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The Lamina Rostralis: Modification of Concepts Concerning the Anatomy, Embryology, and MR Appearance of the Rostrum of the Corpus Callosum

E. Leon Kier and Charles L. Truwit

PURPOSE: To study the anatomy and embryology of the lamina rostralis, and to determine whether the rostrum is, as frequently stated, the last section of the corpus callosum to develop. **METHODS:** The rostrum was analyzed in dissected adult brains and on MR studies in 300 patients with a normal corpus callosum and in 84 patients with a hypogenetic corpus callosum. MR images of intact fetuses and photographs of dissected fetal and adult vertebrate brains were also analyzed. **RESULTS:** The rostrum extends from the genu to the upper end of the lamina terminalis and consists of two sections: a thick beaked segment and the thin lamina rostralis, which blends posteriorly with the lamina terminalis. During fetal development the lamina rostralis changes from a semivertical to a semihorizontal orientation. Many hypogenetic corpora callosi have a semivertical lamina rostralis. A rudimentary beaked segment can be present without a normal genu. **CONCLUSIONS:** The rostrum is not the last segment of the corpus callosum to develop. Rather, the lamina rostralis segment of the fetal rostrum is already present before the genu and splenium develop. Additionally, the beaked segment of the rostrum develops concurrently with maturation of the genu.

Index terms: Corpus callosum, abnormalities and anomalies; Corpus callosum, anatomy; Brain, growth and development; Brain, magnetic resonance

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This investigation was stimulated by the theory that the rostrum is the last segment of the corpus callosum to develop. According to this concept the genu develops first, followed by the body, splenium, and rostrum. A previous investigation corroborated that the corpus callosum develops first in the region of the future anterior body and grows bidirectionally (1). The sequence of development of the rostrum was not studied in that investigation. However, doubts that the rostrum was the last segment to develop were raised because the forward development and the shape of the genu suggested that its growth might be tethered by the rostrum, implying that the rostrum is already present by the time the genu matures.

Doubt about the sequence of development of the rostrum was reinforced by the recent observation on magnetic resonance (MR) images of patients with anomalies of the corpus callosum; that is, of a linear structure coursing from the rudimentary corpus callosum toward the lamina terminalis and anterior commissure. This linear structure was also frequently identified in patients with a normal corpus callosum. Examination of the anatomy of this region showed that the anatomic and neuroradiologic literature does not clearly distinguish the posteriorly pointing thick beak-shaped segment of the rostrum (hereafter referred to as the *beaked segment*) of the corpus callosum from the thin layer (hereafter referred to as the *lamina rostralis segment*) tethering the beaked segment to

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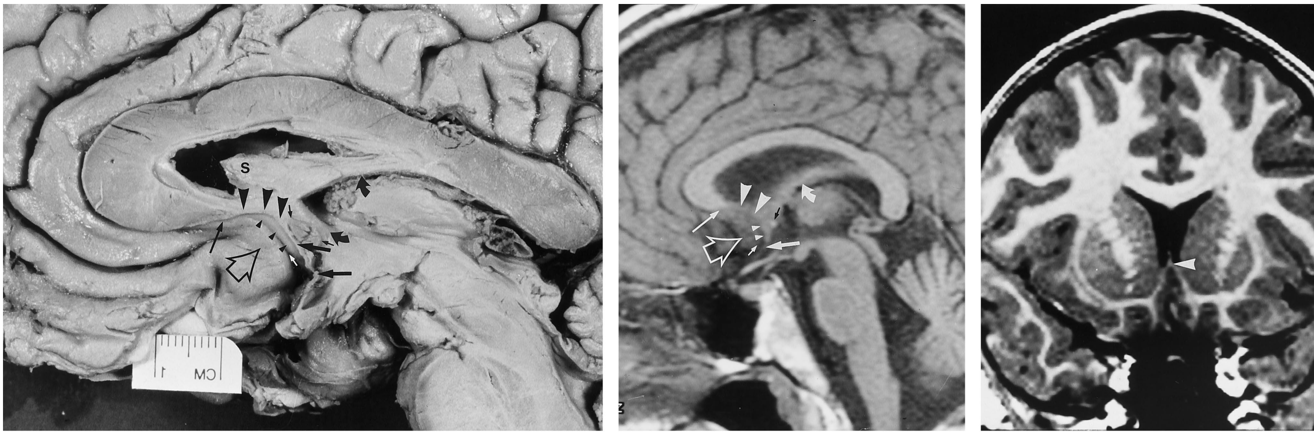


A B C

Fig 1. Photograph of the medial surface of adult cerebral hemisphere (*A*) and sagittal T1-weighted (450/11/1) MR image (*B*) show the two sections of the rostrum of the corpus callosum: the beaked segment and the lamina rostralis segment. The thicker beaked segment (*long thin arrow*) of the rostrum is continuous posteriorly with the thin lamina rostralis segment (*large arrowheads*). The lamina rostralis normally has a nearly horizontal course and curves inferiorly to become continuous with the lamina terminalis (*long thick arrows*) just superior to the anterior commissure (*small black arrows*). The lamina rostralis is continuous superiorly with the septum pellucidum (*S*), which is partially resected. The specimen shows that the paraterminal gyrus (*small arrowheads*) is closely applied against the lamina rostralis and the lamina terminalis, in the region of the anterior commissure. The fornix (*curved arrows*) curves behind the anterior commissure. In *B*, it is difficult to separate the descending portion of the lamina rostralis from the paraterminal gyrus. The paraterminal gyrus is separated from the subcallosal area (*open arrow*) by the posterior paraolfactory sulcus (*small white arrow*).

C, The lamina rostralis (*arrowhead*) can be identified on this coronal T1-weighted (24/5/2; 45° flip angle) 3-D spoiled gradient-echo MR image.

the lamina terminalis. The term *lamina rostralis* has previously been applied to this region (2–5). We postulated that a study of the lamina rostralis might provide a more logical explanation for the sequence of development of the rostrum in relation to the other parts of the corpus callosum.

Materials and Methods

Dissection of the region of the rostrum was performed in six adult human brains that had been preserved in 10% formaldehyde. Sagittal spin-echo MR images of 300 patients with a normal corpus callosum were reviewed to assess the anatomy of the anterior beaked segment of the rostrum and the visibility of the lamina rostralis. The sagittal T1-weighted images were obtained with a section thickness of 5 mm. Images of 40 patients in whom sagittal plane images were acquired using a three-dimensional spoiled gradient-echo sequence were reviewed retrospectively to assess the visibility of the lamina rostralis. Parameters for the 3-D spoiled gradient-echo sequence were 24/5/2 (repetition time/echo time/excitations), 45° flip angle, 256 × 192 matrix, 30-cm field of view, and 1.2-mm section thickness. MR images of 84 patients with hypogenesis of the corpus callosum were reviewed retrospectively to evaluate the presence and configuration of the anterior beaked segment of the rostrum and the posterior lamina rostralis segment. Patients with pericallosal lipomas, patients with holoprosencephaly, and those who had had intraventricular shunting procedures were excluded from this group. In addition, material from a previous investigation (1) was reanalyzed for the presence of the rostrum and, in particular, the beaked segment and the lamina rostralis segment. This material consisted of MR images of 20 intact fetuses, ranging from 13 to 30 weeks' gestational age, and photographs of the dissected medial surface of the brains of eight different human fetal specimens, ranging from 10 to 30 weeks' gestational age. To identify the structures in the region of the rostrum of the corpus callosum, previous studies of human anatomy, embryology, and comparative anatomy were used (6–18).

Results

Dissection of adult human brains revealed that the rostrum of the corpus callosum passes posteriorly from the genu and consists of two segments (Fig 1). The thicker beaked segment is continuous posteriorly with the thin lamina rostralis segment. The lamina rostralis normally has a semihorizontal course and curves inferiorly to become continuous with the lamina terminalis just superior to the anterior commissure. Superiorly, the lamina rostralis is continuous with the septum pellucidum. The specimen and MR image in Figure 2 show the Y shape formed by the lamina rostralis, fornix, and lamina terminalis. The semihorizontal lam-

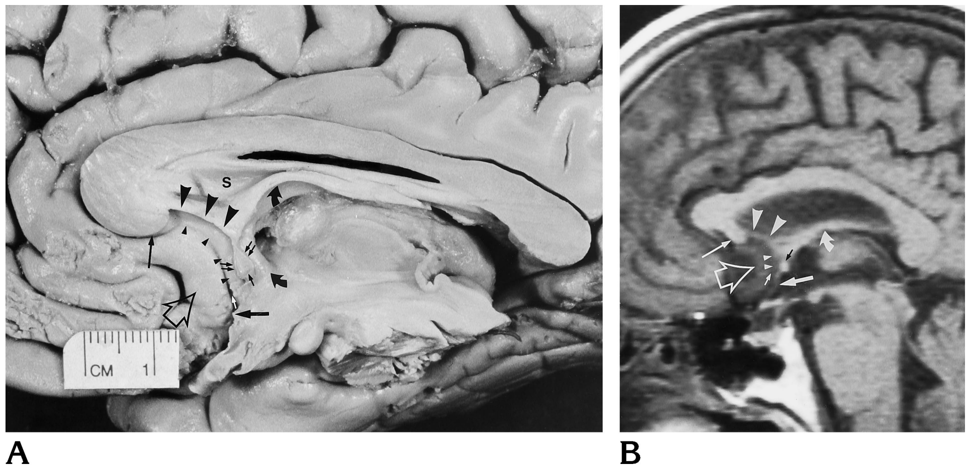


Fig 2. Photograph of the medial surface of an adult cerebral hemisphere (*A*) and sagittal T1-weighted (600/11/1) MR image (*B*) show anatomic variations of the two segments of the rostrum. The beaked segment (*long thin arrow*) has a rounded appearance instead of being pointed, and the lamina rostralis (*large arrowheads*) originates not at the tip of the rounded segment but at a higher level. The junction of the lamina rostralis and lamina terminalis is just above the anterior commissure (*single small black arrow*), which is embedded within the very thin layers (*double small arrows*) of the embryonic lamina reuniens segment of the lamina terminalis. The specimen and the MR image show the Y shape formed by the lamina rostralis, fornix, and lamina terminalis. The semihorizontal lamina rostralis and the fornix (*curved arrows*) make up the arms of the Y, which come together just superior to the anterior commissure. The lamina terminalis (*long thick arrow*) and anterior commissure form the stem of the Y. *Small arrowheads* indicate paraterminal gyrus; *short thin white arrow*, posterior paraolfactory sulcus; *open arrow*, subcallosal area; *S*, septum pellucidum.

ina rostralis and the fornix make up the arms of the Y, which come together just superior to the anterior commissure. The lamina terminalis and anterior commissure form the stem of the Y. The specimens show that the paraterminal gyrus is closely applied against the lamina rostralis and the lamina terminalis in the region of the anterior commissure (Figs 1A and 2A). The paraterminal gyrus descends to a variable degree along the lamina terminalis before passing laterally to become the diagonal band of Broca. On MR images it is difficult to distinguish the descending portion of the lamina rostralis from the paraterminal gyrus (Figs 1B and 2B). The paraterminal gyrus is separated from the subcallosal area by the posterior paraolfactory sulcus, which merges with the superior extent of the cistern of the lamina terminalis (Fig 1). The normal lamina rostralis can be identified on many routine, 5-mm-thick, spin-echo sagittal (Figs 1B and 2B) and coronal (Fig 1C) MR images. The beaked segment of the rostrum may have a rounded instead of a beaked appearance, and the lamina rostralis originates not at the tip of the rounded segment but at a higher level (Fig 2).

MR images of intact fetal specimens show the early presence and developmental changes of the rostrum of the corpus callosum. An MR image of a 14-week-old fetal specimen shows the anchoring of the rudimentary corpus callosum by the lamina rostralis anteriorly and the fornix posteriorly (Fig 3A). The genu and splenium are not yet formed. The lamina rostralis and fornix course superiorly, in a semivertical orientation, from the lamina terminalis region of the third ventricle. An MR image of a 22-week-old fetal specimen shows a larger corpus callosum that has grown bidirectionally. The genu and splenium are now present (Fig 3B). The superior end of the rostrum has thickened to form the beaked segment, which continues into the lamina rostralis. The lamina rostralis now has a semihorizontal course. The findings on the MR studies of the fetal specimens were corroborated by reviewing the studies by Retzius (9) and Hochstetter (11) (Fig 4). Examination of the photographs of the dissected fetal specimens did not disclose any findings useful for understanding the development of the rostrum.

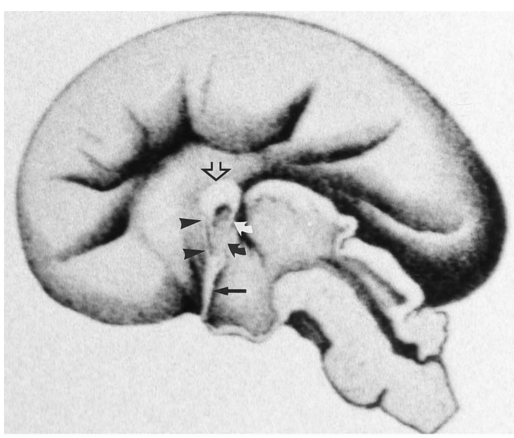
Review of the spin-echo sagittal T1-weighted images of 300 consecutive clinical cases showed the following results: In 254 cases the corpus callosum had a beaked segment of the rostrum. The beaked segment pointed posteriorly in 221 cases and posteroinferiorly in 23 cases. In 13 cases the beaked segment was more rounded than beaked. The lamina rostralis was identified in 207 of the same 300 consecutive clinical cases. In 46 cases the rostrum

A B

Fig 3. Sagittal T1-weighted spoiled gradient-echo (30/7/2, 35° flip angle [*A*]; 45/8/2, 45° flip angle [*B*]) MR images of intact fetal specimens show the early presence and developmental changes of the rostrum of the corpus callosum.

A, A 14-week-old fetal specimen shows the anchoring of the rudimentary corpus callosum (*open arrow*) by the lamina rostralis (*arrowheads*) anteriorly and the fornix (*curved arrows*) posteriorly. The rostrum and fornix course superiorly, in a semivertical orientation, from the lamina terminalis region (*thick arrow*) of the third ventricle.

B, A 22-week-old fetal specimen has a larger corpus callosum that has grown bidirectionally (*open arrows*). The beaked segment of the rostrum (*thin arrow*) is now present and continues into the lamina rostralis (*arrowheads*). The lamina rostralis and fornix (*curved arrow*) now have a semihorizontal course above the lamina terminalis (*thick arrow*) of the third ventricle.



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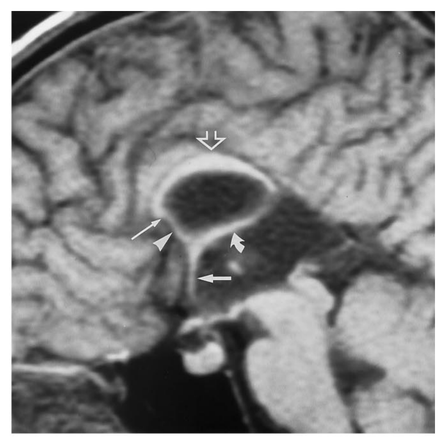

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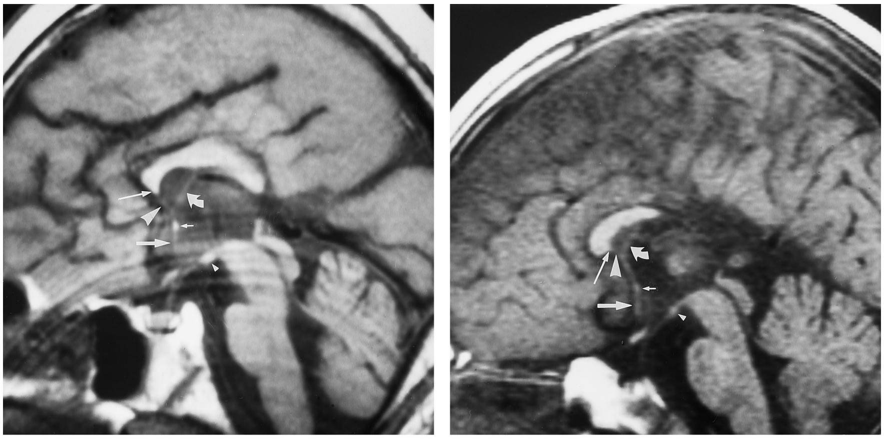
Fig 4. Illustration shows the lamina rostralis of the rudimentary fetal corpus callosum. A vertically oriented lamina rostralis (*arrowheads*) is present in a 14-week-old fetal specimen. The lamina rostralis anteriorly and the fornix (*curved arrows*) posteriorly are anchoring the rudimentary corpus callosum (*open arrow*). The vertically oriented lamina rostralis and fornix form the vertical arms of a Y, with the stem formed by the lamina terminalis (*straight arrow*). Of note is the similarity to the fetal MR image (Fig 3A) (from Retzius [9], arrows and arrowheads added).

Fig 5. Sagittal T1-weighted (500/11/1) MR image of a patient with an abnormal corpus callosum. The hypogenetic corpus callosum (*open arrow*) is anchored by the semivertical lamina rostralis (*arrowhead*) anteriorly and by the fornix (*curved arrow*) posteriorly. A rudimentary beaked segment (*thin arrow*) of the rostrum is present without a formed genu. This image shows the Y shape formed by the lamina rostralis, fornix, and lamina terminalis (*thick arrow*). The appearance of the corpus callosum, lamina rostralis, and fornix in this case is that of arrested development between the fetal stages depicted in Figure 3.

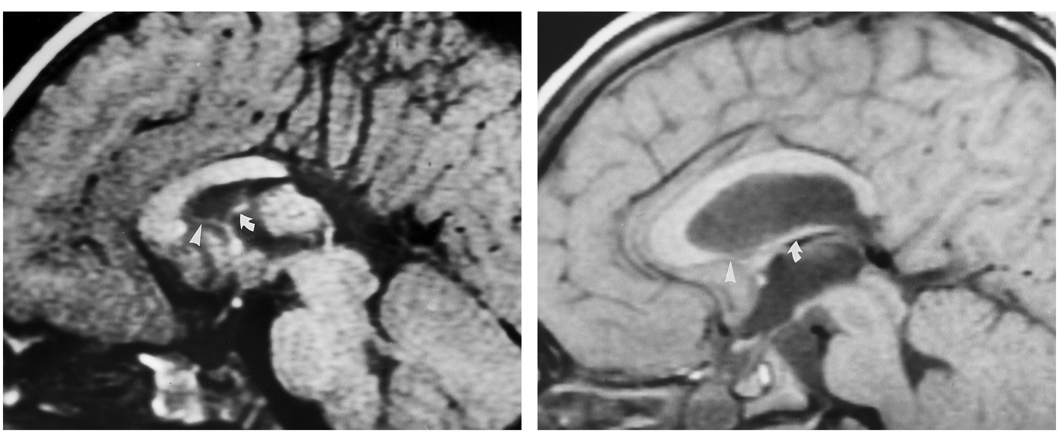
could not be evaluated because of motion or an inadequate midline image. Importantly, in some of these cases the lamina rostralis could be identified even when the beaked segment of the rostrum could not be evaluated. The lamina rostralis was identified in 36 of the 40 patients in whom spoiled gradient-echo sagittal images were obtained.

The lamina rostralis was also identified on the MR studies of 44 of the 84 cases with a hypogenetic corpus callosum. In 16 of these 44 cases, only a rudimentary corpus callosum was present. In the remaining 28 cases, six showed the presence of a normal genu and 13 had a hypogenetic genu. Nine cases showed the presence of a normal or hypogenetic body of the corpus callosum without the presence of a genu. All the cases with hypogenesis of the genu had a normal or hypogenetic body. A normal or rudimentary beaked segment of the ros-



A B

Fig 6. Sagittal T1-weighted (700/14/2, *A*; 600/19/1, *B*) MR images of patients with corpus callosal anomalies show the presence of the lamina rostralis (*large arrowhead*) and a rudimentary beaked segment (*long thin arrow*) of the rostrum without a formed genu. The normal human genu always projects in front of a line connecting the mammillary body (*small arrowhead*) with the anterior commissure (*short thin arrow*) and continuing toward the region of the corpus callosum. In these cases there is no callosal tissue in the expected position of the normal genu. These cases also illustrate the Y configuration formed by the lamina rostralis, fornix (*curved arrow*), and lamina terminalis (*thick arrow*). In *B*, the lamina rostralis and fornix do not separate at the level of the anterior commissure but more superiorly.



A B

Fig 7. Sagittal T1-weighted (600/20/2) MR images of patients with corpus callosal abnormalities show the normal orientation of the lamina rostralis. The arms of the Y formed by the lamina rostralis (*arrowhead*) and fornix (*arrow*) have a semihorizontal course. The normal orientation of the lamina rostralis results from normal development of the genu and anterior body of the corpus callosum. In these cases the abnormalities involve the posterior body and splenium of the corpus callosum and the anterior body; the genu and rostrum are normal.

trum was present in 22 of the 44 cases in which the lamina rostralis was present. The beaked segment of the rostrum was present in four cases with a rudimentary corpus callosum, in 12 cases with a normal or hypogenetic genu, and in six cases with a normal or hypogenetic body. The splenium was present in only seven cases, four with a genu and three with only the body present.

In 29 of the 44 cases, the lamina rostralis had a semivertical orientation. In cases with marked hypogenesis of the corpus callosum, the rudimentary corpus callosum was bordered by the semivertically oriented lamina rostralis and fornix (Fig 5). The hypogenetic corpus callosum is anchored by the Y formed by the lamina rostralis, fornix, and lamina terminalis. The lamina rostralis and the fornix form the arms of the Y. The lamina terminalis and anterior commissure form the stem. A rudimentary beaked segment of the rostrum is present below the rudimentary genu. The appearance of the corpus callosum, rostrum, and fornix in the case in Figure 5 is consistent with arrested development between the two fetal stages shown in Figure 3.

Many of the cases with a hypogenetic corpus callosum and with a semivertical lamina rostralis have a rudimentary beaked rostral segment without a normal genu (Fig 6). These cases show the Y configuration formed by the lamina rostralis, fornix, and lamina terminalis. In some cases, the lamina rostralis and fornix do not separate at the level of the anterior commissure but more superiorly (Fig 6B). In 18 cases the orientation of the lamina rostralis was semihorizontal, similar to the orientation in brains with a normal genu (Fig 7). In these cases the abnormalities involved the posterior body and splenium of the corpus callosum and the anterior body; the genu and rostrum were mostly normal.

Discussion

Although the rostrum of the corpus callosum is anatomically defined as extending from the genu to the lamina terminalis (5, 16), the beaklike appearance, both anatomically and on MR images, is limited to the anterior myelinated segment (Fig 1). The anterior beaked segment is often considered by neuroradiologists and other investigators as the entire rostrum. It seemed appropriate to reintroduce the term *lamina rostralis of the corpus callosum* for the thin, nonmyelinated part of the rostrum, which extends posteriorly from the tip of the beaked segment to the upper end of the lamina terminalis (Figs 1A and 2A). The junction of the lamina rostralis and lamina terminalis is just above the anterior commissure, which is embedded within the very thin layers of the embryonic lamina reuniens segment of the lamina terminalis (Fig 2A). The term *lamina rostralis* is listed in medical dictionaries (4, 5), and is also described in some older anatomic texts (2, 3). Although the term has been dropped from use in the current literature, the distinct appearance of the lamina rostralis on MR images merits its reintroduction into the neuroradiologic and anatomic literature.

Reintroduction of the term *lamina rostralis* also makes sense from an embryologic point of view. The lamina rostralis arises from the embryonic lamina terminalis (19). The corpus callosum develops in the thicker, actively proliferating region of the lamina terminalis (2, 20). The developmental significance of the lamina rostralis became obvious once it was identified on MR images and its anatomy established. A review of the classic anatomic studies by Retzius and Hochstetter (9, 11) disclosed that the lamina rostralis is present in the illustrations showing the development of the corpus callosum, although it is not mentioned in the text or labeled on the illustrations (Fig 4). The lamina rostralis appears to be a remnant of the thicker rostral end of the prominent lamina terminalis of the young fetal brain. From the earliest stages of development, the callosal primordium appears to be anchored anteriorly by the lamina rostralis and posteriorly by the fornix (Figs 3 and 4). The lamina rostralis, with normal growth of the frontal lobes and maturation of the callosal genu, changes in orientation from a semivertical course to a more horizontal direction (Fig 3). The observation that the lamina rostralis and fornix appear to anchor the developing corpus callosum was made by analyzing our material and the illustrations in the work of Retzius and Hochstetter. These and other authors do not discuss this concept.

The presence of the lamina rostralis in patients with a rudimentary corpus callosum (Figs 5 and 6) also confirms that the lamina rostralis segment of the rostrum of the corpus callosum is present from the earliest stages of development of the corpus callosum. The presence of the lamina rostralis in almost half the cases with abnormalities of the corpus callosum reviewed retrospectively suggests that it would be identified in a much larger number of cases if searched for prospectively. This would be especially true if thin sagittal images were obtained. The change in orientation of the lamina rostralis results from the increased flexion of an enlarging genu. In several cases of hypogenetic corpora callosi, the orientation of the lamina rostralis is semihorizontal, similar to the orientation in brains with a normal corpus callosum (Fig 7). In these cases the abnormalities involve the posterior body and splenium. The anterior body, the genu, and rostrum are mostly normal. One may postulate that the presence of a normal, posteriorly pointing beaked segment of the rostrum is the result of the anchoring effect of the lamina rostralis.

The sequence of development of the rostrum has been at variance in the literature. An anatomic study (21) states that the rostrum and splenium develop after the trunk of the corpus callosum; an early neuroradiologic article described a unidirectional development of the corpus callosum with the rostrum as the first section to develop (22). The concept that the rostrum is the last segment of the corpus callosum to develop entered the neuroradiologic literature (23) from a frequently cited article by Rakic and Yakovlev (20), which states that the rostrum of the corpus callosum develops after the growth of the splenium. However, Sidman and Rakic (24) state that "the zone of fusion of the attendant callosal decussation extend first forward, then down, and finally back again to form the genu and rostrum of the corpus callosum."

According to the previously stated anatomic definition, the rostrum extends from the genu to the lamina terminalis. This investigation demonstrated that the lamina rostralis segment of the rostrum is present at the earliest stages of the appearance of the rudimentary corpus callosum in the region of the future body, and before the development of the genu and splenium (Figs 3–5). In a previous investigation (1) it was established that the normal human genu always projects in front of a line connecting the *m*amillary body with the *a*nterior commissure and continuing toward the region of the *c*orpus callosum, the MAC line. In the cases in Figures 5 and 6 there is no callosal tissue in the expected position of the normal genu as determined by the MAC line. However, the cases in Figures 5 and 6 show the presence of the rudimentary beaked segment of the rostrum without the presence of a normal genu. These cases highlight two important findings: first, the lamina rostralis is present without the presence of a genu and splenium; and second, a rudimentary beaked segment of the rostrum appears to be present without the presence of a genu. Thus, the inevitable conclusion has to be drawn that the lamina rostralis segment of the rostrum forms before the genu and splenium, and, at the very least, the beaked segment of the rostrum develops concurrently with the genu.

The early presence of the rostrum in human embryology makes sense in view of the long and complex evolutionary history of the corpus callosum. Abbie (12) states that "since the frontal pole of the corpus callosum does not leave the lamina terminalis the whole of the callosal arc—rostrum, genu and part of the body—must be derived from the body of the linear callosum of lower placentals." According to Johnson (25) and Abbie (12), the enlargement and arching of the corpus callosum cause the stretching of the septum pellucidum. The controversy of an open versus closed cavum septi pellucidi has been reviewed by several authors (12, 20, 26).

The beaked segment of the rostrum and the lamina rostralis can be identified in many mammals (12–14, 27–32), some of whom have a genu that is much less developed than the human genu. This suggests that some segments of the rostrum are phylogenetically and embryologically older than the human genu.

In summary, this investigation establishes that the rostrum is not the last segment of the corpus callosum to develop. Rather, the lamina rostralis segment of the fetal rostrum is already present before the genu and splenium develop. Additionally, the beaked segment of the rostrum develops concurrently with maturation of the genu.

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