Visual Pathways

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Vision in Animals

Miller PE, Murphy CJ. Vision in Dogs. JAVMA. 1995; 207: 1623.


Optic nerve
Optic chiasm
Lateral geniculate nucleus
Optic radiation
Striate cortex
Optic tract
Hypothalamus: regulation of circadian rhythms
Pretectum: reflex control of pupil and lens
Superior colliculus: orienting the movements of head and eyes
Visual Fiber (Retinotopic) Segregation

- each cerebral hemisphere receives information from contralateral **visual field**
- nasal retinal fibers decussate, temporal retinal fibers do not...right nasal hemiretinal fibers cross over project to left cerebrum, right temporal fibers remain uncrossed and project to right cerebrum
- target in right half of visual field (right visual hemifield) ⇒ right nasal retina and left temporal retina ⇒ left optic tract ⇒ left dLGN ⇒ left cerebral hemisphere
Visual Fiber (Retinotopic) Segregation

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Nasal Retina = Temporal hemifield

Fibers Decussate

Temporal Retina = Nasal hemifield

Fibers Remain Ipsilateral
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target in right half of visual field (right visual hemifield) ⇒ right nasal retina and left temporal retina ⇒ left optic tract ⇒ left dLGN ⇒ left cerebral hemisphere
target in left half of visual field (left visual hemifield) ⇒ left nasal retina and right temporal retina ⇒ right optic tract ⇒ right dLGN ⇒ right cerebral hemisphere
Visual Fiber Segregation

Object in **right** visual hemifield projects to:
- **right** nasal hemiretina
- **left** temporal hemiretina
- **left** cerebrum

Object in **left** visual hemifield projects to:
- **left** nasal hemiretina
- **right** temporal hemiretina
- **right** cerebrum
Assessing Visual Pathways

- pupillary light reflex incl. chromatic testing
- (optic) dazzle reflex
- optokinetic reflex
- electroretinogram
- visual-evoked response
Brainstem Reflexes and Visual Pathways

Afferent Arm Before LGB ... PLR/Dazzle and Vision Abnormal

Cortical ... PLR/Dazzle normal; Vision Abnormal

**ipRGCs
(Optic) Dazzle Reflex Test

- partial eyelid blink in response to bright light
  - subcortical reflex
  - eyelids may open then close
  - contralateral closure < or sometimes absent

- afferent=optic nerve/tract to rostral colliculi
- efferent= CN VII

- present 1-2 days postnatally in dogs/cats
DAZZLE REFLEX

Obicularis oculi mm.

CN II

LGB

Pretectal Nuclei

Rostral Colliculi

CN VII nuclei

CN VII

nuclei
Other Rostral Colliculus-Mediated Reflexes

- Coordination of eye movements in response to visual stimulus (rostral colliculi to CN III, IV, VI)
- Turning of head and neck in response to visual stimulation (motor fibers in spinotectal tract)
- Reticular activation system (activates cortex)
Assessing Vision and Visual Pathways

- menace response
- obstacle or maze course
- visual placing reaction
  - hold dog in air, advance to table edge...both forelegs will extend
- visual cliff
  - clear plexiglas extended over edge of table...visual animal stops at table edge
  - large animals = present birth
  - dogs/cats = 4 week
- patching or occluding for unilateral vision loss
Menace Response

- cortically mediated eyelid closure +/- head withdrawal and globe retraction
  - complex “response” not reflex
- requires intact retina, optic nerve/tract/radiation, visual cortex, inter-cerebral cortices pathways, descending pathways to brainstem and CN VII
- undefined connection with cerebellum:
  - may result from pathway passing through cerebellum OR from loss of cerebellar facilitation/modulation of motor cortex
  - cerebellar lesion results in ipsilateral (unilateral) or bilateral menace response loss with normal vision
Automated Visual Field Testing
Hemianopia (vision loss/deficit in ½ of visual field in one or both eyes)

- **homonymous hemianopia:**
  - loss of one hemivisual field (e.g. loss of right visual field from loss of nasal retinal fibers in right eye and temporal fibers in left eye)
  - any unilateral lesion caudal to chiasm

- **heteronymous hemianopia:**
  - loss of two hemivisual fields (e.g. loss of both temporal visual fields from loss of both nasal retinal fibers):
    - chiasmal lesions if affect only crossed fibers (bitemporal hemianopia)
    - Siamese cats (binasal hemianopia)

- **quadrantic hemianopia:**
  - partial unilateral lesion caudal to chiasm
Hemianopia (vision loss/deficit in ½ of visual field in one or both eyes)

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Characteristics of Visual Pathway Lesions

- Retina
- Pre-chiasmal optic nerve
- Optic chiasm
- Optic tract
- Lateral geniculate body
- Optic radiation
- Occipital (visual) cortex
- Parietal and frontal (motor) lobe
- Cerebellum
Unilateral Retinal Chain, Intraocular Retinal Ganglion Lesions

- lack of direct and consensual (to fellow eye) PLRs
- positive swinging flashlight test/cover uncover (Marcus-Gunn pupil)
- PLRs may persist with advanced retinal disease and visual deficits (ipRGCs, high intensity blue light stimuli)
- ipsilateral visual deficits (menace response)
- ipsilateral optic dazzle deficits
Unilateral Prechiasmal Optic Nerve Lesions

- signs identical to retinal disorders
Optic Chiasmal Lesions

- total lesions cause bilateral PLR and visual deficits
- PLR deficits may be recognized before visual deficits
- abnormalities in behavior, appetite, temperature regulation, endocrine function dysfunction and visceral motor activities
Central Chiasmal Lesions

- Common in humans with pituitary macroadenomas
- may cause **heteronymous hemianopia** e.g. only crossing fibers affected:
  - bitemporal hemianopia …crossing fibers from nasal hemiretina involved, loss of both temporal visual fields
Humans = pituitary stalk directed rostroventrally, main mass of gland directly below chiasm (10mm), macroadenomas often involve central chiasm and are a common cause of vision loss.

Dogs = pituitary stalk directed caudoventrally, main mass of gland is caudal (posterior) to chiasm, macroadenomas or other tumors uncommon cause of vision loss.
Unilateral Optic Tract Lesions

- similar to unilateral retinal or prechiasmal optic nerve but more dilated pupil contralateral to lesion
- subtle anisocoria
- more miotic pupil persists in the same eye regardless of which eye is stimulated
- visual field contralateral to affected tract is diminished or lost
  - contralateral homonymous hemianopia
  - vision loss most obvious in eye contralateral to lesion
- visual field testing performed by directing menace response stimuli from lateral and medial to midline (patching or occlusion)
Lesions in Optic Tract

- proximity to internal capsule (all ascending and descending fibers to and from motor cortex)
- contralateral postural reaction deficits with normal gait (proprioceptive pathways)
Bilateral Retina, Optic Chiasm
Optic Nerve or Tract Lesions

- lesions in both retinas more common than (>)
  chiasm > both optic nerves > caudal commissure > optic tracts

- bilateral mydriasis, PLR deficits, visual deficits commensurate with lesion
Lesions of Optic Radiation

- Contralateral homonymous hemianopia
Lesions of Optic Radiation

- proximity to caudal limb of internal capsule (ascending and descending fibers from motor cortex):
  - complete contralateral homonymous hemianopia
  - contralateral hemiplegia and hemianesthesia
Unilateral Visual Cortex Lesions

- Complete, contralateral homonymous hemianopia
Diagram of the visual system showing the left and right eyes, optic nerve, optic chiasm, optic tract, lateral geniculate nucleus, optic radiation, and striate cortex. The diagram also includes visual field illustrations for both eyes.
Visual Cortex Projections

- To **opposite visual cortex** via corpus callosum
- To **motor cortex** of both cerebral hemispheres
- To **cerebellum** by way of pons
- To **rostral midbrain** (rostral colliculi and to CN III, IV, VI nuclei, directly or indirectly through rostral colliculi)
Visual Cortex

- rostral and medial regions:
  - steropsis and processing
  - analysis
  - form, pattern, texture

- caudal and lateral regions:
  - menace blink response

- rostral region:
  - visual placing

- caudal and medial regions:
  - conjugate eye movements (orientation and attention of eyes to visual target)
  - corticotectal pathways directly to brainstem (rostral colliculi, CN III, IV, VI nuclei directly or indirectly through rostral colliculi)
Rostral Visual Cortex:
visual placing

Motor Cortex

forelimbs
Visual Cortex

- **rostral and medial regions:**
  - stereopsis and processing
  - analysis
  - form, pattern, texture

- **rostral region:**
  - visual placing
  - to motor cortex

- **caudal and lateral regions:**
  - menace blink response
  - to motor cortex

- **caudal and medial regions:**
  - conjugate eye movements (orientation and attention of eyes to visual target)
  - corticotectal pathways directly to brainstem (rostral colliculi, CN III, IV, VI nuclei directly or indirectly through rostral colliculi)
Caudomedial Visual Cortex: Conjugate gaze, orientation to visual targets

Extraocular mm.
Visual Cortex Connections (de Lahunta)

- Visual cortex and rostral midbrain (rostral colliculi, CN III, IV, VI nuclei, gaze centers) have extensive interaction in mediating visually guided behavior:
  - Total bilateral rostral colliculectomy caused inattention to all visual stimuli and loss of visual placing and menace
  - Mesencephalic tegmentum (CN III, IV, VI, and gaze centers) lesions cause loss of visual perception of movement and spatial orientation
  - Unilateral lesion of the tegmentum cause contralateral deficit and postural dystonia (severe torsion of head) from vision loss
  - Bilateral removal of visual cortex, cats can still detect objects in lateral visual field via direct rostral collicular projections from eye
Complete, Unilateral Visual Cortex Lesions

- Complete, contralateral homonymous hemianopia
- Loss of menace blink response in contralateral visual field
- Loss of conjugate eye movements to target in contralateral visual field
- Loss of contralateral visual placing
Bilateral Visual Cortex Lesions

- complications of anesthesia (hypoxia)
- polioencephalomalacia (thiamine deficiency)
- lead intoxication in ruminants
- metabolic storage diseases in dogs and cats
- cranial trauma with contrecoup effect (human)
Parietal Lobe and Frontal Lobe Lesions

- loss of menace response and visual placing in contralateral visual field
- no loss of vision
- no loss of conjugate gaze (orientation and attention to target stimuli)....mediated by visual cortex with corticotectal projections directly to brainstem gaze centers
Cerebellar Lesions

- Contralateral or bilateral mydriasis with normal PLR
- Ipsilateral or bilateral absence of menace blink response with normal vision
QUESTIONS?