The Musculature

ODS 514
Anatomy and Physiology of the Masticatory System

Reading: Mohl, et al., Chapter 7

W.D. McCall, Jr., Ph.D.

Topics to be Covered

I. Properties of muscle
II. Muscles of mandibular function
III. Electromyography
IV. Some trigeminal reflexes
V. Selected dental controversies

I. Properties of Muscle

A. Common with limb muscle
   1. Length-tension curve
   2. Force-velocity curve
   3. Determinants of muscle force

B. Peculiar to jaw muscles
   1. Anatomy of origins and insertions
   2. Location of some sensory cell bodies
   3. Organization of some reflexes

The Length-Tension Experiment

1. Set muscle length
2. Stimulate nerve to muscle
3. Record force

Features:
1. Tetanic force > twitch force
2. Fast & slow fibers differ
3. Part of force is passive
The Force-Velocity Experiment

1. Set weight to lift
2. Stimulate muscle
3. Measure velocity

Load-clamp recordings at four different force levels during tetanus

Length
Force
Slope = Velocity = Length/Time

Biphasic force-velocity relationship

Features:
1. Delay from action potential to twitch
2. More force from a shower of action potentials

Determinants of Muscle Force

1. Length
2. Velocity
3. Delay from electrical to mechanical events
4. Number of motor units recruited
5. Frequency of stimulation
6. Anatomy of origin and insertion

Topics to be Covered

I. Properties of muscle
II. Muscles of mandibular function
III. Electromyography
IV. Some trigeminal reflexes
V. Selected dental controversies

II. Muscles of mandibular function

A. Jaw closing muscles
   1. Masseter
   2. Temporalis
   3. Medial pterygoid

B. Jaw opening muscles
   1. Anterior digastric
   2. Lateral pterygoid

Masseter

Origin: zygomatic process of the maxilla and inferior border of zygomatic arch
Insertion: angle of the mandible inferior, lateral side of ramus
Innervation: masseteric nerve
Function: elevate mandible
Temporalis

Origin: temporal fossa and temporal fascia
Insertion: coronoid process of the mandible
Innervation: temporal nerve
Function: elevate mandible

Medial Pterygoid

Origin: pterygoid fossa and medial surface of lateral pterygoid plate
Insertion: ramus and angle of the mandible
Innervation: medial pterygoid nerve
Function: elevate mandible
Lateral Pterygoid -- Inferior Head

Origin: lateral surface of lateral pterygoid plate

Insertion: anterior neck of the mandible

Innervation: branch of masseteric or buccal nerve

Function: pull condyle and disk along the eminence
Lateral Pterygoid -- Superior Head

Origin: infratemporal fossa of greater sphenoid wing

Insertion: anterior neck of the mandible

Innervation: branch of masseteric or buccal nerve

Function: pull condyle and disk along the eminence

Digastric

Origin: posterior digastric mastoid notch of temporal bone

Insertion: anterior digastric lingual, inferior border of the mandible

Innervation: Posterior digastric--facial nerve, Anterior digastric--mylohyoid, mandibular nerve

Function: lower mandible, raise hyoid
Topics to be Covered

I. Properties of muscle
II. Muscles of mandibular function
III. Electromyography
IV. Some trigeminal reflexes
V. Selected dental controversies

III. Electromyography

A. Mechanism
B. Electrodes
C. Electronics
D. Caveats
E. Strengths

A. MECHANISM: Muscle Action Potentials

Across membrane: 90 mV
Extracellular: about 90 µV
EMG signal is attenuated at the skin by about 1000

B. ELECTRODES

Caveats

A. Electrical activity must be calibrated to be directly related to muscle force.
B. Jaw muscles are redundant: six jaw closers, and they all are active in closing. (You cannot control the muscles independently. The forces on the jaw must satisfy Newton’s equations.)

Determinants of Muscle Force

Item | Seen in EMG?
--- | ---
A. Recruitment | Yes
B. Frequency | Yes
C. Length | No
D. Velocity | No
Strengths of Electromyography

A. Know precisely when muscle is active.
B. Know roughly how active.
C. Insight into activity of motor neuron.

Topics to be Covered

I. Properties of muscle
II. Muscles of mandibular function
III. Electromyography
IV. Some trigeminal reflexes
V. Selected dental controversies

IV. Some trigeminal reflexes

A. Jaw closing reflex
B. Jaw opening reflex
C. Blink reflex
D. Tongue reflex
E. Gagging
F. Swallowing
G. Modulating influences

THE BIG PICTURE

<table>
<thead>
<tr>
<th>FUNCTION</th>
<th>EXAMPLE</th>
<th>NEURAL CIRCUIT</th>
<th>LOCATION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postural</td>
<td>Jaw jerk</td>
<td>Reflex</td>
<td>Brainstem</td>
</tr>
<tr>
<td>Protection</td>
<td>Gagging, Jaw opening</td>
<td>Reflex</td>
<td>Brainstem</td>
</tr>
<tr>
<td>Rhythmic</td>
<td>Chewing, Breathing, Walking</td>
<td>Pattern generator</td>
<td>Brainstem</td>
</tr>
<tr>
<td>Complex</td>
<td>Speech</td>
<td></td>
<td>Cortex</td>
</tr>
<tr>
<td>function</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Types of Reflexes

1. Postural
2. Protective
3. Cardiovascular
4. Respiratory
5. Digestive
6. Humoral

The Jaw Jerk Reflex (Postural)

R.M. Bradley, Figure 10-12
The Jaw Opening Reflex (Protective)

V. Selected Controversies
A. Rest position: passive elasticity vs. active contraction
B. Mastication: alternating reflexes vs. central pattern generator
C. Electronic devices for TMD diagnosis
D. Myofascial pain and trigger points

A. Rest position hypotheses
1. Passive elasticity
2. Active contraction
   a. Stretch reflex
   b. TMJ receptors
   c. Airway patency

Rest Position: Evidence
Passive Elasticity
- Length-tension curve
- Negative EMG search

Active Contraction
- Sleep in chair
- MN inhibition in sleep
- Positive needle EMG
- Positive surface EMG

Surface EMG, µV
Vertical Jaw Opening, mm

B. Mastication hypotheses
A. Hypotheses
   1. Alternating reflexes (Sherrington, 1917)
   2. Central pattern generator (Lund, 1971)
B. Significance: part of the theme,
   “Be skeptical and be critical”
Outline

1. Dental significance
2. Data to be explained
3. Reflex theory for mastication
4. Central pattern generator

1. Dental Significance

A. Your system
B. Understand mechanisms
C. A plea for skepticism

2. Data to be explained

A. Muscle activity
   1. Closers and openers alternate
   2. Cycle duration about one second
B. Jaw motion
   1. Parts of cycle
   2. Closing, occlusal, & opening phases
   3. Variability

Data from one subject

Average: 1060 ms

Observations:
1. Three phases to jaw motion: closing, occlusion, opening
2. Occlusal phase substantial
3. Cycle time about one second
4. Activity of closers and openers alternate
Observations:
1. No IPSP in motor neurons of jaw opener muscle
2. Jaw opening reflex inhibited during closing
3. Both EPSP & IPSP in motor neurons of jaw closer muscle
4. Jaw closing reflex inhibited during opening

Reflex theory for mastication

A. Context
1. Sherrington
2. Reflexes
3. Paradigm

B. Experiment
1. Decerebrate
2. Observe reflexes

B. Experiment
1. Decerebrate
2. Observe reflexes
   a. Jaw closing reflex
   b. Jaw opening reflex
3. Interpretation: basis of chewing (1917)

C. Problems (not seen at the time)
1. Reflex loop times
   a. Jaw Closing ~15 ms
   b. Jaw Opening ~ 20 ms
   c. But cycle time ~ 1000 ms
2. Length of occlusal phase
   a. Expect short if reflex
   b. But, in fact, it is long
3. Effect of deafferentation
   a. Would abolish reflexes
   b. But efferent pattern continues
4. Reflexes inhibited
D. Reasons for continued belief (into ’70’s)
   1. Elegant simplicity of theory
   2. Faith in paradigm of reflexes
   3. Stature of Sherrington
E. Plea for your skepticism. Ask questions.
   1. What experiment would disprove theory?
   2. What alternative hypothesis would be plausible?

Central Pattern Generator

A. Approach: successive approximations
B. Reference:
   James P. Lund,
   Mastication and its control by the brain stem,

Central Pattern Generator: First Approximation

Central Pattern Generator: Overall Roles

Cortex

Rhythm generator: overall length and duration of cycle

Rhythm generator sets this interval.
Central Pattern Generator: Overall Roles

- Cortex
- Rhythm Generator
- Burst Generator
- Motor Nucleus
- Jaw Muscles

Burst generator: duration and pattern within the overall cycle

Central Pattern Generator: Overall Roles

- Cortex
- Rhythm Generator
- Burst Generator
- Motor Nucleus
- Jaw Muscles

Central Pattern Generator: Overall Roles

- Cortex
- Rhythm Generator
- Burst Generator
- Motor Nucleus
- Jaw Muscles

Central Pattern Generator: Overall Roles

- Cortex
- Rhythm Generator
- Burst Generator
- Motor Nucleus
- Jaw Muscles

Jaw muscles: convert the neural activity to force on the mandible

Central Pattern Generator: Overall Roles

- Cortex
- Rhythm Generator
- Burst Generator
- Motor Nucleus
- Jaw Muscles

Jaw muscles: convert the neural activity to force on the mandible

CPG: Second Approximation

- Cortex
- Rhythm Generator

Evidence for rhythm generator:
1. Correct anatomical projections from cortex.
2. Electrical stimulation of cortex leads to rhythmic activity.
3. That stimulation can be random or regular.
4. Lesions of pathway abolish rhythmic activity.
5. Rhythmic activity seen in paralyzed animal.

CPG: Second Approximation

- Cortex
- Rhythm Generator

Nucleus reticularis paragigantocellularis
Nucleus reticularis gigantocellularis

PGC
GCr
GCC
CPG: Second Approximation

- Cortex
- Rhythm Generator
- PGC (not rhythmic)
- GCr (rhythmic)
- GCc (rhythmic)
- Nucleus reticularis paragigantocellularis
- Nucleus reticularis gigantocellularis
- Contralateral side
- Burst Generator
- VII
- XII

CPG: Second Approximation

- Cortex
- Rhythm Generator
- Burst Generators
- Openers
- Closers

CPG: Second Approximation

- Cortex
- Rhythm Generator
- Burst Generators
- Motor Nucleus
- Openers
- Closers

CPG: Third Approximation

- Cortex
- Rhythm Generator
- PGC
- GCr
- GCc
- Trigeminal Ganglion
- Burst Generators
- Openers
- Closers

CPG: Third Approximation

- Cortex
- Rhythm Generator
- Burst Generator
- Motor Nucleus
- Openers
- Closers
- Mesencephalic Nucleus
- Muscle Spindles, Periodontal ligament receptors
Summary of central pattern generator

Parts and roles:
- Cortex -- turn on and keep on
- Rhythm Generator -- overall interval
- Burst Generator -- intervals within cycle
- Motor Nucleus -- drive individual muscles
- Muscles -- convert neural activity to force
- Sensory feedback -- adapt to changes

C. Electronic devices for TMD diagnosis

Hypotheses:
1. Resting EMG greater in TMD patients
   (No convincing evidence)
2. Jaw position differs in TMD patients
   (No convincing evidence)

Topics to be Covered

I. Properties of muscle
II. Muscles of mandibular function
III. Electromyography
IV. Some trigeminal reflexes
V. Selected dental controversies
   A. Rest position
   B. Mastication
   C. Electronics for TMD diagnosis
   D. Myofascial pain and trigger points

Myofascial Trigger Points

- First described by Travell (1942)
- Hyperirritable spots located in taut bands of skeletal muscle
- Range from 2 to 5 mm in diameter
- Two types
  - Active TrP - gives referred pain
  - Latent TrP - gives local pain

Controversies

1. Existence of trigger points (reliability)
2. Existence of electrical activity
3. Mechanism leading to electrical activity
4. Treatment

Three lines of evidence for existence

1. Reliability improved by training
2. Persistence of clinical observations
3. Epidemiology
Epidemiology of Trigger Points

- Fibromyalgia Patients: 84%
- Head and Neck Pain Patients: 55%
- Normal Subjects: 50%

Simons’ Hypothesis: Dysfunctional Neuromuscular Junction

Prediction #1: Action potentials

Prediction #2

EMG amplitude will depend on location and depth of the monopolar needle.

Electrical Activity from Trigger Points

A. FIRST REPORT (Weeks and Travell, 1957)

B. NEGATIVE REPORTS
   1. Kraft et al. (1968)
   2. Zidar et al. (1990)
   3. Durette et al. (1991)

C. POSITIVE REPORTS
   1. Hubbard and Berkoff (1993)
   2. McNulty et al. (1994)
   3. Hong and Simons (1998)
   4. Chen et al. (1998)

EMG and Needle Depth

- Needle depth: 22mm
- Needle depth: 37mm

Advancing needles

- Trigger point
- Control point
- Surface
Prediction #1
Action potentials. OK.

Prediction #2
EMG amplitude will depend on location and depth of the monopolar needle.

Prediction #3
EMG amplitude will remain stable over an extended recording time.

EMG and Recording Time

Stability of EMG amplitudes over recording periods

In summary...
A. Trigger points show electrical activity
B. Narrow range of depths
C. Reliable over time
D. Activity inhibited by shock to nerve (thus, activity depends on motor neurons)
E. Speculation: acetylcholine hypothesis needs revision
Summary

I. Properties of muscle
II. Muscles of mandibular function
III. Electromyography
IV. Two trigeminal reflexes
V. Selected dental controversies