Supplement 1 for

The Amsterdam Ultra-high field adult lifespan database (AHEAD): A freely available multimodal 7 Tesla submillimeter magnetic resonance imaging database

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**Globus pallidus internal and external segment**

The Globus Pallidus (GP) is a crescent structure with an elongated shaped oriented along the rostrocaudal brain axis. The GP comprises an internal segment (GPI), which is located medial to the external segment (GPE). The segments are separated by the medial medullary lamina (MML), and the GPE is separated from the striatum by the lateral medullary lamina (LML). Surrounding landmarks include the thalamus located posterior to the GP, and the caudate nucleus which is located dorsally. Laterally the putamen is found, and medioventral to the GP the subthalamic nucleus and the substantia nigra. At more central levels, the GP is located superior to the SN and STN, and at the caudal extent to the red nucleus (RN).

Parcellation

The GPE is first identified in the coronal view (Fig. 2). First, the border between the GPE and the striatum is delineated on T1-weighted contrasts. This is done on consecutive slices following the structure first in the anterior followed by the posterior direction. Additionally, the transverse plane can be used to identify the striatal-GPE border if required. The internal capsule visible on T1-weighted contrasts is then used to define the rostral border of the GPE in the axial view.

Subsequently, parcellations are continued using the QSM contrast, using the coronal view moving in an anterior direction. On the QSM contrast, the MML can be identified, allowing the separation of GPI and GPE. At the level of the optic chiasm, the anterior part of the GPE has a rounded or triangular shape at levels where the GPI is absent. The size of the GPE decreases in an anterior direction until disappearing rostral to the anterior commissure. Note that the anterior commissure can cross through the GPE, however, given the limited visibility of the subcommissural GPE, we chose not to include the ventral GPE in the delineations for practical reasons. At central levels of the GP, the GPI is located medial to the GPE presenting as a rounded or triangular structure. More caudally, the GPE moves in a lateral direction assuming a crescent shape over the GPI, which at the same time increases in size. At the level of the SN and RN the GPE and GPI gradually decrease in size. First the GPI and eventually also the GPE disappears around the central level of the RN.

Both the T1-weighted and QSM contrasts are checked for consistency of the delineations, and the 3D view is used for confirmation of the expected anatomical shape. Figs. 2-7 illustrate the visibility of the GPI/e on QSM and T1-weighted contrasts at various anatomical levels.
Fig. 2: Globus pallidus internal and external segment (GPI and GPe) in a central view on QSM. Top row QSM contrast, note the boundary between the GPI and GPe are formed by the medial medullary lamina in black. Yellow = GPe, Light blue = GPI.
Fig. 3: Globus pallidus internal and external segment (GPI and GPe) at the level of the mamillary bodies on a T1-weighted contrast. Top row T1-weighted contrast, note the boundary between the GPe and the hypointense striatum which is located lateral to the GPe. Yellow = GPe, Light blue = GPI.
Fig. 4: Globus pallidus internal and external segment (GPI and GPe) in a rostral view on the QSM contrast at the level where the anterior commissure crosses the third ventricle. Top row QSM contrast, note the absence of the GPI from the coronal view at these rostral levels. Note the increased visibility of the dorsal GPI/e border as a result of the hypointense appearance of the internal capsule. Yellow = GPe, Light blue = GPI.
Fig. 5: Globus pallidus internal and external segment (GPI and GPe) in a rostral view on T1-weighted contrast at the level where the anterior commissure crosses the third ventricle. Top row T1-weighted contrast, note the limited contrast between the GPe, the internal capsule and the anterior commissure at this level. Note the limited visibility of the ventral pallidum. Yellow = GPe, Light blue = GPI.
Fig. 6: Globus pallidus internal and external segment (GPI and GPe) in a more caudal view on a QSM contrast. Note the clear visibility of other iron rich structures including the STN and SN at this level. Top row QSM contrast, note the limited contrast between the GPe, the internal capsule and the anterior commissure at this level. Yellow = GPe, Light blue = GPI.
Fig. 7: Globus pallidus internal and external segment (GPI and GPe) in a more caudal view on a T1-weighted contrast. Note the reduced visibility of other iron rich structures including the STN and SN at this level as compared to the QSM contrast in Fig. 6. Top row T1-weighted image, note the clear visibility of the border between the striatum and the GPe. Yellow = GPe, Light blue = GPI.
**Subthalamic nucleus**
The STN is a biconvex lens-shaped nucleus located between the red nucleus (RN) and the comb system at the dorsomedial border of the substantia nigra (SN). The STN is an iron rich structure so that it appears hyperintense in QSM images.

Fig. 8: Subthalamic nucleus (STN) in a central coronal view (adapted from Mai et al). Note the clear biconvex shape of the STN.

**Parcellation**
The QSM contrast is used for the parcellation of the STN. First, the RN is identified for anatomical orientation. The RN is located medial to the inferior region of the putamen close to the brain's midline. If this structure is visible, the SN typically curves around its inferior and lateral edge, with the ventral tegmental area (VTA) located between the SN and the RN. At more caudal levels, the GP will disappear. The view is set in a rostral position where the STN appears at the superior medial edge of the SN in the coronal plane as presented in Fig. 8. Moving further in a rostral direction, the STN will increase in size, and the border to the SN will become increasingly clear. The RN will become smaller in the rostral direction, levels at which the STN is expected to have its characteristic ellipsoid shape. Parcellations are started at the center of the STN in the coronal view, where the visibility of the STN/SN border is relatively high. In cases that the location of the border is not clear, the delineation is continued in consecutive slices, and the missing delineation will be filled in at a later stage at which more information from adjacent slides is available. Delineations are continued in the caudal direction. Again, use all three view-points to parcellate dependent on the visibility of the individual structures. This can vary between individuals. Caudal to the starting point, the RN will appear medially, as the STN decreases in size.
Note, at this point, it may become more difficult to determine the borders of the STN. At this level three planes of view should be used. Continue moving in the caudal direction and delineate the STN until the RN reaches its maximum diameter. Around this level, the STN will disappear. The size of the shape is then checked at all levels, and remaining borders are filled in.

The same procedure is followed in a rostral direction, parcellating on all the slices in which the STN is visible. At more rostral levels, the IC borders the STN laterally. More rostral, the mamillary bodies (MB) will appear as hyperintense structures in the QSM images. The MB can appear as two individual rounded structures, or as a single structure (due to partial voluming effects). At these levels, the STN and SN start to decrease in size. At these levels, the coronal and axial view generally provide the best contrast between the STN and its surrounding structures. Move further rostral and segment until the STN and SN disappear, typically the MB will be present as a clear hyperintense circular structure at these levels. After completion of the parcellation at the rostral end, the entire STN shape is checked and remaining parts are completed. The STN parcellation is then checked in all views to confirm consistency.
Fig. 9: The subthalamic nucleus (STN, red) appears as a hyperintense structure in the QSM contrasts due to its high iron content. At these levels, the substantia nigra (SN) and red nucleus (RN) also appear hyperintense in the QSM contrasts, and can be used for anatomical orientation. Note the increased visibility of the STN/SN border in the coronal view. Additionally, note the limited visibility of these structures in the T1-weighted contrast.
Fig. 10: More rostral view of the STN at the level of the mamillary bodies (visible in the T1-weighted contrast). Note the slightly more medial position of the STN at this coronal level.
Fig. 11: More caudal view of the STN. Note the slightly more lateral position of the STN at this coronal level.
Substantia Nigra

The SN is a curvilinear structure, divided into the substantia nigra pars compacta (SNp) and substantia nigra pars recticulata (SNr). Given the low contrast between the SNp and SNr, the SN is parcellated as a single structure. The SN is located inferiomedial to the globus pallidus (GP), and lateral to the mammillary bodies (MB). The inferior tip of the SN can typically be observed at the level of the MB in the coronal view, with the lateral tip extending slightly above the MB. The SN is oriented at an oblique angle, with the superior tip further lateral to the MB than the inferior region.

Parcellation

The substantia nigra is parcellated using the QSM contrast. The MB is used for anatomical orientation. At the level of the MB, the GPe, GPi, and putamen will also be visible. The MB is located anterior to the SN within the brain, to locate the SN, move towards a more caudal position. When moving more caudal in the coronal plane slices, the STN moves in a lateral direction, and its lateral part will separate from the SN. These levels provide a better SN/STN separation and provides a convenient starting point for the delineation. All visible borders of the SN are delineated on while moving in a more rostral direction. Delineations of the structure are guided by its visibility. If possible, continue to segment the superior medial border between the SN and STN as well as using the coronal view. Additionally, use the sagittal view if the coronal view does not provide the desired SN/STN contrast. In case of inadequate border visibility in these views, this border will be identified at a later stage. After disappearance of the SN in rostral slices, move caudally from the starting point. Continue to delineate the SN. Again, use all three planes, depending on which displays the border that is delineated best. This will vary between individuals. At levels more caudal to the start point, appears medially At levels where the RN increases in size, the SN will decrease in size.
At the level where the RN has its maximum diameter, the STN has typically disappeared. At this point, when you start to reach the posterior extent of the SN, some of the voxels within the SN can show lower intensity, seeming splitting the SN. In the axial view this may resemble a swallow tail. The hypointensity has been attributed to nigrosome 1, a cluster of dopaminergic cells within the SN. These hypointense voxels are included in the parcellation. Delineation in adjacent slices will help resolve unclear borders. Delineation is continued in the caudal direction, the SN and RN will both decrease in size. Continue to move caudal until the RN disappears. At this point, a small part of the posterior region of the SN will still be visible. More caudally the SN will disappear. Delineation of the SN is then completed.
Fig. 13: The substantia nigra (SN) appears as a hyperintense structure on the QSM contrast as a result of its high iron content. In coronal levels, the medial part of the SN lies inferior to the lateral parts of the SN. The RN provides a clear anatomical reference point. Note the limited visibility of the SN on the T1-weighted contrast.
Fig. 14: The substantia nigra (SN) decreases in size in more rostral levels. Note the clear visibility of the mamillary bodies at these levels in the T1-weighted contrast.
Fig. 15: The substantia nigra (SN) decreases in size and appears in a larger angle in more caudal levels.
**Red nucleus**

The RN is an iron-rich nucleus in the tegmentum of the rostral midbrain. It has a distinct oval-shaped and located close to the midline of the brain. A clear landmark for the location of the RN is the substantia nigra (SN), a dark crescent-like shaped structure that is curved around the ventrolateral side of the RN. In the sagittal plane, the RN and SN can be roughly located inferior to the nuclei of the thalamus (Th) and superior to the pons. In the coronal plane, the RN lies medial to the subthalamic nucleus (STN) and SN, and inferior to the third ventricle (3V) and thalamus (Fig. 16). The RN consists of a more caudal magnocellular part and a more rostral parvocellular part that relay functionally different motor fibers systems. On MRI, these segments cannot be distinguished. Therefore, the RN is parcellated as a single structure.

**Parcellation**

The RN is identified as a hyperintense structure in the coronal view on the QSM contrast. Moving from rostral to caudal, the RN will appear after disappearance of the putamen and pallidum and emergence of the SN and STN. The STN will decrease in size and eventually disappear as the RN and SN increase and the space between them becomes smaller. After the RN has reached maximum diameter, the decussating fibers from the superior cerebral peduncles will appear inferomedial to the RN. From there, the RN will decrease in size until it disappears typically at the same level as the SN. In the coronal view, segmentation can pose challenges at the ventrolateral and inferomedial borders, and on sagittal views, the RN can look less consistent (e.g., more triangular shape) and show more interference from crossing fibers tracts. Typically, the other views provide additional information which allows detailed parcellation of the RN. The 3D mask should be generally ovoid and not have any significant abnormalities such as large protrusions or indentations on the surface.

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Fig. 16: Red nucleus (RN, R in this Fig.) in a central coronal view (adapted from Mai et al.). Note the clear delineation of the structure close to the midline of the brain.
Fig. 17: The red nucleus (RN) at a central level is clearly visible as a rounded structure in all three viewing planes in the QSM contrast. Note the limited visibility of the RN in the T1-weighted contrast.
Fig. 18: The red nucleus (RN) at a rostral level can still clearly be identified as is decreased in size. Note the limited visibility of the RN in the T1-weighted contrast.
Fig. 19: The red nucleus (RN) at a caudal level can still clearly be identified as is decreased in size. Note the limited visibility of the RN in the T1-weighted contrast.
References