Balance & Gait Disorders
Balance Building

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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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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
 Floors1-8 are stereotypical
## Wide Base

**Cortical**

**Subcortical White Matter**

**Basal Ganglia**

**Thalamus**

**Cerebellum**

**Brainstem**

**Spinal Cord**

**Peripheral Nerve**

**Neuromuscular jn**

**Muscle**

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Wide means ataxic; also tend to be unsteady

Think drunk
# Turns

<table>
<thead>
<tr>
<th>Area</th>
<th>Steps to Turns</th>
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<tr>
<td>Cortical</td>
<td>10 wide</td>
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<td>Subcortical White Matter</td>
<td>9 wide</td>
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<td>Basal Ganglia</td>
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<td>Peripheral Nerve</td>
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<td>Neuromuscular jn</td>
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<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

Spinal cord

CPG

Sensory feedback

Output Locomotion
Physiology-Spinal Cord
Central Pattern Generator, CPG

Stimulate in animals
Brainstem

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

PPN

- Tectospinal
- Rubrospinal
- Corticospinal
- Reticulospinal
- Vestibulospinal

Cerebral (Cortical/Subcortical)

Basal Ganglia

Thalamus

Cerebellum

CPG

Sensory feedback

Output Locomotion
Imaging human supraspinal locomotor centers in brainstem and cerebellum

Fig. 2  BOLD signal changes superimposed for standing, walking, and running (<i>p</i> < 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

3- Modulates activity of descending tracts

Stance  Swing
cerebellectomy

Motor cortex

GP  VL  Thalamus
SubT

Red  SC  VN  RF

2-VOR

CS,RbS,TS,RS,VS

CPG

DSCT  SOCP  VSCT  SRCP
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 (Petren, 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
Balance/Gait Building

Cerebral Cortex (frontal limbic) → DA

Glu

Striatum → GABA

Thalamus

Cerebellum → GABA

Brainstem → *

MLR (PPN) → Ach, Glu

Pontomedullary Reticular Formation → Ach, Glu

Optic nerve → Tectum

Subthalamic nucleus → GABA

GABA

DA

GABA

GABA

5-HT, NA, DA

CPG

Peripheral Nerve → Muscle

(spinal feedback)
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
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

Kafri (Giladi). J Neuroimag 2013
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)
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<th>floor</th>
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<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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<td>+/- Multiple</td>
<td>Reduced +/- asymmetric</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