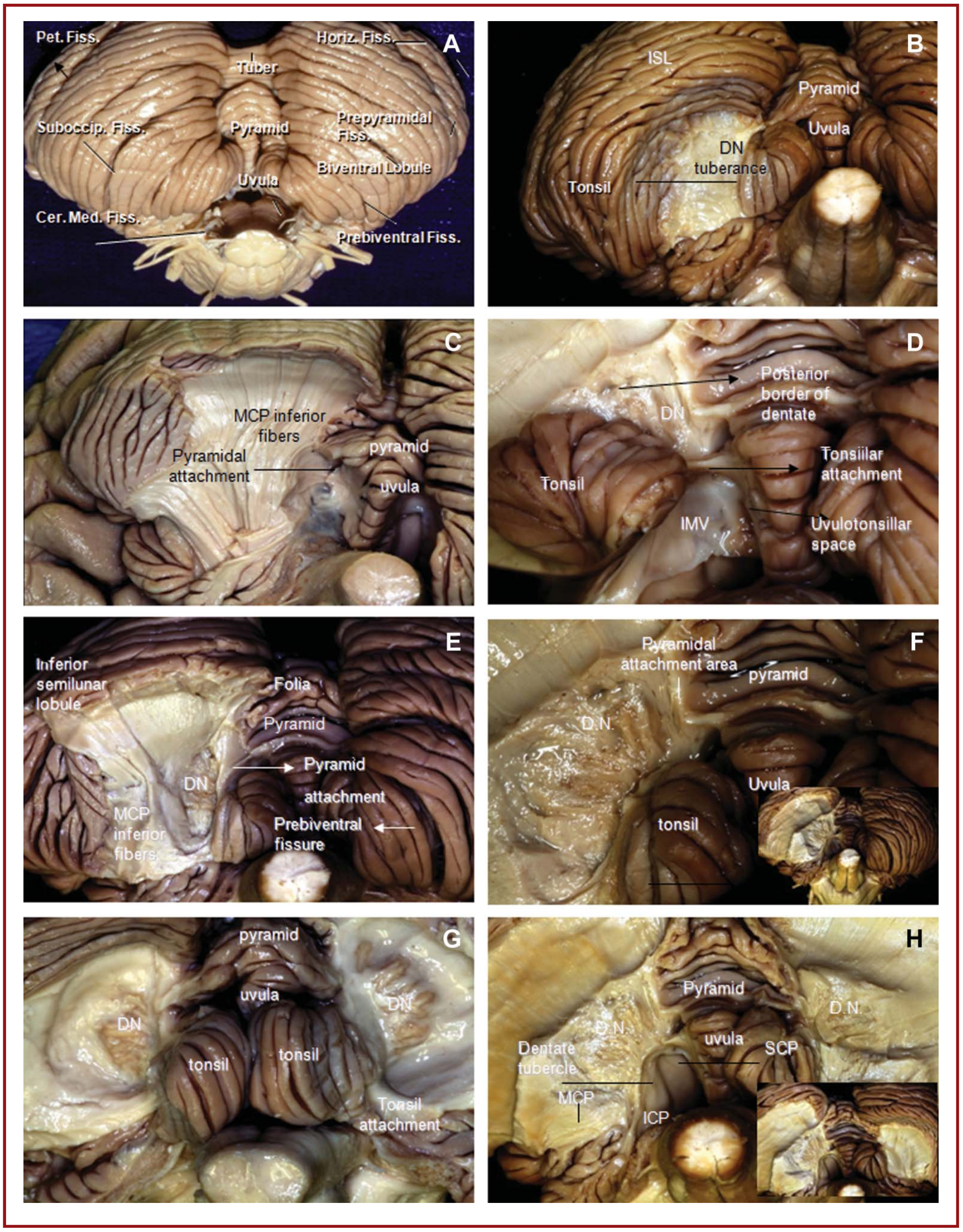
Pet. Fiss.
Horiz. Fiss.
A
Tuber
Suboccip. Fiss.
Pyramid
Prepyramidal Fiss.
Biventral Lobule
Uvula
Cer. Med. Fiss.
Prebiventral Fiss.
B
ISL
Pyramid
Uvula
DN tuberance
Tonsil
C
MCP inferior fibers
Pyramidal attachment
pyramid
uvula
D
Posterior border of dentate
DN
Tonsillar attachment
Tonsil
IMV
Uvulotonsillar space
E
Inferior semilunar lobule
Folia
Pyramid
DN
Pyramid attachment
MCP inferior fibers
Prebiventral fissure
F
Pyramidal attachment area
pyramid
D.N.
Uvula
tonsil
G
pyramid
uvula
DN
DN
tonsil
tonsil
Tonsil attachment
H
Pyramid
D.N.
D.N.
uvula
SCP
Dentate tubercle
MCP
ICP

FIGURE 7. **A**, *the suboccipital surface. The vermis sits in a large median depression, the posterior cerebellar incisura, between the cerebellar hemispheres. The anatomic parts of the vermis within the incisura from top to bottom are the folium, tuber, pyramid, and uvula. The parts of the hemispheric surface from top to bottom are the superior and inferior semilunar and biventral lobules and the tonsils. These lobules extend beyond the suboccipital surface to the other surfaces of the cerebellum. The prebiventral fissures between the inferior semilunar and the biventral lobules separate the hemispheres into superior and inferior parts, and the prepyramidal fissure between the pyramid and tuber separates the vermis into superior and inferior parts. From top to bottom, the corresponding vermian and hemispheric parts are the uvula and the tonsils, the pyramid and the biventral lobules, the tuber and inferior semilunar lobules, and the folium and the superior semilunar lobules. The petrosal (horizontal) fissure, the most prominent fissure on the petrosal surface, extends onto the suboccipital surface and divides the superior half of the suboccipital surface between the superior and inferior semilunar lobules. Between the biventral and tonsillar lobules is the prebiventral fissure, which is important for approaching the fourth ventricle via the supratonsillar approach.* **B**, *biventral lobule has been dissected. The pyramid and biventral lobules constitute the lobus pyramidis. The pyramid is a conical projection, forming the largest prominence of the inferior vermis. The lateral border is separated from the inferior semilunar lobule by the postpyramidal fissure. The pyramid has attachment to the dentate nucleus (DN) laterally. The uvula has an attachment at the base of the tonsils and the uvula and pyramid form an important landmark for the location of the DN. The base is directed forward, and it is on a line with the anterior border of the tonsil. The base is separated from the flocculus by the postnodular fissure. White matter in this area is formed with middle cerebellar peduncle fibers.* **C**, *cerebellar attachment point of the pyramid. The folium and the tuber, superior to the pyramid, form the apex of the suboccipital part of the vermis. These structures are posteriomedial to the DN. The uvula is the medial part of DN. The tonsil is located anterior, inferior and medial to the DN.* **D**, *the lower half of the diamond-shaped formation, the uvula, projects downward between the tonsils. The uvula and pyramid are very close to the DN in comparison with the other midline structures.* **E**, *some fibers projecting posteriorly are referred to as the middle cerebellar peduncle (MCP) inferior fibers. Middle cerebellar peduncle fibers can be distinguished laterally and medially. Note the DN at this level, which is medial to the trajectory of the supratonsillar approach.* **F**, *closure view of* **E**. *The DN border is inferior to the tonsil attachment area medially; the pyramidal attachment is 1.8 mm away from the medial border of the DN.* **G**, *after dissection of gray matter bilaterally, the DN is reached. The tonsil attachment area is superior and anterior to the DN.* **H**, *note that the tonsillar peduncle merges with the inferior cerebellar peduncle (ICP) to lead to the peduncular white matter lateral to the fourth ventricle, deepening the slice through the middle cerebellar peduncle. In addition, the anatomic relationship between the peduncle and the DN can be observed. DN tuberance is lateral to the inferior cerebellar peduncle. The uvula and pyramid have attachments to the medial border of the DN. CC, corticocerebellar; ISL, inferior semilunar lobule; LM, lateral lemniscus; N, nodule; PC, pontinocerebellar; SCP, superior cerebellar peduncle; SL, simple lobule; SMV, superior medullary velum; SSL, superior semilunar lobule.*

proximity. The lateral walls of the incisura are formed by the medial part of the cerebellar hemispheres. Deep clefts, known as the vermohemispheric fissures, separate the vermis from the hemispheres. The vermian surface within the incisura has a diamond shape. The upper half of the diamond-shaped formation has a pyramidal shape; thus, it is called the pyramid. The pyramid attachment site is located in the cerebellum and bears some significance in determining the localization of the DN, which is just lateral to the attachment area (Figures 7 and 8). The folium and the tuber, superior to the pyramid, form the apex of the suboccipital part of the vermis. These structures are posteromedial to the DN. The pyramid attachment side is approximately 1.8 mm away from the DN. It is closer to the DN than the other midline structures. The nodule, the lowermost subdivision of the vermis, is hidden deep in the uvula. The nodule has attachment to the DN tuberance at the lateral recess, and the midline of the nodule is 5 mm away from the DN (Figure 10).

The hemispheric portion of the suboccipital surface is formed by the superior and inferior semilunar and biventral lobules and the tonsils. This portion is important for the supratonsillar and subtonsillar approaches. During dissection through the tonsillobiventral fissure, the inferomedial border of the DN can be observed (Figures 8 and 9).

The lateral surface of each tonsil is covered by the biventral lobule, and the fissure between them is called the biventral fissure. The posterior aspect of the superior pole faces the uvula medially and the biventral lobule laterally. Retraction of the tonsil or incision through the biventral lobule may result in damage to the DN. The tonsil has some connection with the middle cerebellar peduncle fibers that curve around the DN and tonsil attachment area (Figures 7-9).

The tonsils and biventral lobule have been separated and the white matter in between is known as the tonsillobiventral fissure. This is an important landmark for the supratonsillar approach. This white matter is formed mainly by the middle cerebellar peduncle fibers. When dissection is continued within the white matter, the inferior border of the DN can be observed, and continued dissection of the white matter posteriorly exposes the middle cerebellar peduncle fibers. The middle cerebellar peduncle in the tentorial surface has 2 main fibers, some of which follow a parallel course to the DN, and others curve around it. In the tentorial surface, middle cerebellar peduncle fibers curve and project to the contralateral side, but on the suboccipital surface, middle cerebellar peduncle fibers that curve around the inferior DN do not pass to the contralateral side and instead project posteriorly. On the suboccipital surface, the pyramid and uvula form the area where the DN is closest to the surface. The DN makes its tuberance, which is an important landmark, at the lateral recess in cadaveric dissections. The DN tuberance is located superiorly and lateral to the superior vestibular nucleus area (Figures 6, 7, 9B, and 10).

Important anatomic pathways examined are shown in Tables 1-3.

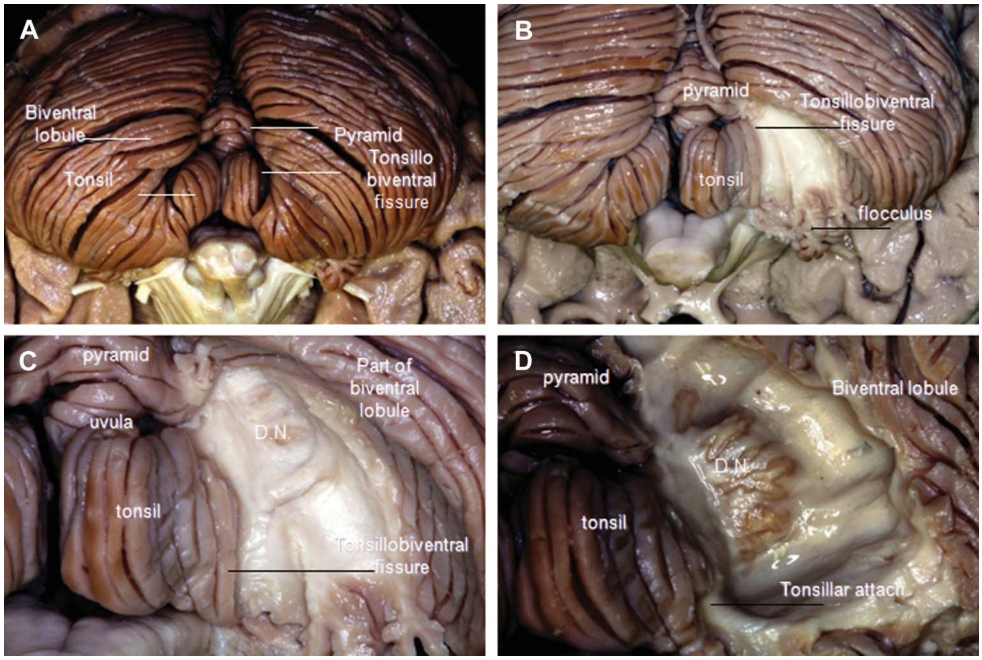

FIGURE 8. **A**, *another specimen with suboccipital surface, step-by-step dissection.* **B**, *the right biventral lobule is dissected. The tonsillobiventral fissure is located posterior to the tonsil and anterior to the biventral lobe.* **C**, *after dissection of white matter that is mainly the middle cerebellar peduncle (MCP) fibers, the right biventral lobule has been dissected to demonstrate the tonsillobiventral fissure and beginning of the dentate nucleus (DN). The gray matter of the DN is seen.* **D**, *enlarged posterior view of the same hemisphere. The right tonsil attachment area and middle cerebellar peduncle fibers have been dissected to expose the DN. ICP, inferior cerebellar peduncle; ISL, inferior semilunar lobule; LM, lateral lemniscus; N, nodule.*

Other Important Structures in Relation to the DN

The abducens nucleus and tuberance of facial fibers are in the same anatomic line with the DN at the axial section. The DN and its fibers form the roof of the facial and abducens nucleus in the fourth ventricle (Figures 9B and 10).

Three fissures can be observed around the brainstem. The first is the cerebellomesencephalic fissure, which extends from the pineal region downward between the cerebellum and the superior half of the fourth ventricle. Superior cerebellar peduncles are located in the anterior wall of this fissure. The medial side of this fissure is 16.6 mm away from the hilus of the DN, and it is important for the brainstem or the superior cerebellar peduncle at the supracerebellar infratentorial approach. The second fissure is the cerebellopontine fissure, which is formed by the folding of the cerebellum around the lateral sides of the pons and is intimately related to the lateral recesses. The middle cerebellar peduncle is located in this fissure and carries the corticocerebellar and pontinocerebellar tracts. The posterior limb of this fissure is 17.1 mm away from the closest part of the DN, and it is important for approaching the cerebellum and brainstem from the lateral side. The dorsal border of the superior limb is 8.6 mm away from the superolateral side of the DN.

The third fissure is the cerebellomedullary fissure that extends superiorly between the cerebellum and the medulla and is intimately related to the inferior half of the roof. This fissure mainly carries the inferior cerebellar peduncle fibers and extends upward around the cerebellar tonsils and the lower half of the roof of the fourth ventricle, which is formed by the tela choroidea and the inferior medullary velum. This fissure is highly important for the telovelar, subtonsillar, and transcerebellomedullary approaches. The inferior medullary velum attachment site and nodule has a very close relation with the DN tuberance at the lateral recess. The flocculonodular lobe attachment area at the lateral recess of the fourth ventricle is 2.9 mm away from the DN tuberance at the lateral recess. The flocculus attachment point is in relation to the superior and middle vestibular nuclei. The tip of the flocculus is 12.2 mm away from the lateral side of the DN (Figure 7).

The postpyramidal fissure passes across the vermis between the pyramid and tuber vermis, and in the hemispheres, it courses behind the tonsil and biventral lobules (Figures 7 and 9). The postpyramidal fissure is located inferiorly and posteriorly, 5.8 mm away from the lateral border of the DN. The DN is located superior, anterior, and medial to the biventral lobule. The inferior

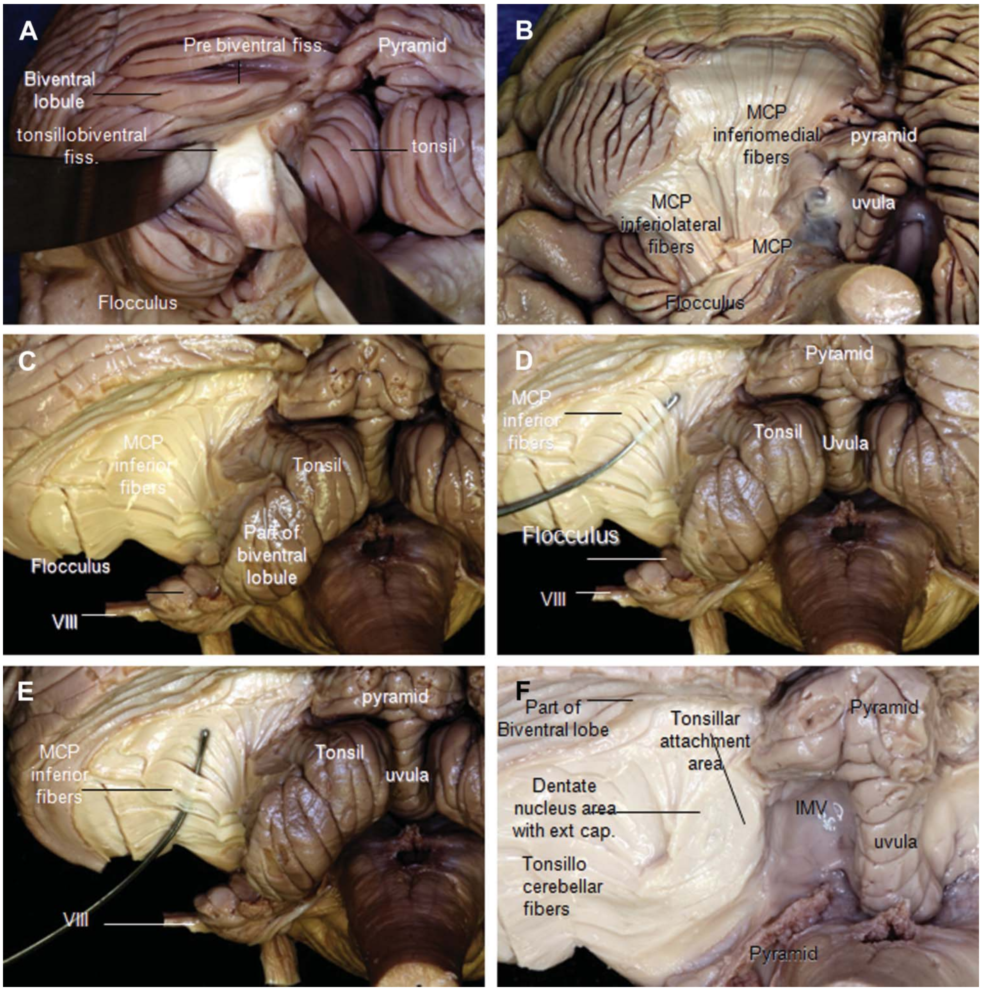

FIGURE 9. *Continues.*

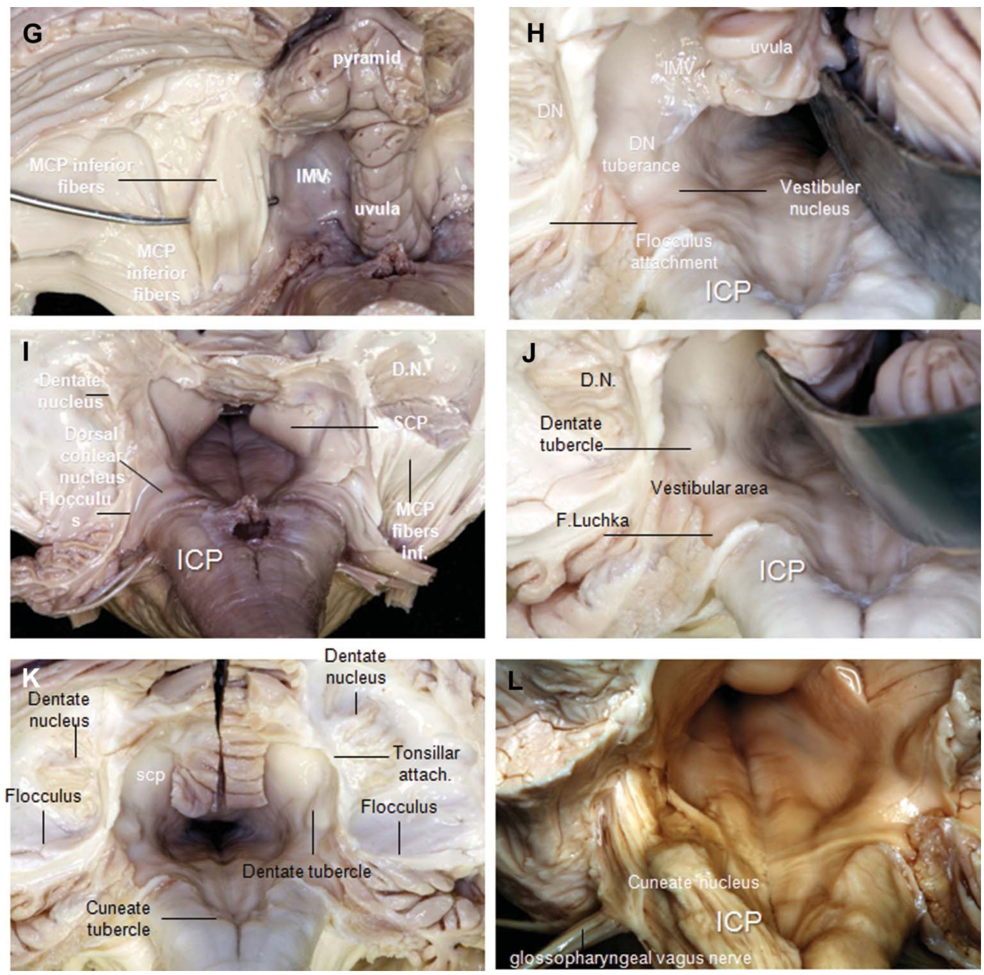

FIGURE 9. *Suboccipital surface of the cerebellum.* **A**, *the biventral lobule is retracted laterally. The tonsillobiventral fissure is exposed.* **B**, *middle cerebellar peduncles (MCP) convey the fibers from anterior to posterior up to semilunar lobules. These fibers wrap the dentate nucleus (DN) like an envelope and are superior to the tonsil attachment area.* **C**, *some fibers project laterally, whereas some curve and project posteriorly. Curved fibers of the middle cerebellar peduncle are inferior and lateral to the DN.* **D**, *after dissecting some part of the tonsil from the attachment area, middle cerebellar peduncle fibers are exposed medial and superior to the flocculus attachment site. As shown in other figures, just superior to these fibers, the DN can be observed. These fibers create an eminence medially that is formed by the DN.* **E**, *some fibers in relation to the tonsils have been reached with continued dissection. These fibers are called the middle cerebellar peduncle inferior fibers. The tonsil has an attachment area to the cerebellum superolaterally.* **F**, *at the later stages of dissection, eminence of the DN and thin white matter of the external capsule inferior to the DN are seen.* **G**, *when the slice is deepened through the middle cerebellar peduncle, the relationship of the peduncle and the DN is demonstrated.* **H**, *the vestibular area is located inferior to the DN. The dorsal cochlear nucleus is located lateral and anterior to the DN tuberance.* **I**, *the middle cerebellar peduncle and the tonsils have been dissected, and the DN is seen with its tuberance at the lateral recess of the fourth ventricle. The left tonsil has been dissected; the DN tuberance is located bilaterally at the lateral recess of the fourth ventricle. The tonsillar attachment area is located lateral to the DN tuberance.* **J**, *closure view of the fourth ventricle. The inferior medullary velum has been dissected, and the close relationship of the DN with the flocculus attachment area to the superiovestibular nucleus is seen.* **K**, *suboccipital surface from inferior view. The DN has been dissected bilaterally. The tonsillar attachment area is located anterior and inferior to the DN. The nodule (N) is located at the midline, and the DN is located on the 2 lateral sides of the nodule. The superior cerebellar peduncle is located bilaterally and symmetrically.* **L**, *the cuneate nucleus is located medial to the glossopharyngeal and vagus nerves. The vestibulocochlear nerve and nucleus have been dissected. Cuneocerebellar fibers are seen. These fibers enter the cerebellum via the inferior cerebellar peduncle (ICP), which is just lateral to the DN tuberance. ISL, inferior semilunar lobule; LM, lateral lemniscus.*

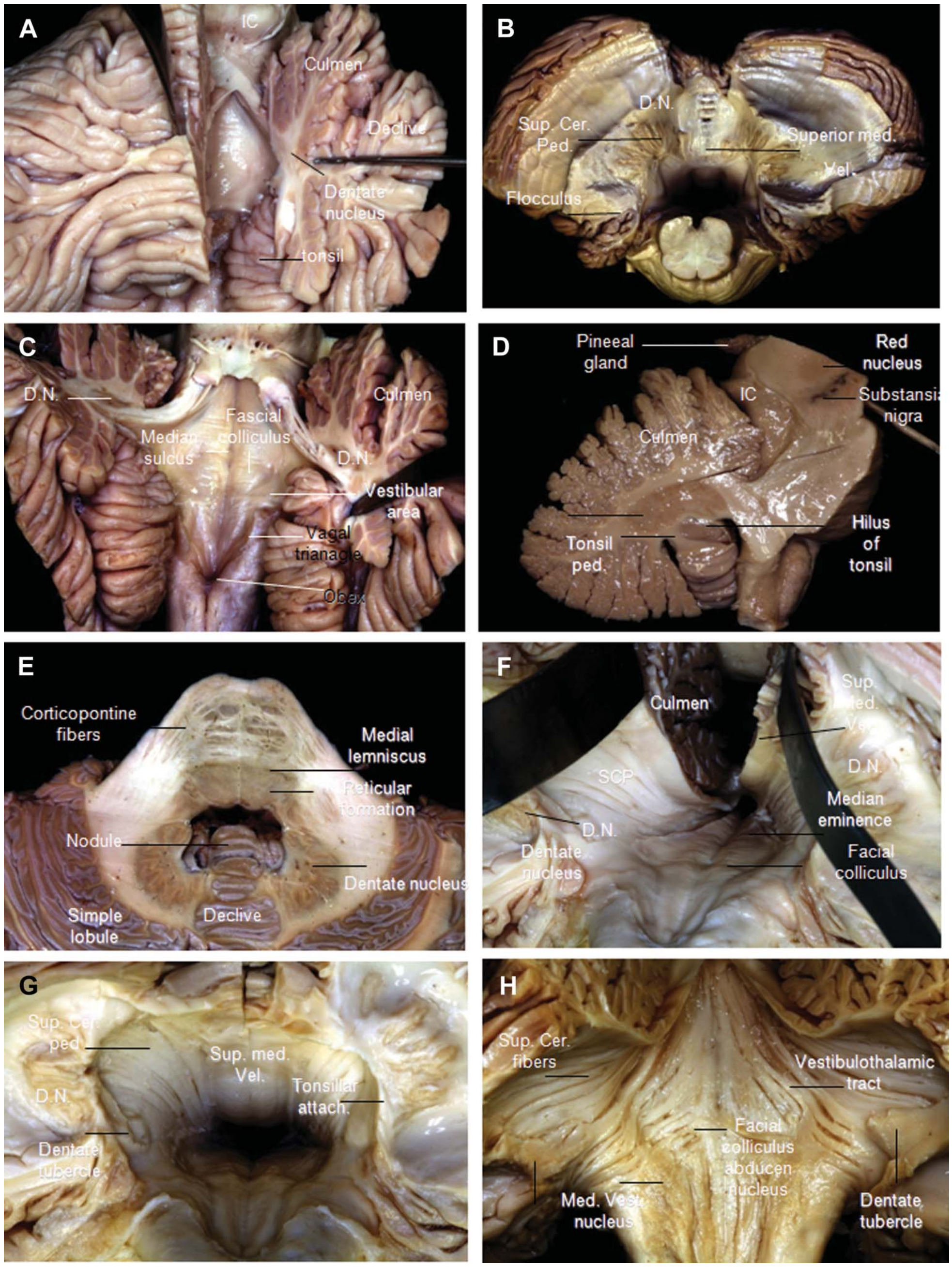
A
IC
Culmen
Declive
Dentate nucleus
tonsil
B
D.N.
Sup. Cer. Ped.
Superior med. Vel.
Flocculus
C
D.N.
Culmen
Fascial colliculus
Median sulcus
D.N.
Vestibular area
Vagal triangle
Obex
D
Pineeal gland
Red nucleus
IC
Substansi nigra
Culmen
Tonsil ped.
Hilus of tonsil
E
Corticopontine fibers
Medial lemniscus
Reticular formation
Nodule
Dentate nucleus
Simple lobule
Declive
F
Culmen
D.N.
SCP
Median eminence
D.N.
Dentate nucleus
Facial colliculus
G
Sup. Cer. ped.
Sup. med. Vel.
Tonsillar attach.
D.N.
Dentate tubercle
H
Sup. Cer. fibers
Vestibulothalamic tract
Facial colliculus abducen nucleus
Med. Vest. nucleus
Dentate tubercle

FIGURE 10. **A**, *transvermian sharp dissection of the cerebellum 5 mm lateral from the midline. When the right hemisphere is laterally retracted, the superior fovea and medial eminence located laterally to the median sulcus are seen. The superior fovea and facial colliculus are seen at the fourth ventricle floor. On the right side, the dentate nucleus (DN) attachment to the superior cerebellar peduncle (SCP) is demonstrated.* **B**, *inferior view of the cerebellum. All gray matter has been dissected. The DN is seen bilaterally and symmetrically. The 2 DNs are very close to each other, each being 5 mm lateral to the vermian (midline) area. Therefore, the transvermian approach has a high risk of damaging the DN.* **C**, *the cerebellum is divided into 2 parts, and each part has been retracted laterally to provide a better view of the fourth ventricle floor. The facial colliculus is just medial to the vestibular area and inside the median sulcus.* **D**, *sagittal section of the cerebellum 5 mm lateral from the midline. Among the cerebellar vermian structures, the nodule (N) is visible below the DN.* **E**, *the cerebellum has been sliced from the tentorial surface to the suboccipital surface. The DN can be seen bilaterally and close to the vermian area. Nodules are located centrally, and both nuclei are located lateral to the nodule.* **F**, *the vermis through the midline has been dissected and retracted laterally. The DN is just beneath the retractor. The superior cerebellar peduncles are located medially to the DN.* **G**, *inferior view of the fourth ventricle. Transvermian dissection causes damage first to the superior cerebellar peduncle fibers, and if the surgeon continues laterally, the DN may be damaged. Both DNs with their gray matter have been dissected in the lateral recess. Superior cerebellar peduncle fibers and superior medullary velum (SMV) form the roof of the fourth ventricle.* **H**, *posterior view of the fourth ventricle with its floor. Facial colliculus fibers and abducens nucleus are observed. The DN is superior and lateral to the vestibular area. The foramen Luschka is inferior to the DN. CC, corticocerebellar; ICP, inferior cerebellar peduncle; ISL, inferior semilunar lobule; LM, lateral lemniscus; MCP, middle cerebellar peduncle; PC, pontinocerebellar.*

and superior semilunar lobule receives fibers from the DN, and these fibers are mainly pontinocerebellar fibers. The tip of the superior semilunar lobule is 17.1 mm away from the DN posteriorly. The tip of the inferior semilunar lobule is 15.2 mm away from the DN (Figures 7-9).

The uvula and tonsils make up the lobus uvula. The medial border of the DN is 2.1 mm away from the attachment of the uvula to the cerebellum. The medial side of the DN is 10.9 mm away from the tip of the tonsils at the suboccipital surface. The supratonsillar area is the area where the tonsils are attached to the cerebellum; its distance from the DN is 0.6 mm (Figures 7 and 8).

The pyramid and biventral lobules constitute the lobus pyramidis. The pyramid is a conical projection forming the largest prominence of the inferior vermis. The lateral border is separated from the inferior semilunar lobule by the postpyramidal fissure. The pyramid has an attachment to the DN on the medial side

TABLE 2. **Relationship Between the Dentate Nucleus and the Function of Fibers**

Major Fibers Related to Dentate Nucleus	Position in Relation to Dentate Nucleus	Interaction With Dentate Nucleus	Function of the Fibers
Superior cerebellar peduncle	Anterior medial	From hilus of dentate nucleus	Plays a important role in motor coordination
Dentatorubrothalamic			
Inferior cerebellar peduncle	Anterior and superior	Goes lateral to medial access to the dentate nucleus	Balance, posture, muscle tone
Spinocerebellar			
Vestibulocerebellar			
Olivocerebellar			
Cuneocerebellar			
Middle cerebellar peduncle	Wraps around the dentate nucleus from the lateral margin of dentate nucleus and over the dentate	Superior lateral and inferior lateral cross both sides of the dentate nucleus; pontinocerebellar fibers cross the other side	Coordination of voluntary motor activity, timing
Corticocerebellar			
Pontocerebellar			
Lateral lemniscus	Superoanterior medial to dentate nucleus	Superolateral crosses oblique to superior cerebellar peduncle	Is a tract of axons in the brainstem that carries information about sound from the cochlear nucleus to various brainstem nuclei and ultimately the contralateral inferior colliculus of the midbrain
Trigeminothalamic	Superoanterior medial to	Like lateral lemniscus but passes more medially	Receives discriminatory tactile and pressure
Tonsillocerebellar	Posteroinferior	It conveys inferoposterior	Function is unknown

TABLE 3. Cerebellar Fiber Tract Connections

Inferior cerebellar peduncle		
Afferent paths		
Olivocerebellar tract	Lateral hemispheres and cerebellar nucleus	Contralateral inferior olivary nucleus
Vestibulocerebellar tract	Fastigial nucleus, flocculonodular lobe, and uvula	Ipsilateral vestibular nucleus and vestibular ganglion
Reticulocerebellar tract	Spinal region of cerebellar vermis	Ipsilateral lateral reticular nucleus
Posterior sinocerebellar tract	Hind-limb region of cerebellar cortex	Ipsilateral Clarke column
Trigeminocerebellar tract	Dentate and emboliform nucleus	Bilateral principal sensory and spinal nucleus
Cuneocerebellar tract	Fore-limb and upper trunk region of Cerebellar cortex	Ipsilateral accessory cuneate nucleus
Arcuatocerebellar fibers (striae medullares)	Flocculus	Bilateral arcuate nucleus
Efferent paths		
Cerebello-olivary tract	Inferior olivary nucleus	Fastigial nucleus
Cerebellovestibular tract	Vestibular nucleus	Fastigial nucleus and direct axons of Purkinje cells in flocculus, nodule, anterior, and posterior vermis
Cerebelloreticular tract	Pontine and medullary reticular nucleus	Fastigial nucleus
Middle cerebellar peduncle		
Afferent paths		
Pontocerebellar tract	Neocerebellar cortex	Contralateral pontine nucleus
Superior cerebellar peduncle		
Afferent paths		
Anterior spinocerebellar tract	Hind-limb region of cerebellar cortex	Ipsilateral Clarke column
Tectocerebellar tract	Intermediate vermis and lobulus simplex	Bilateral superior and inferior colliculi
Efferent paths		
Cerebellorubral fibers	Red nucleus	Contralateral globose and emboliform nucleus
Dentatothalamic fibers	Ventral intermediate and ventral anterior nucleus of thalamus	Contralateral dentate nucleus
Fastigioreticular fibers	Reticular nucleus of midbrain, pons, and medulla oblongata	Ipsilateral fastigial nucleus

at the cerebellum. The distance between the bases of the pyramid at the superolateral part (the attachment area) is 1.8 mm away from the DN (Figures 8 and 9).

In the sagittal section through the center of the vermis, superior cerebellar peduncle fibers and the superior medullary velum can be observed, along with an arbor vitae appearance. After sharp dissection of the cerebellum from posterior to anterior, the fourth ventricle can be observed with the facial colliculus. Facial nucleus and its fibers have been dissected in the specimen to demonstrate the relationship between the nucleus and its fibers with DN tuberance (Figure 10). When the cerebellum is sharply dissected step by step from posterior to anterior, no gray matter can be encountered in the first 2 cm of dissection. In the second 2 cm of dissection, a symmetrical appearance of the DN can be observed. In the third 2-cm dissection, the DN disappears (Figure 11).

Operative Approaches

The suboccipital and supracerebellar approaches have been used for lesions in the suboccipital hemispheres and vermis. They have also been adapted for lesions located in the quadrigeminal cistern. Important anatomic landmarks detected on careful examination of the suboccipital surface of the cerebellum include the tonsils, uvula, and middle line. The average distances between the lateral border of the DN and the pyramidal attachment of the cerebellum, tip of the tonsil, and nodule are 1.8, 10.9, and 5.0 mm, respectively. The DN is localized at the lateral line of the uvula and pyramid. However, during resection, the tonsil can be best viewed only in the lower pole and upper pole. The anatomic landmark for the superior limit of the removal is the tonsil. However, during the resection, only the inferior pole of the tonsil is well visualized. The inferior medullary attachment velum is separated from the basal surface of the DN by, on average, 2.6 mm. When viewed from its medial aspect, the midline of the DN is separated from the middle line by, on average, 5 mm. The culmen, which is 9.6 mm distant from midline, is an important landmark. The DN is located anterior to the tentorial fissure, and the lateral border of the nucleus is separated from the midline by, on average, 17 mm (Figure 11).

DISCUSSION

In 1977, Chan-Palay et al[8] described the detailed anatomy of the cerebellar DN of monkeys. In that study, circumferential fibers encircling the lateral boundaries of the dentate were observed. DTI became an important adjunct to conventional MRI for clinical and basic studies of cerebellar ataxias and

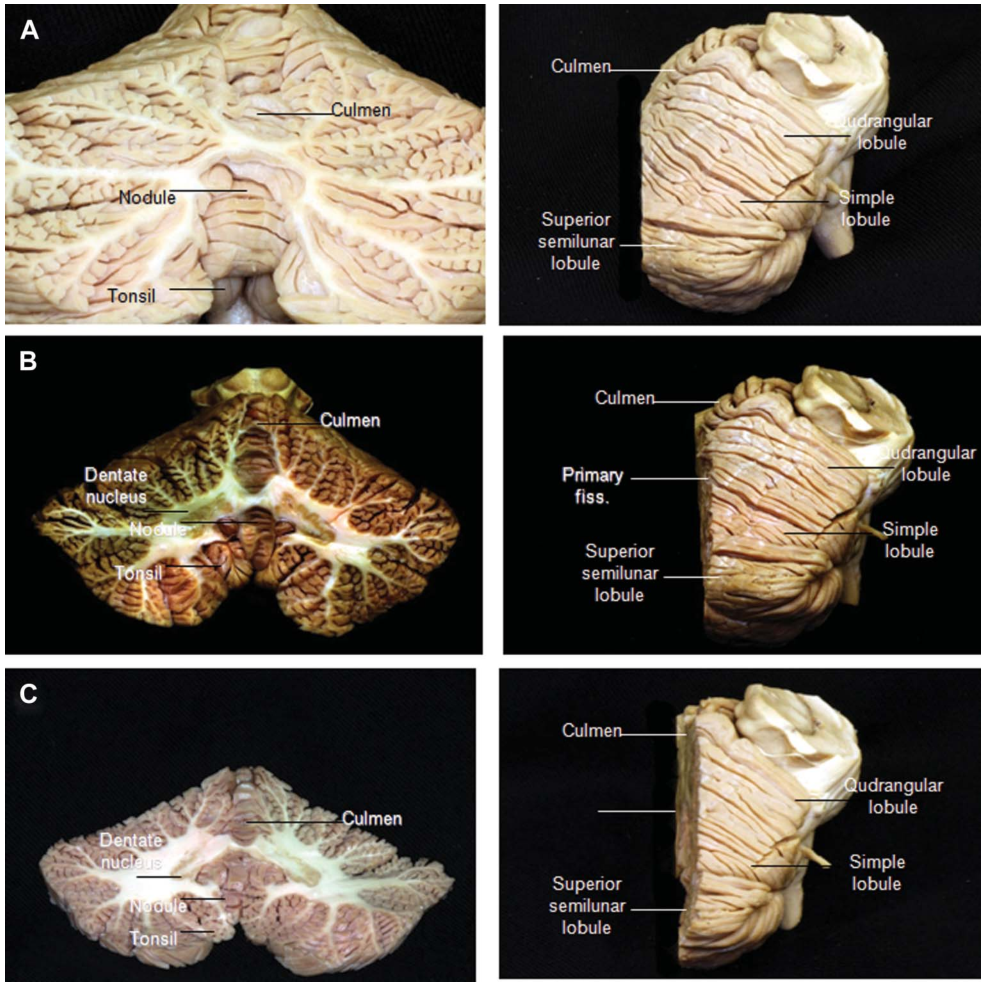

FIGURE 11. *The cerebellum has been sharply dissected step by step from posterior to anterior.* **A**, *in the first 2 cm of sharp dissection, no gray matter can be seen.* **B**, *in the second 2 cm, the dentate nucleus (DN) can be seen on both sides symmetrically.* **C**, *in the third 2 cm, no DN impression is seen in the cerebellum.*

congenital disorders involving the cerebellum and brainstem.[11] In the present study, the microsurgical anatomy of cerebellar peduncles and their relationship with neighboring fasciculi were investigated by use of a novel fiber dissection technique. As the dissection progressed, photographs of each progressive layer were obtained, and stereoscopic images were created by use of the 3-dimensional anaglyphic method.[14] The surgical importance of the cerebellum has been emphasized in many studies,[15-17] which are very helpful in understanding the cerebellar anatomy.

Previously, projections to the primary motor and premotor areas of the cerebral cortex have been shown to originate from dorsal portions of the dentate. In contrast, projections to prefrontal and posterior parietal areas of cortex originate from ventral portions of the dentate. Thus, the dentate contains anatomically separate and functionally distinct motor and nonmotor domains.[10,11]

Although the cerebellum was not originally conceived as an eloquent area, further research has proven the role of the cerebellum in different cognitive functions.[18,19] The embryologic origin of the cerebellum and its cerebral associations also suggest the presence of a network of connections between the cerebellum and cerebrum that play a role in cognition at upper levels.[18,20] Furthermore, vascular disorders of the cerebellum have been shown to result in cognitive dysfunction.[21] Similarly, studies examining the concept of diaschisis have shown the role of the cerebellum in different cognitive tasks.[22,23]

The DN is mostly responsible for planning and execution of fine movements.[7] Because any type of motor function requires sensory information, the DN is likely to receive and modulate this sensory information, although specific mechanisms remain unclear. Although the primary role of the DN is control of movement, it also plays a role in sensory processing[24] and is involved in proprioception, nociception, and processing of somatic input.[25-27]

As can be seen in our dissections, the DN is located centrally and bilaterally in both cerebellar hemispheres. The major afferent group of fibers to the DN are represented by the middle cerebellar peduncle; the superior cerebellar peduncle represents the major efferent group of fibers. The major pathway from the superior cerebellar peduncle is the dentatorubrothalamic tract, and major pathways from the middle cerebellar peduncle are the cortico-cerebellar and pontinocerebellar tracts. Superior cerebellar peduncle fibers ascend anteriorly and superiorly to the DN. The middle cerebellar peduncle fibers wrap the DN superiorly and inferiorly.

In the supratonsillar approach, the DN is located under the biventral fissure and is thus more susceptible to injury when this approach is used to access the fourth ventricle. In subtonsillar and telovelar approaches, the DN remains in a safe area.[28,29]

In the lateral mesencephalic approach, the superior cerebellar peduncle fibers lie very close to the lateral mesencephalic sulcus. In this approach, the trigeminothalamic tract, the lateral and medial lemniscuses, and the crus cerebri may be damaged.

The microsurgical anatomy of the cerebellomedullary fissure and the surgical entrance into the fourth ventricle and lateral recess through the tela choroidea and inferior medullary velum were first described in a series of article from the University of Florida in the early 1980s.[30] DN protuberance is at the lateral recess and is superolateral to the vestibular area. Only the tela needs to be opened to expose lesions in the lower half of the floor. Opening the velum exposes the superolateral recess and facilitates the exposure of the DN.[30,31] The lateral recess can be opened without damage to the DN in the telovelar approach.[6]

The incision through the inferior portion of the vermis during the transvermian approach exposes the underlying nodule, which must be incised to gain access to the fourth ventricle. This incision through the vermis is limited by the position of the superior medullary velum, which is closely related to the anterior portion of the nodule. The superior medullary velum forms the medial part of the superior half of the roof. The splitting of the inferior cerebellar vermis may cause caudal vermis syndrome,[30,31] resulting in an equilibrator disturbance with truncal ataxia, gait disturbance, oscillation of the head and trunk, and nystagmus. Moreover, because the DN is located along the posterolateral margin of the roof of the fourth ventricle adjacent and rostral to the superior pole of the tonsil, this nucleus may be damaged during splitting of the cerebellar vermis.[32,33]

When the DN is damaged, the resulting equilibrium disturbances are more severe than those observed with vermian lesions and are often accompanied by intentional tremor during voluntary movement of the extremities.[6] Splitting the inferior portion of the vermis may also play a role in cerebellar mutism,[33] a transient complication following the removal of a cerebellar and fourth ventricle tumor.[34,35] Although the exact anatomic substrate for cerebellar mutism remains unknown, the inferior portion of the vermis, including the pyramid, uvula, and nodule, has been implicated. The nodule area seems to be more important in mutism syndrome.[36-39]

The vestibular area, the portion of the floor lateral to the median eminence and the sulcus limitans, is located at the lateral limit of the floor of the fourth ventricle. The DN is located lateral and superior to the vestibular area. The inferior fovea is a depression in the sulcus limitans located lateral to the hypoglossal triangle.[37] The median eminence contains the facial colliculi in its upper part and the hypoglossal and vagal triangles and the area postrema in its lower portion. DN tuberance is an important landmark during the approach to the fourth ventricle floor, and this may help explain the pathophysiology of oropharyngeal apraxia.[38] The median eminence is crossed by the funiculus separans. When brainstem lesions are approached, the median eminence can be used as a landmark microsurgically and endoscopically. Lateral to the median eminence is another tuberance in lateral recess known as the DN tuberance.[40-42]

The fourth ventricle is continuous with the cerebellopontine angle through the foramen of Luschka at the lateral recess.[40,43,44] The superior half of the roof is formed medially by the superior medullary velum and laterally by the inner surfaces of the superior cerebellar peduncles that carry the afferent fibers of the DN. The inferior medullary velum blends into the peduncles of the flocculus laterally and the surface of the nodule medially. DN is located lateral to the nodule. Transvermian and superior medullary velum approaches require attention to the nucleus, which is located just lateral to the nodule.[45]

The observed asymmetry of the DN in all cadaveric samples may be due to age-related atrophy, drug use, or psychiatric disorders.[46] Asymmetry and volumetric changes in cerebellar anatomy have previously been a subject of research interest.[47,48] It is possible that anatomic data will underestimate the volume in the living brain as a result of shrinkage artifacts. The mean volume of the nuclei, being substantially larger than that in anatomic specimens, may also reflect the inclusion of the interposed nuclei. According to our observations during anatomic dissection, the DN column showed signs of asymmetry without lateralization, and the right DN was larger compared with the left DN, although the difference was insignificant.

CONCLUSION

We have presented a microsurgical anatomic approach to the cerebellum. Although extensive literature data exist on methods to avoid excision of normal cerebellar tissue, no anatomic assessments have been performed to examine the safe surgical entry zones using fiber dissection involving the DN. In this study, we have described the anatomic position of the DN and have shown that supra-tonsillar and transvermian approaches have a closer anatomic relationship with the DN compared with telovelar and subtonsillar approaches. We believe that this information will be useful for neurosurgeons.

Disclosure

The authors have no personal financial or institutional interest in any of the drugs, materials, or devices described in this article.

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COMMENT

This is an interesting, thorough, and detailed article that meticulously depicts the microsurgical anatomy of the dentate nucleus and its projection system through the human cerebellum. In addition to describing anatomical implications, the physiological importance of different structures, and the consequences of their damage to neurological function, the article also offers us a tour of surgical approaches to cerebellar lesions in conjunction with relevant safety and cautionary tips. The strength of this article is that it emphasizes the normal anatomy of the dentate nucleus and cerebellum along with the surgical anatomy to the best extent that can be achieved in a cadaver specimen.

It should be pointed out, however, that not all afferent and efferent dentate nucleus fiber tracts that knowingly exist in peduncles could be displayed by the fiber dissection technique. It is also very noteworthy to emphasize that cerebellar pathological processes may significantly alter the normal anatomy.

I personally learned about the importance of Klingler's fiber dissection technique in the neurosurgical education and scientific microsurgical anatomic investigations years ago from Dr Ugur Ture, while we were working together during our 2.5-year fellowships with our teachers, Drs Gazi Yasargil and Ossama Al-Mefty at the Department of Neurosurgery in Little Rock, Arkansas. I would make the suggestion that all residents familiarize themselves with this technique during the neurosurgery training process, and occasionally perform different anatomical projects using this method later on in their neurosurgical careers. This will help them better familiarize with the intricate brain 3-D anatomy and complex fiber-tumor relationships that they will encounter during various surgical approaches.

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