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6th International Workshop on Breathing Pacemakers

Indications and Preoperative Evaluation of Patients

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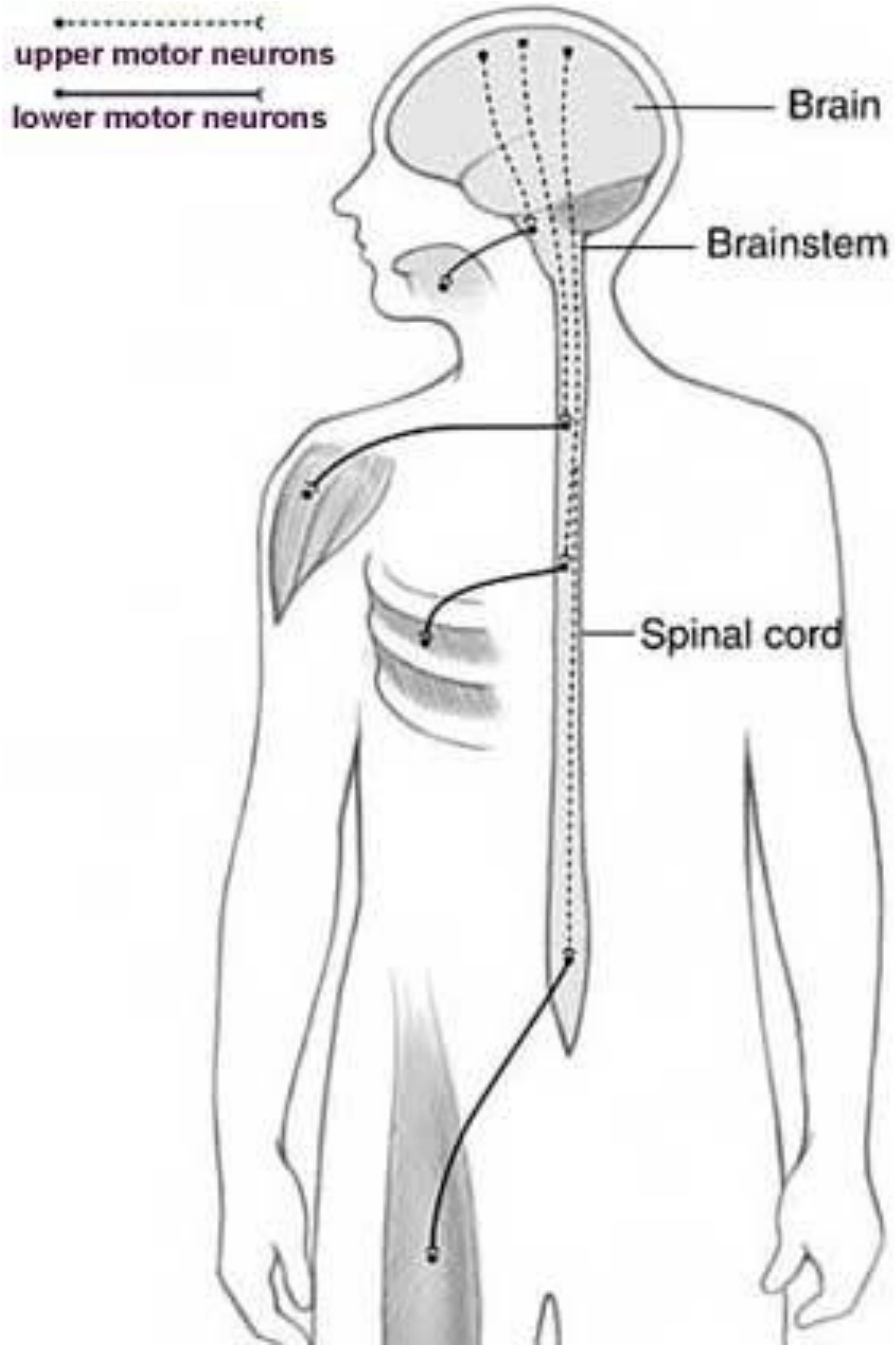
Objectives

- Discuss neurologic control of respiration
- Review phrenic nerve physiology
- Explain diagnostic testing in diaphragm weakness

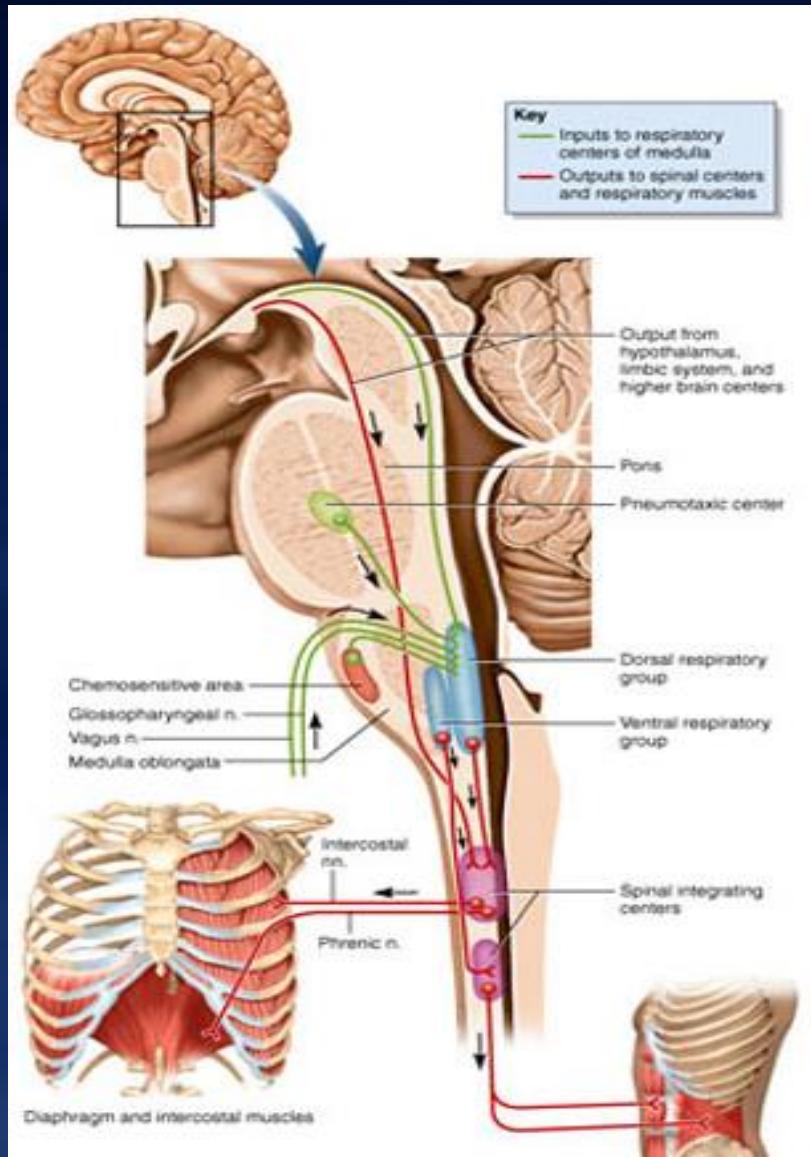
Motor control

- Generally a two neuron process
  - Cortical upper motor neuron to anterior horn cell
  - Anterior horn cell to muscle
- Interruption anywhere along the pathway can cause weakness


upper motor neurons
lower motor neurons
Brain
Brainstem
Spinal cord

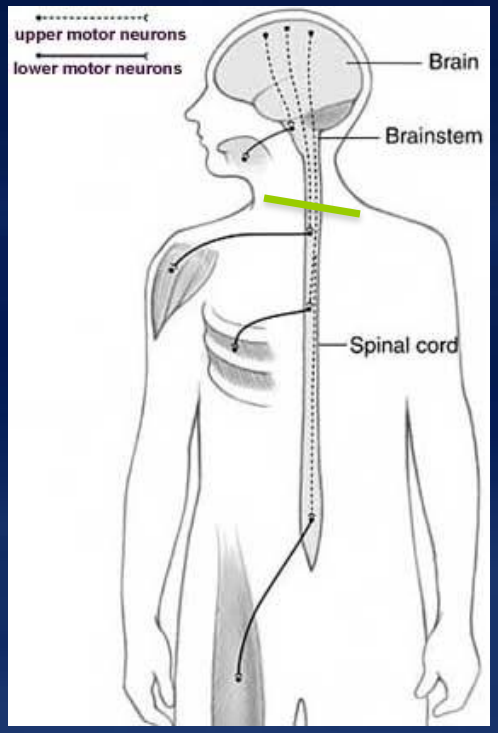
Respiratory muscle control

- Voluntary/Involuntary control
  - Cortical input provides volition
  - Pontine centers
    - Apneustic center (inspir)
    - Pneumotaxic center (expir)
  - Medullary centers
    - VRG
      - Primary driver of breathing
      - Output to the phrenic nerve via spinal integrating center
    - DRG
      - Integrates pontine centers



Phrenic nerve

- Anterior horn cells at C3-5 cervical level
- Solely composed of lower motor neuron axons



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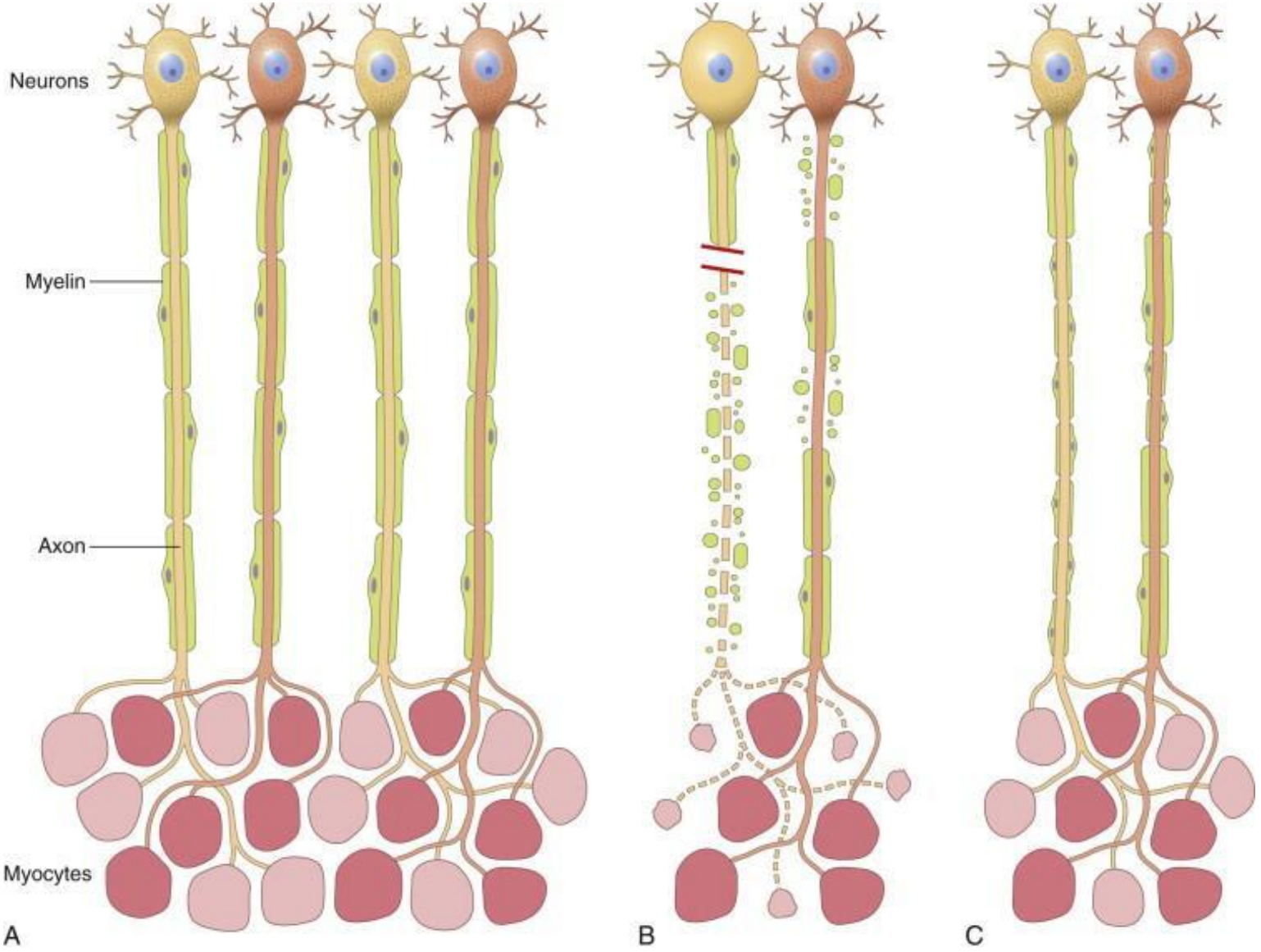
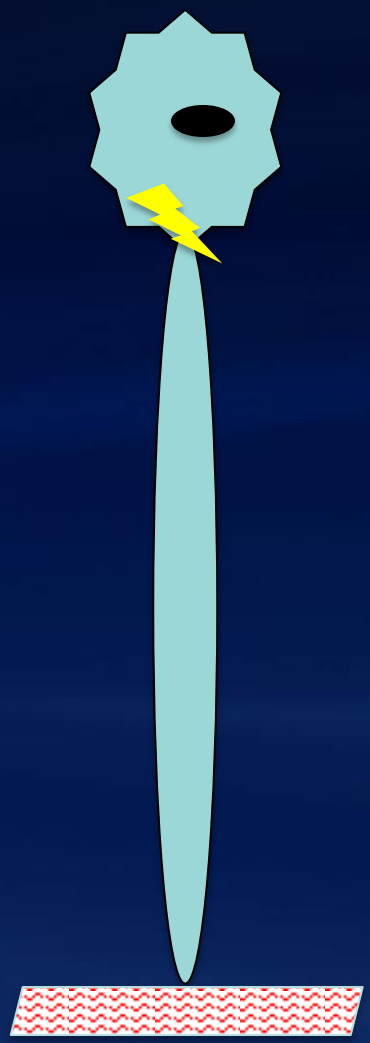
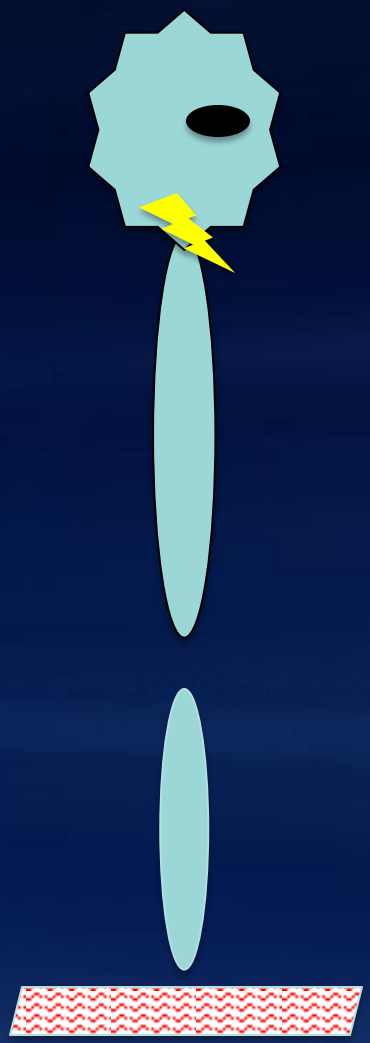
Axonal degeneration

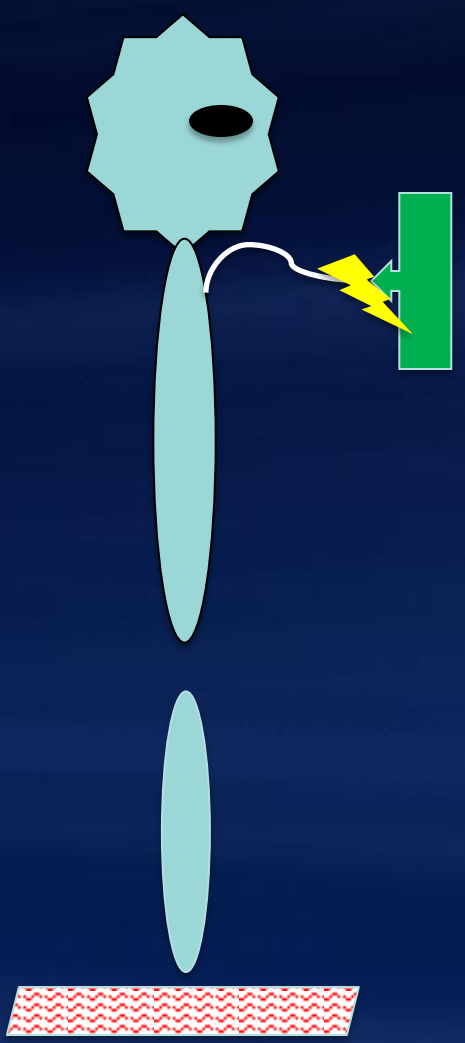




Normal Phrenic



Injured Phrenic



Paced Injured Phrenic

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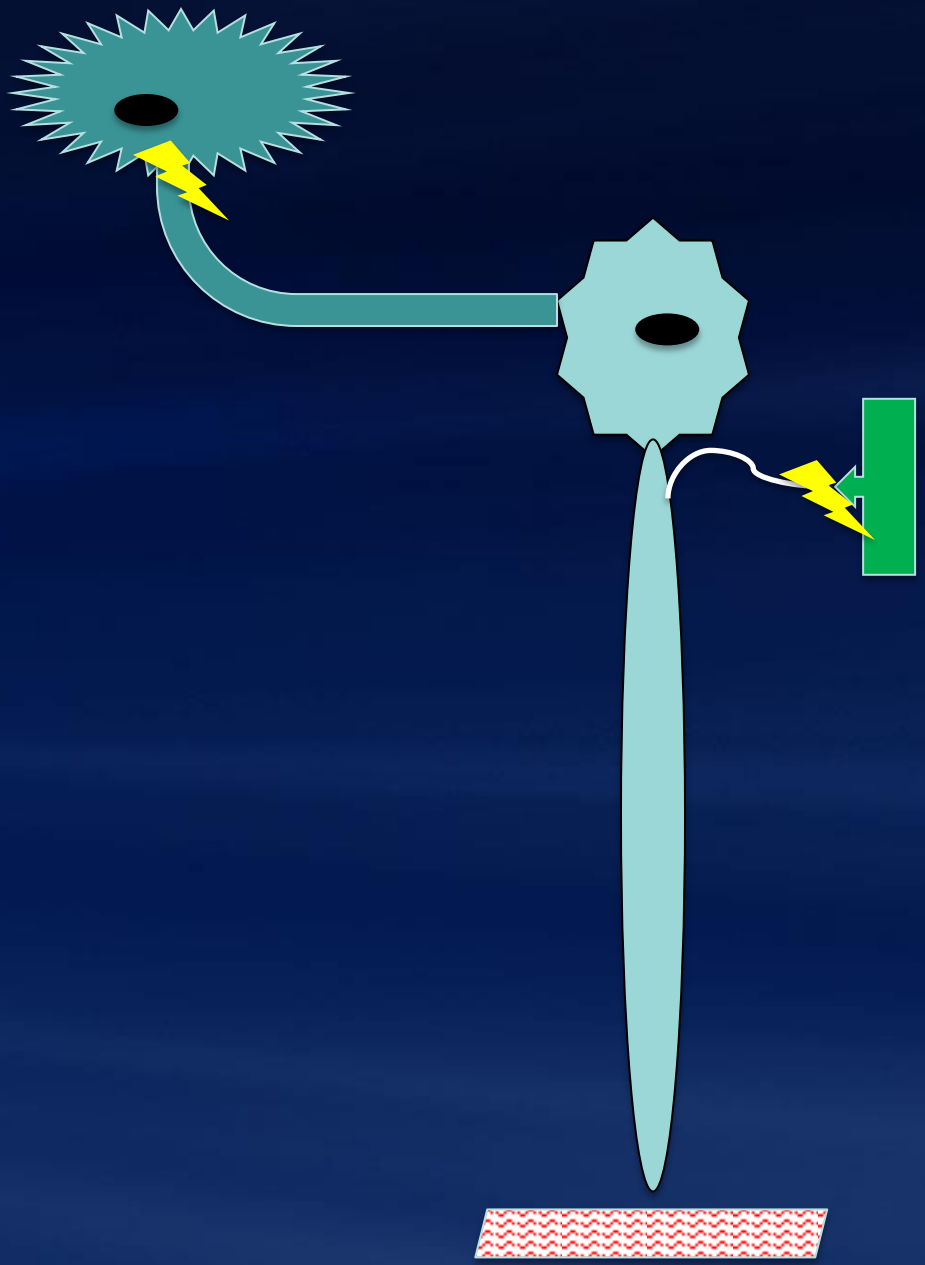

Normal Phrenic

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Pathology Amenable to Pacing

Amenable

- Upper motor neuron lesions
  - High cervical cord injury
- Respiratory center lesions
  - Central sleep apnea
  - Brainstem stroke
  - Pontine tumors
  - MS
- Muscle diseases?
  - Disuse atrophy
  - Pompe disease

Rarely amenable

- Phrenic nerve lesions
  - Brachial neuritis
  - Trauma
  - Head/Neck cancers
- LMN disorders
  - Charcot Marie Tooth
  - ALS
  - Spinal muscular atrophy

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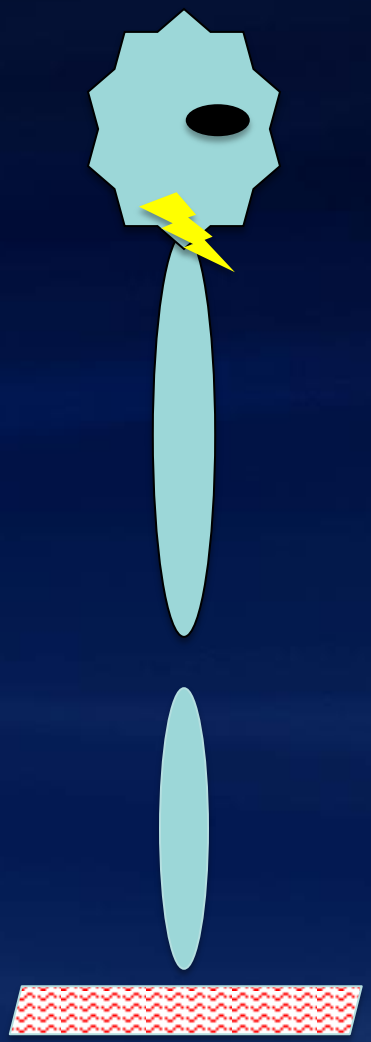
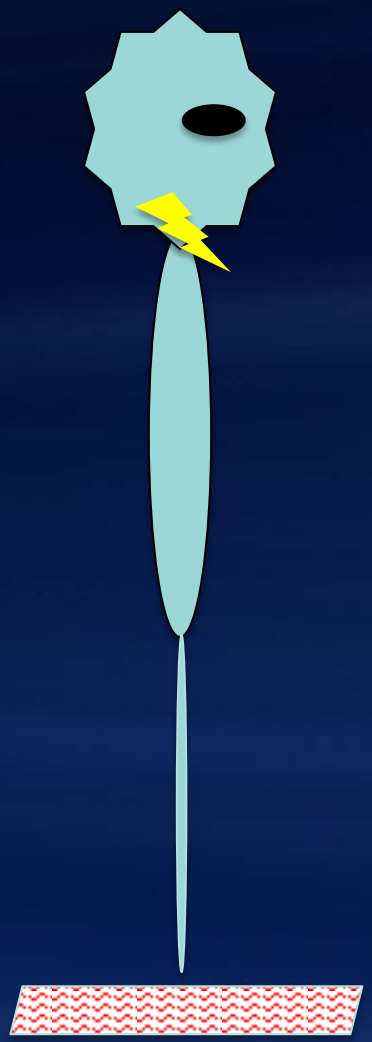


Vs.

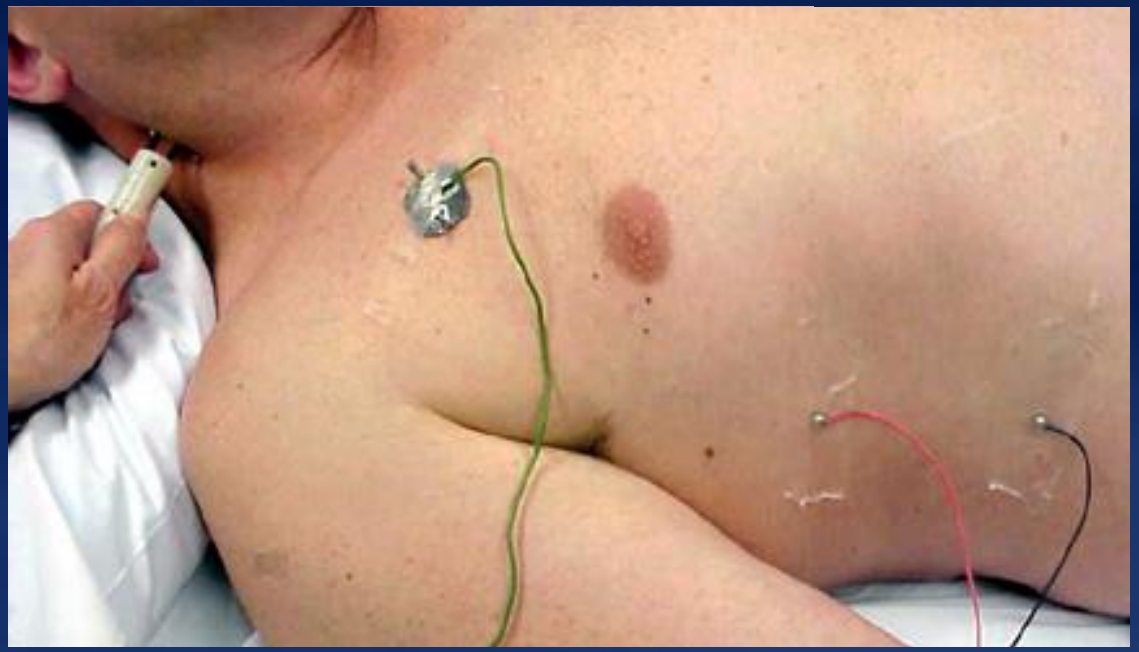


Injured Phrenic

Partially Reinnervated Phrenic

Phrenic Nerve Conduction Study

- Mimics pacing
  - Stimulate phrenic nerve at neck
  - Record diaphragm muscle response (CMAP)
  - Right and Left performed independently



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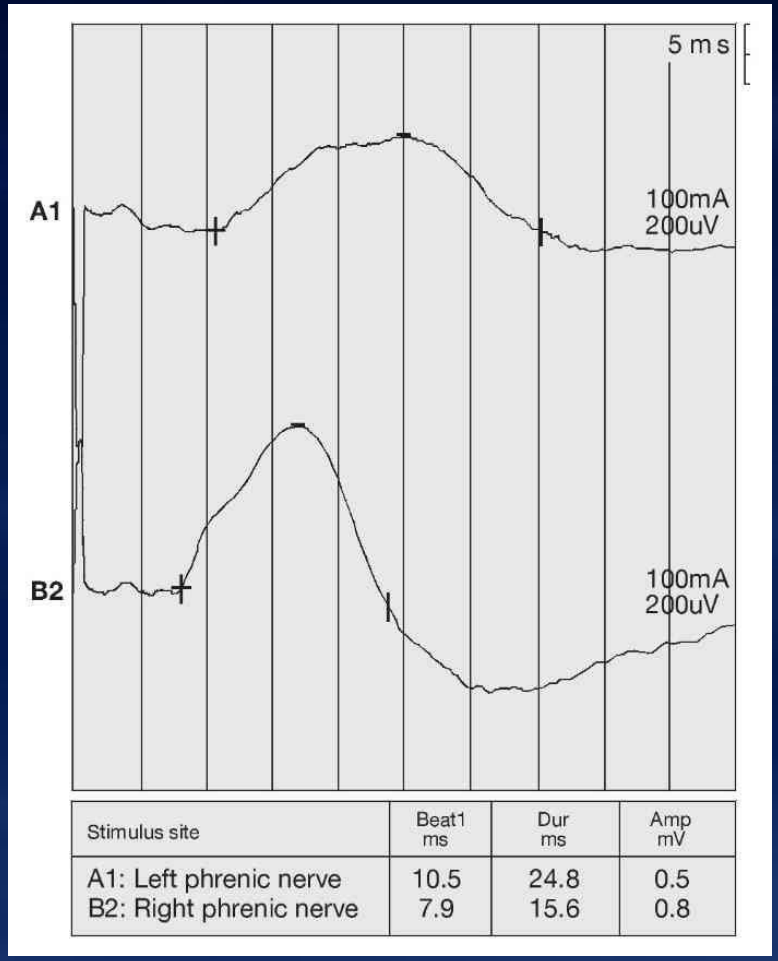
Phrenic Nerve Conduction Study



Stimulus site	Beat1 ms	Dur ms	Amp mV
A1: Left phrenic nerve	10.5	24.8	0.5
B2: Right phrenic nerve	7.9	15.6	0.8

Arch Bronconeumol 2010;46:390-2

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Phrenic Nerve Conduction Study

Pros

- Ex-vivo test of pacing
- Objective and measurable
- Easily compares sides

Cons

- Focuses on anterior diaphragm
- Not all neurologists comfortable
- Must time stimulation
- Body habitus
- Postitioning

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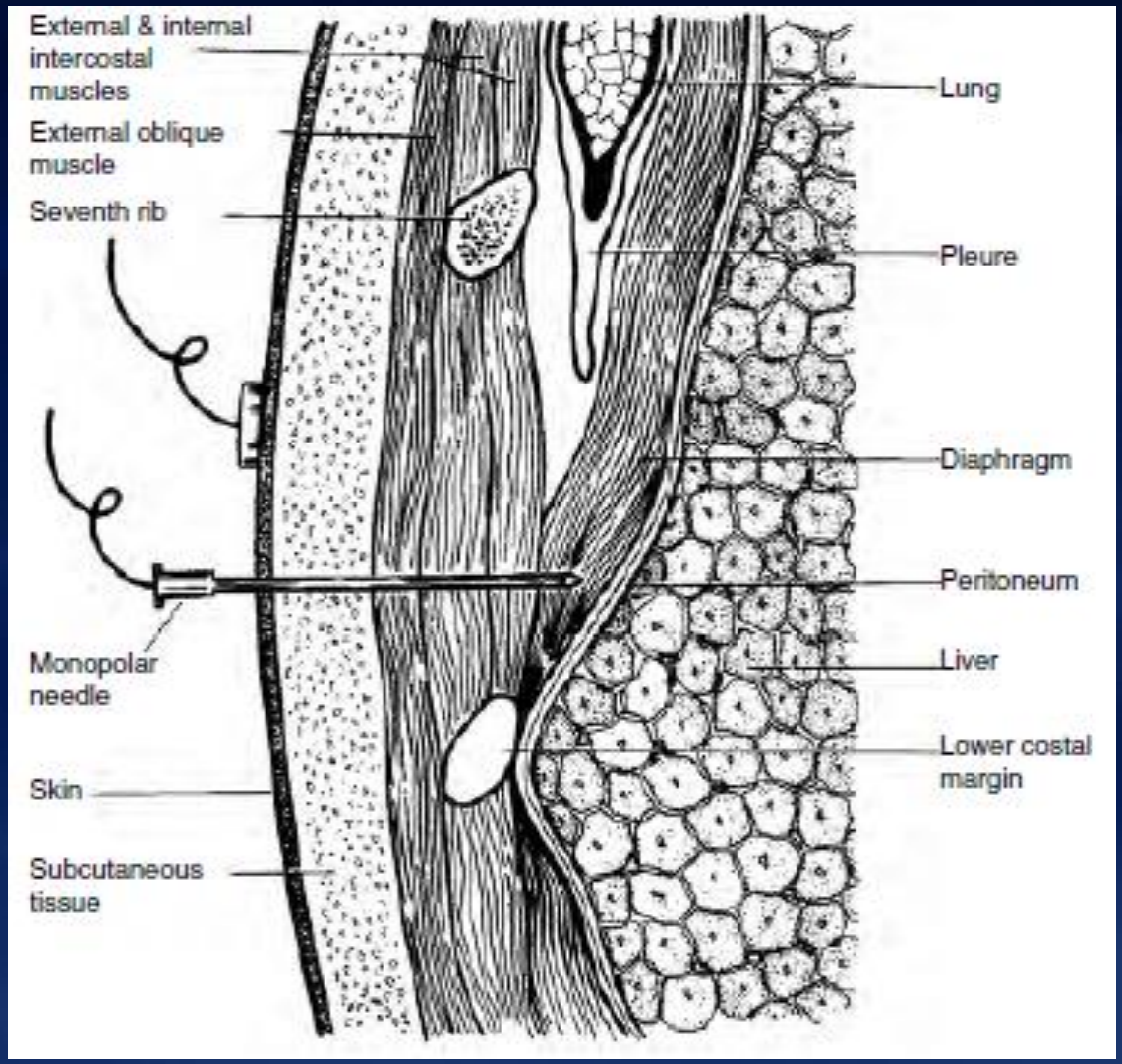
Needle Electromyography



Handbook of Clin Neurophys. J. Daube. Vol. 7.

Needle Electromyography

Pros

- Distinguishes muscle from nerve pathology
- Detects ongoing denervation versus reinnervation

Cons

- Painful
- Risk of pneumothorax
- Can only study one side
- Positioning


SNIFFING

Video Fluoroscopy

Pros

- Real-time assessment
- Readily available
- Easily compares sides

Cons

- Focuses on anterior diaphragm
- No localization information
- Must rely on radiologist
- Paradoxical movement
- Radiation

Ultrasound

- Emerging as a useful technique
  - Parameters still being developed
    - Thickness
    - Movements
- Can be combined with nerve conduction studies
  - Helpful when body habitus is a problem

Conclusions

- Etiology/pathophysiology of diaphragmatic paralysis critical to pacing decision
  - Diseases of lower motor neurons are generally resistant to pacing
  - Central nervous system diseases are most amenable
- Evaluation can be multimodal and utilize objective measures of diaphragm function
  - NCS, fluoroscopy, ultrasound