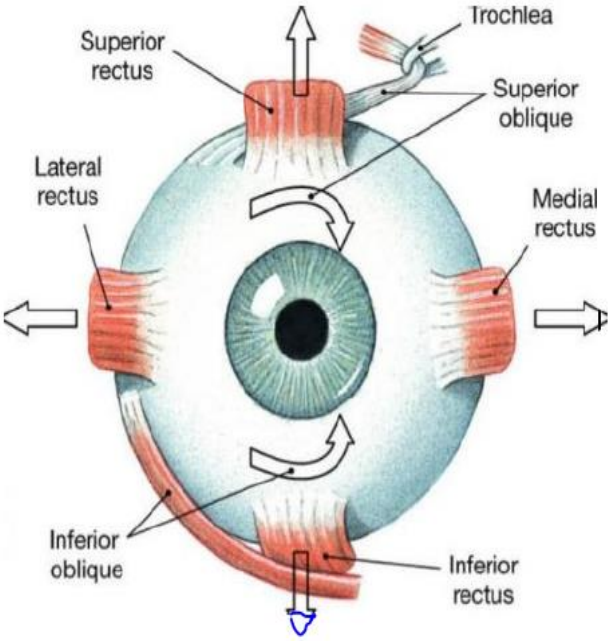
Control of Eye Movement

• Brain regions related to ocular motility include the following:
1. Primary Motor Area, specifically the facial region
2. The Pre-motor area, specifically the Frontal Eye Field (8)
3. The Parietal/Posterior Eye Field (areas 5&7 in the Parietal Lobe)

The Ocular Muscles

- Orders from the previously mentioned centers are sent to the ocular muscles.
    - Orders could be reflexes, conscious, or unconscious
- There is a total of 6 muscles in the eye displayed in the figure 1 below:
- A total of 3 cranial nerves supply these muscles: The Oculomotor, The Trochlear, and the Abducens Nerve.
- The Oculomotor Nerve supplies the:
    - Superior Rectus
    - Medial Rectus
    - Inferior Rectus
    - Inferior Oblique
- The Trochlear Nerve supplies the:
    - Superior Oblique
- The Abducens Nerve supplies the:
    - Lateral Rectus

Figure 1



Remember: All musles are supplied by CN3 except SO4 and LR6

Ocular Nerve Injuries

Oculomotor Nerve Injury

- Supply to the Superior Rectus, Medial Rectus, Inferior Rectus, and Inferior

Oblique will be cut. The only muscles working would be the Lateral Rectus and Superior Oblique. Consequently, the eye will be positioned in a down and lateral position.

Trochlear Nerve Injury

- The Superior Oblique would cease to function. Since the original function of the superior oblique is to depress and bring the eye inward, the eye will be slightly elevated and extorted. You will find that the patient is walking while he rotate his head in the opposite direction of the affected eye rotation to correct his vision. His will also chin be tucked in and down. If not treated, this could lead to diplopia or blurry vision. Refer to figure 3.

Abducent Nerve Injury

- Eye Moves Medially. Refer to figure 4.

Figure 3

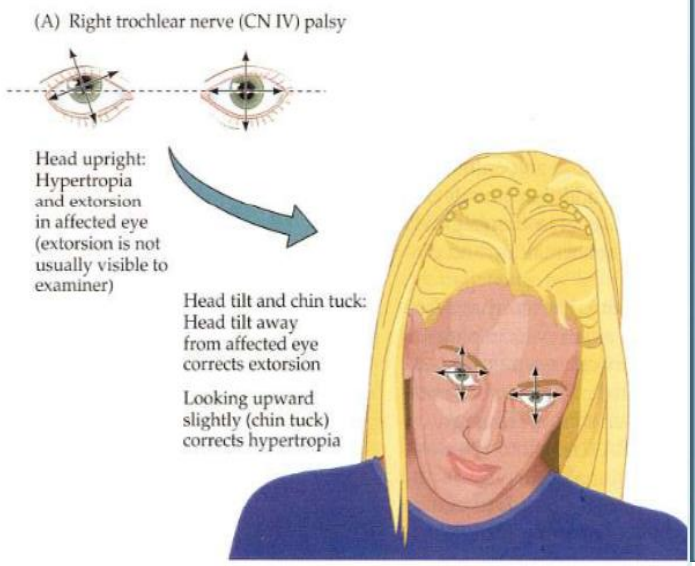
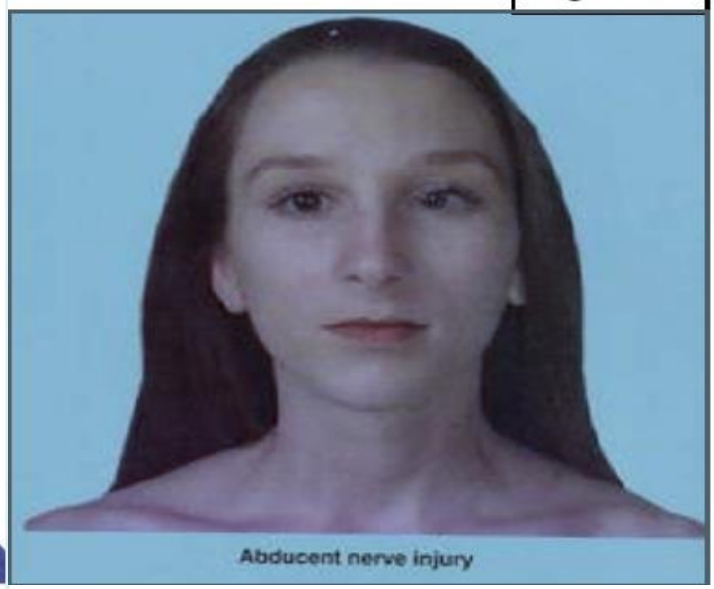


Figure 4



Types of Eye Movement

Conjugated Eye Movement

- A type of movement where eyes move together in the same direction.
- Suppose both eyes are moving to the right direction.
    - The right eye has to move laterally→ Lateral rectus(CN6-Abducent)
    - The left has to move medially→Medial Rectus(CN3-Oculomotor)

- Thus, two nerves work together to move both eyes in the same direction.
    - As mentioned in lecture 10, there is a connection between the oculomotor and abducent nerve. These connections are further explained below.
    - Let's take the previous example of moving both eyes to the right:
      1. The order is first sent to the **Abducent nerve**(right one in this case)
      2. The Abducent Nerve activates the **contralateral Oculomotor nerve**(the left one in this case) through **MLF**[1]**.** (The MLF is a long structure extending from the lower brain stem to the upper brain stem. It contains ascending and descending fibers. When we talk about MLF related to vision we refer to the superior part of MLF).

    - There are also inhibitory connections between the abducent and oculomotor nerves. In order for the right eye to move to the right(laterally), the Lateral Rectus is activated. But remember that the antagonist muscle is usually inhibited to have an easy and smooth movement for any muscle. Thus, we also need to inhibit the Medial Rectus in the right eye.
      Consequently we conclude that the right abducent activates the left oculomotor BUT inhibits the right oculomotor.
- Orders for these types of movements descend **indirectly** from the cortex. They are first sent to nuclei in the brain stem then to the nuclei of eye movement(3,4 and 6) that are specialized for specific eye movements such as saccadic and jumpy/pursuit eye movement.
- There are several nuclei in the brainstem that function to aid in conjugated eye movements.

Dis-conjugated Eye Movement

- Eyes move in different directions(could be physiological or pathological)
- It could happen involuntarily when looking at a close object to get better focus.
- It could happen voluntarily when people cross their eyes. Some people can also voluntarily move both eyes in different directions.
- In these types of movements, orders from the brain descend **directly** to the nuclei.

Injuries to the MLF

- Can be due to stroke or multiple sclerosis for example
- To differentiate between right and left MLF injuries one should know these facts:
    - The right MLF is related to the right Oculomotor and left Abducent (which are responsible for looking to the left)
    - The left MLF is related to the left Oculomtor and right Abducent (which are responsible for looking to the right)

Injury to the Right MLF

- When moving both eyes to the right: the right Abducent sends signals to left Oculomotor through left MLF. Thus, the patient's eye movement to the right will be normal
- When moving both eyes to the left: the left Abducent sends signals to the right Oculomotor through the right MLF. Thus, the patients left eye will normally move to the left BUT the right eye won't move to the left.

Injury to the Left MLF

- When moving both eyes to the right: the right Abducent will send signals to the left Oculomotor through the left MLF. Thus, the patient's right eye will normally move to the right BUT his left eye won't move to the right.
- When moving both eyes to the left: the left Abducent will send signals to the right Oculomotor through the right MLF. Thus, the patients eye movement to the left will be normal.

In conclusion, a patient with injury to the right MLF will not be able to move his right eye to the left. A patient with injury to the left MLF will not be able to move his left eye to the right.

Injury to Both MLFs

- When moving both eyes to the right: the right Abducent will send signals to the left Oculomotor through the left MLF. The patient's right eye will move to the right but his left eye won't move to the right
- When moving both eyes to the left: the left Abducent will send signals to the right Oculomotor through the right MLF. The patient's left eye will move to the left BUT his right eye won't move to the left
- This type is more common since both are near the midline

• In conclusion, the patient's left eye is able to move ONLY left and his right eye is able to move ONLY right.

Whether the MLF is unilaterally or bilaterally injured, the condition is called ***Inter-nuclear Ophthalmoplegia.***

MLF Lesions Related to Blood Supply

• Lesions usually occur through the distribution of one blood supply.
• Blood vessels running to supply the Abducent Nerve also supply the MLF fibers on the same side of that Abducent.

One and A Half Syndrome

• A type of syndrome where blood supply on either sides of MLF is compromised with the Abducent nucleus at the same side if lesioned

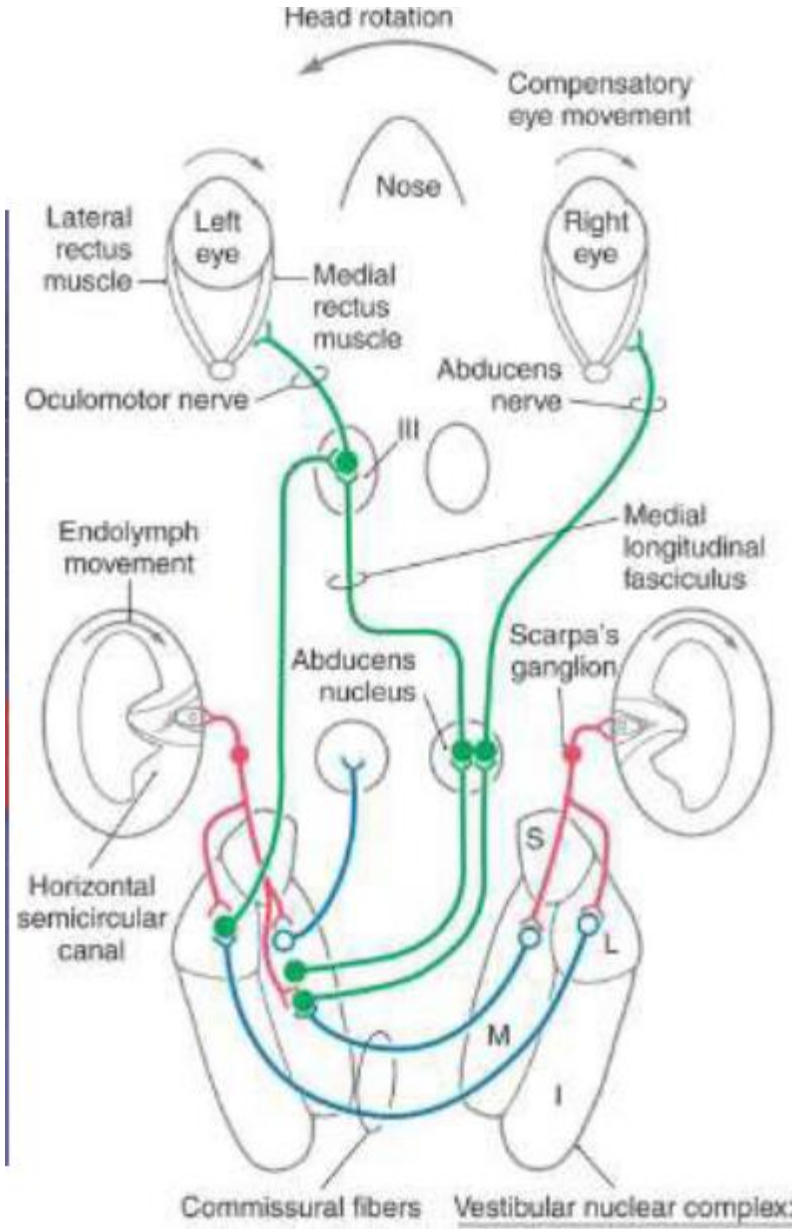
- **If the Left blood supply** is compromised: the left Abducent and left MLF will loose their blood supply.
  - When moving the eyes to the *left*: the left Abducent should send signals to the right Oculomotor through the right MLF. However, the left Abducent's blood supply is compromised and the nerve will cease to function. Thus, **NO** eye movement will occur whatsoever.
  - When moving the eyes to the *right*: the right Abducent should send signals to the left Oculormotor through the left MLF. Since the right Abducent is innervated just fine, the patient's right eye will move to the right. However, the left eye will not be able to move to the right since the left MLF is compromised.
- By using the same logic, **when the right blood supply** is affected the right Abducent and right MLF are affected. Only the patient's left eye will move to the left. However, his right eye will **not** move neither right nor left since the right Abducent and right MLF are affected.
- <u>In conclusion:</u>
  - If the left blood supply was affected for example →the left eye can't move at all , while the right eye can only move to the right . and that's why the syndrome is named so (the entire movement of one eye and half of the other one will be disabled .

If the right blood supply is affected the opposite would happen (the only possible movement would be moving the left eye to left)

Vestibulo-ocular Reflex

The vestibular system also controls eye movement. The vestibular system gives orders to move the eye opposite to the direction of the body. For example, If you move your head to the left your eyes will go to the right.

To be able to do so , the vestibular nucleus will send orders to the Abducent nucleus to move the eyes. And since we want to move the yeys to the contralateral side, the vestibular nucleus will send orders to the contralateral Abducent nucleus, which then will send the order to the contralateral oculomotor nucleus as shown in the figure .



The Caloric Test

The test depends on the fact that the baseline firing depends on temperature; when temperature increases, the baseline firing increases.

(1) In a normal individual:

- When I raise the temperature **in his left ear** for example, the baseline firing in the left eat increases. The left vestibular system is sending more stimuli from the left comparing to the right. The CNS will think that the patient's head is rotating from right to left and **the eyes will move to the right** and then beat back to the center (move fast to the left).

- When I put warm water **in his right ear**, his **eyes will move to the left** and then return to the center. This happens because the baseline firing increased in the right side, leading to activation of the contralateral (left) abducent moving his eyes to the left. When we put cold water in the same ear, the opposite happens. The baseline firing in the right ear will decrease, the CNS will think that his head is rotating to the left and his eyes will move slowly to the right and then beat fast back to the center (which we call nystagmus shifting to the right or leftbeating nystagmus).
This test is commonly used when we want to assess the function of the brain stem especially when the patient is in a coma. It can show if there is a problem anywhere in the pathway; either in the vestibular system, abducent, MLF or oculomotor.

(2) Low brainstem lesion: If there is a problem in the brainstem at the level of the vestibular nuclei (the vestibular nuclei are damaged), **the eyes will not move** when we put cold or warm water.

(3) MLF lesion: If the lesion in the brainstem is higher, it will damage MLF or one of the nuclei that controls eye movement. Normally, the vestibular system activates the Abducent nerve which activates the contralateral oculomotor nerve.

Since both MLFs are injured, only one eye will move in this case. Which eye moves depends on the temperature of water(cold or hot). Refer to figure 5