Balance and Gait Disorders

- Nothing to Disclose
Balance and Gait Disorders

OUTLINE

- Balance Building - concept of Gait Level
- Videos of patients
Balance and Gait

- Walking is unique - each one of us has our unique finger (foot) prints
- Bipedalism is essentially a human endeavor
Evolution of Bipedalism

**Human evolution:**
- Split from chimpanzees 6 Mya
- Between about 3-6 Mya: combined humanlike (biped) and apelike (arboreal, etc)
- Around 4 Mya: mostly bipedal (Lucy)
- Since about 2 Mya: became fully bipedal
- Since 200,000: homo sapiens
  - Same skeleton as now
  - We all are ONE SPECIES
- Evolution ongoing!
Human Evolution

- http://humanorigins.si.edu/evidence/human-family-tree
Benefits of Bipedalism

- Makes it easier to pick fruits and other food from low-lying branches
- Frees hands for carrying food, tools, or babies
- Enables early humans to appear larger and more intimidating
- Helps early humans cover wide, open landscapes quickly and efficiently
Balance and Gait

- **Balance**: ability to stand up and remain upright against the force of gravity (equilibrium)
- **Gait**: generation of rhythmic stepping movements to advance in space (locomotion)
Balance and Gait

- Balance and gait abilities in man depend on a hierarchal system of muscles, nerves, and interconnected central nervous system structures that is amazingly similar to that seen all way “down” to the snail!

- Walking is not an aimless process and is essential for survival of animal and human

- For this reason, disorders of balance and gait have serious consequences to the inflicted
Balance and Gait

- Although arthritic and orthopedic illness can cause balance and gait problems
- Most balance/gait disorders are neurological
- Thus important to examine balance/gait, especially that they can be essentially the only thing that is abnormal on exam
- Examples:
  - midline cerebellar, early NPH, cautious gait of elderly, etc
Balance and Gait

- Balance/Gait pattern on exam may be the only differentiating finding between illnesses. Example:
  - Cervical stenosis and early normal pressure hydrocephalus

- Balance/gait disorders coexist and thus will be discussed together under rubric of balance and gait disorders, BGD
Balance and Gait Disorders, BGD

Epidemiology

- BGD prevalent especially in the elderly, making them among most common complaints in neurology
- Prevalence of BGD in the elderly older than 65 years is 14% and jumps up to about 50% in persons over age 85 years.
- Psychogenic BGD is seen in up to 40% of patients with psychogenic movement disorder (Baik & Lang 2007).
You can diagnose a neurological disorder by observing gait?
Anatomy of Balance and Gait System
A Skyscraper Analogy
Balance & Gait Building of 10 floors

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8
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<tr>
<th>Cortical</th>
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<td>Subcortical White Matter</td>
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<td>Muscle</td>
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Psychogenic is “over the top”
Balance Building

- Each component of the balance/gait system, i.e. each floor, gives a unique pattern of BGD that is identifiable and localizable. Thus the concept of **GAIT LEVEL** (akin to sensory level)

- BGD due to floors 1-8 are **stereotypical**
- BGD due to floor 9-10 (including psychogenic) **vary**
## Balance & Gait Building

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<td>Muscle</td>
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Floors 1-8 are stereotypical
Wide Base

- Cortical
- Subcortical White Matter
- Basal Ganglia
- Thalamus
- Cerebellum
- Brainstem
- Spinal Cord
- Peripheral Nerve
- Neuromuscular jn
- Muscle

<table>
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Wide means ataxic; also tend to be unsteady
Think drunk
# Turns

<table>
<thead>
<tr>
<th>Structure</th>
<th>Steps to Turns</th>
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<tbody>
<tr>
<td>Cortical Muscle</td>
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<tr>
<td>Subcortical White Matter</td>
<td>9 wide</td>
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<td>Basal Ganglia</td>
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<td>Thalamus</td>
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<tr>
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<tr>
<td>Peripheral Nerve</td>
<td>3 wide</td>
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<tr>
<td>Neuromuscular jn</td>
<td>2</td>
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<tr>
<td>Muscle</td>
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Balance and Gait Exam

- Can patient walk on own
- Wide (ataxia)
- Steady (unsteady: ataxia)
- Walk on toes/heel (motor)
- Romberg (sensory)
- Tandem (testing all)
- Tandem + eyes closed (in young)
- Turn > 5 steps (parkinsonism)
How does the Balance/Gait System Work?
BG System

Cerebral (Cortical/Subcortical)

Basal Ganglia

Thalamus

Cerebellum

Brainstem

VN

Spinal cord

CPG

Output

Locomotion

Sensory feedback
Physiology-Spinal Cord
Central Pattern Generator, CPG

Stimulate in animals
**Brainstem**

- **Locomotor Regions**
  - MLR, DLR & VLR, SLR, CLR
  - PPN

**Output Locomotion**

- Sensory feedback

**Key Structures**

- Cerebral (Cortical/Subcortical)
- Basal Ganglia
- Thalamus
- Cerebellum

**Pathways**

- Tectospinal
- Rubrospinal
- Corticospinal
- Reticulospinal
- Vestibulospinal

**Central Pattern Generator (CPG)**

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**Note:**

- The diagram illustrates the neural pathways involved in locomotion and sensory feedback. The CPG plays a key role in generating rhythmic movements.
Imaging human supraspinal locomotor centers in brainstem and cerebellum

Fig. 2  BOLD signal changes superimposed for standing, walking, and running (<italic>p</italic> <hsp sp="0.12"/> 0.05, FDR). Color-coding as shown in the right upper corner. The white frame indicates the area with...
Red Nucleus-Dentatorubrothalamic tract

Figure. MRI of patient showing hyperintense lesion (arrow) in area of left dorsomedial red nucleus (TR 2,222 msec; TE 80 msec).

Felice, 1990

Contrapulsion

Karimi & Fattal, 2004
Cerebellum

1- Coordination Role
compares external with internal signals

2- VOR

3- Modulates activity of descending tracts

cerebellectomy

Stance Swing
Floor 8
Basal Ganglia

- Parkinsonism
  - Tremor
  - Rigidity
  - Bradykinesia
  - Postural instability
Now we reach top floors 9, 10
Historical List of Names of Cerebral BGD

- Astasia-abasia (Blocq, 1888)
- (Bruns) Frontale ataxie-1892
- Trepidante abasie (Petrén, 1901)
- Marche à petits pas (Marie, 1902)
- Corticale Apraxie (Heilbronner, 1905)
- Innervatory apraxia (Kleist, 1907)
- Limb-kinetic apraxia (Westphal, 1907)
- Gait apraxia (Gerstmann & Schilder, 1926)
- Trunk apraxia (Sittig, 1929)
- Frontal disequilibrium (Van Bogaert & Martin, 1929)
- Arteriosclerotic parkinsonism (Critchley, 1929)
- Senile gait (Critchley, 1931, 1948; Koller, 1983, 1985)
- Magnetic, repellent, & trunk apraxia (Denny-Brown, 1958)
- Slipping clutch syndrome (Denny-Brown, 1958)
- Pure Akinesia (Imai and Narabayashi, 1974)
- Axial apraxia (Lakke, 1985)
- Akinetic parkinsonism (FitzGerald, 1989)
- Lower half parkinsonism (Thompson, 1987)
- Lower body parkinsonism (FitzGerald, 1989)
- Primary progressive freezing gait (Achiron, 1993)
- Gait ignition failure (Atchison, 1993)
- Subcortical disequilibrium (Nutt, 1993)
- Subcortical gait disorders (Nutt, 1993)
- Frontal gait disorders (Nutt, 1993)
- Nonspecific disequilibrium of the elderly (Fife, 1993)
- Higher level gait disorder (Tyrrell, 1994)
- Vascular parkinsonism (Zijlmans, 1995)
- Frontal lobe gait disorder (Thompson, 2001)
- Gait apraxia-term revisited (Della Sala, 2002)
- Ignition apraxia, disequilibrium apraxia or mixed (Liston, 2003)
- Vascular higher level GD (Martin and O'Neill 2004)
- Psychogenic disadaptation (Mourey et al 2004)
- Elderly with cautious gait of unknown origin (Giladi 05)
- Senile paraplegia (Thompson 07)
- Parkinsonian ataxia (Thompson 07)
- Mild parkinsonian signs concept (Louis & Bennett 07)
- Higher level Gait Disorder (Huber-Mahlin et al, 2010)
- Higher level Gait Disorder (Giladi 2013)
Location of Cortical (Frontal) Areas Associated with Balance & Gait

Premotor

1º Motor

Supplementary Motor Area

Grabowski, 2002
Cortical-Subcortical Connections

- Brainstem
- Cerebellum
- Thalamus
- Basal Ganglia
- Frontal
- Limbic/Paralimbic
- Parietal
- CPG
- Sensory feedback
- Output
- Locomotion
White Matter and Gait

- In a study of 701 elderly pts, gait speed (measured 4m walk) was followed over mean of 4.7 yrs
- White matter volume is associated with slowing gait speed over time

Willey. J of Neurology, Nov 2012
Location of Subcortical White Matter Signal Associated with BGD

Red areas: statistically significant difference in signal abnormality between good & bad gait score
1- **Frontal** (80-90% sensitive) & **Parietal** (Bi-100% specific)
2- **Contiguous** with ventricles
3- **Symmetrical**

Benson, 2002
Location of White Matter Signal

Same amount of white matter signal
- Top bad gait (contiguous & symmetrical)
- Bottom: good gait

Top: bad gait - more signal
Abnormal Tractography in elderly with cautious gait and abnormal postural reflex vs elderly controls
Causes of Cerebral BGD

- **Medications/Inactivity**
  - Example post inner ear infection
- Vascular (white matter): Vascular Parkinsonism
- Cautious gait
- Other Parkinsonism
- Hydrocephalus: NPH
  - Over diagnosed
- Frontal lesions (stroke/tumor)
Causes of Subjective Sense of Imbalance with Normal Exam

- Delayed recovery from (undiagnosed) “labyrinthitis”
- Inactivity/polypharmacy
- Cautious gait
- Early parkinsonism
- Stroke: mid pons, posterolateral thalamus
- Orthostatic tremor
- Migraine related (very rare)
<table>
<thead>
<tr>
<th>floor</th>
<th>name</th>
<th>rhythm</th>
<th>Base width</th>
<th>Step height</th>
<th>Steps to turn*</th>
<th>Arm swing</th>
<th>Romberg</th>
<th>Tandem</th>
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<tbody>
<tr>
<td>9-10 c/sc</td>
<td>Variable can be only cautious</td>
<td>+/- Non-rhythmic WIDE +/- reduced +/- Multiple</td>
<td>Reduced +/- asymmetric</td>
<td>+/- abnl</td>
<td></td>
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<tr>
<td>8 BG</td>
<td>Parkinsonism</td>
<td>Festination (only on this floor!)</td>
<td>reduced Multiple ≥ 5 even &gt;10</td>
<td>Reduced +/- asymmetric Early is nl</td>
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<tr>
<td>7 thalm</td>
<td>Ataxia Astasia</td>
<td>Bit wide</td>
<td></td>
<td></td>
<td></td>
<td>+/- positive¶ Min abnl</td>
<td></td>
<td></td>
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<tr>
<td>6 cbl lm</td>
<td>Ataxia</td>
<td>Non-rhythmic WIDE</td>
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<td>abnl</td>
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<tr>
<td>5 BS</td>
<td>Mild ataxia</td>
<td>Bit wide</td>
<td></td>
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<td>+/- positive¶ Min abnl</td>
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<tr>
<td>4 cord</td>
<td>Spastic</td>
<td>Bit wide</td>
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<td>+/- min abnl</td>
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<td>3 vestib</td>
<td>cautious</td>
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<td>Positive¶ Min abnl</td>
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<td>3 nerve</td>
<td>Sensory ataxia</td>
<td>Non-rhythmic WIDE</td>
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<td>Positive abnl</td>
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<td>1-2 m/n-m</td>
<td>waddling</td>
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Empty boxes mean normal except steps to turn: can be normal at 1-2 or minimally abnl at 3-4 in BGD floors 1-7. ¶ Lateropulsion
VIDEOS
Thank you