DYNAMIC CORE STABILITY IN CHILDREN WITH CEREBRAL PALSY

Shelley Mannell PT, Julie Wiebe PT

Conflict of Interest Statement

Both Shelley Mannell PT and Julie Wiebe PT provide continuing education courses, live and online, for various academic institutions, organizations, clinics and conferences.

Objectives:

Upon completion of this course, you will be able to:
1. Explain how the core functions in typical development and the development of children with CP, based on the current literature.
2. Identify the important role of alignment for activation of the inner core.
3. Identify the connection between breathing pattern, inner core muscle activation, and outer core muscle activation.
4. Demonstrate a basic understanding of the principles underlying an alternative clinical model for core stability used in children with CP.

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Tug O’ War

Integration: TAP

Stability that is responsive to the demands of function (non-uniform response)

- Teamwork
- Alignment
- Preparation

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Gears in the Core Machine

Teamwork

The Core Machine
- Machine is optimized when all gears work together.
- Gears must move or the machine will fail
- Coordinated interaction will produce central stability

Teamwork

Pastoral and Respiratory Functions of the PFM
Hodges, Sapsford, Pengel (2007)
- PFM followed respiratory cycle (ant, not post)
- PFM expiratory activity more associated with abs (low-level tonic activity w/bursts at mov’t frequency)
- PISTON

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Changes in IAP during Postural and Respiratory Activation of the Human Diaphragm
Hodges et al (2000):

- Balanced interplay between the diaphragm, pelvic floor and abdominals preserves relative IAP throughout the respiratory cycle.
- A dynamic and coordinated model of core function
- 5th member of our team
- Intersection of multiple systems
- Breath gives us a new gateway
Teamwork

- The Piston, driven by the action of the diaphragm, is a dynamic model for core function.
- Accessing the deep core system through breath provides a gateway for our pediatric clients.

Integration: TAP

Stability that is responsive to the demands of function (non-uniform response)

- Teamwork
- Alignment
- Preparation

Alignment

The Core Machine

Machine works best if all the gears line up
Alignment

- Muscles are strongest at the midpoint of available ROM
- Muscles are weakest when long or short
- Neutral Pelvis and Ribcage alignment (ribcage over pelvis) puts the Core in midrange positioning.

Different Ways to Balance the Spine
Claus et al (2009):
- Flat, Long Lordosis, Short Lordosis, Slump
- Short Lordosis best activity for TA and Multifidus
- Flat-Least***

Alignment: Claus et al

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Alignment: Claus et al

Different Ways to Balance the Spine
Claus et al (2009):
- Flat, Long Lordosis, Short Lordosis, Slump
- Short Lordosis best activity for TA and Multifidus
- Flat-Least***

Alignment

Sitting Postures Affects PFM Activity in Parous Women
- Slump, Upright Unsupported, and Very Tall Unsupported (thoracic)
- Increased resting activation of PFM as alignment improved

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Alignment: Sapsford et al

Sitting Postures Affects PFM Activity in Parous Women

- Slump, Upright Unsupported, and Very Tall Unsupported (thoracic)
- Increased resting activation of PFM as alignment improved

Alignment

Neutral Rib Cage and Pelvis

- Position of optimum Core recruitment (range)
- Move toward neutral
- "Sweet Spot" : optimized for your patient
Integration: TAP

Stability that is responsive to the demands of function (non-uniform response)

- Teamwork
- Alignment
- Preparation

Preparation

Neuromuscular Strategy:
Preprogrammed motor control system, engaged through nervous system. The sensory system feeds information to create a graded response.

**Anticipatory + Reactive = Fxn**
Prepares for task + engaged based on demands of task = Function/movement

Preparation

**Transverse Abdominis is not Influenced by the Direction of Arm Movement**
Hodges et al (1997)

- TA EMG increased prior to deltoid regardless of UE direction
- EMG of superficial abdominals varied with movement direction
Preparation

Contraction of the Human Diaphragm During Rapid Postural Adjustments

Hodges et al (1997):
- Same result for the Diaphragm
- Anticipatory contraction occurred regardless of phase of respiration
- Same result for elbow motions, not hand or digits

Hodges et al (2007)
- Same result for the pelvic floor
- Pelvic floor preceded the abdominals

Sjødal et al (2009)
- PF precedes supine LE movement

Leginboeuf et al (2013)
- PF precedes heel strike in running

Integration

Build a clinical model that:
- Teamwork: All gears moving
- Alignment: Optimized
- Preparation: Strategy

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Core Redefined

Core Strategy: Defined

Core Strategy is a system that harnesses the neuromuscular relationship that exists between the Anticipatory Core, Reactive Core, IAP Stability Cycle, Sensory System and the Brain. A cascade of force from the inside-out that provides both the stability and flexibility required to respond to the task at hand. #balance

Questions?
Pediatric Core Research

In contrast to the adult literature, very little pediatric research has specifically investigated the inner core musculature.

Pediatric Research

What do we know about postural control in children with CP?

Pediatric Research

Altered Trunk Movements During Gait in Children with Diplegia: Compensatory or Underlying Trunk Control Deficit?

Heyrman L et al. 2014

- Looked at correlation between trunk movement and LE movement
- Provided support for a primary trunk control deficit NOT just as a result of LE impairment
Pediatric Core Research

Differences in Respiratory and Pulmonary Function Among Children with Spastic Diplegia and Hemiplegia Cerebral Palsy in Comparison with Normal Controls. Kwon YH, Lee HY 2015

- Children with spastic diplegic and hemiplegia generate decreased respiratory pressure

Pediatric Research

Development of Postural Responses During Standing in Healthy Children and Children with Spastic Diplegia Woolacott et al. 1998

- Group of typical children standing in alignment of child with spastic diplegia, showed similar disordered recruitment pattern during postural adjustments

Pediatric Core Research

Anticipatory and Compensatory Postural Adjustments in Sitting in Children with Cerebral Palsy Bigongiari et al 2011

- Tested in sitting
- Main postural control strategy is compensatory
- Increased levels of co-activation in outer core muscles (& others)

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Pediatric Core Research

**Anticipatory Postural Adjustments in Children with Hemiplegia and Diplegia**

Girolami G et al 2011

- Tested in standing
- Higher levels of co-activation reported in outer core muscles (& others)

Pediatric Research

**Effect of Seat Surface Inclination on Postural Stability and Forward Reaching Efficiency in Children with Spastic CP**

Cherng et al. 2009

- Studied effects of seat angle on postural stability and forward reach
- Forward incline (anterior inclination) more beneficial for both stability and reach for typical children and those with CP

Pediatric Research

**Seat Surface Inclination May Affect Postural Stability During Bocci Ball Throwing in Children with CP**

Tsai et al 2014

- GMFCS levels I, II and III
- Anterior inclination associated with better postural stability and improved amplitude of elbow movement

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15-11-30

Pediatric Research

Effects of Seat Surface Inclination on Respiration and Speech Production in Children with Spastic Cerebral Palsy
Shin et al 2015
- FVC was significantly improved with anterior inclination

The Role of Core Function in Typical Development

Typical Development

Examining details of typical development allows us to infer more about the development of the Core musculature

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Typical Development

- At birth, there is relatively low tone in the Core musculature
  
  (Hulme J, 2005)

Implications for Core Activity

- Resting tone of Core gradually increases during the first 2 – 3 years
  
  (Hulme J, 2005)

Implications for Core Activity

- This occurs as motor tracts form increased number and strength of connections with neurons in spinal cord during early movement

Typical Development: Newborn

Physiological Flexion
- High, triangular-shaped rib cage
- Ribs close together

Implications for Anticipatory Core Activity
- Alignment of rib cage allows for inferior excursion of diaphragm only
- Little activity of the PF or TA

Typical Development: Newborn Milestones

Motor Function:
- Belly breathing
- Feeding
- Sleeping
- Uncontrolled elimination

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### Typical Development: 0-3 Months

<table>
<thead>
<tr>
<th>Asymmetry</th>
</tr>
</thead>
<tbody>
<tr>
<td>Expansion of anterior chest with activity of UEs in supine and prone</td>
</tr>
<tr>
<td>Decreased hip flexion with LE activity</td>
</tr>
</tbody>
</table>

### Implications for Anticipatory Core Activity

- Some increased excursion of diaphragm contributes to increased activity in PF
- Increased excursion of diaphragm, activity of PF and LEs contributes to activation of TA; the team is developing

### Implications for Reactive Core Activity

- Pushing against surface in prone begins to activate reactive core *Posterior oblique synergist* (POS = contralateral latissimus dorsi and glute max)
  (Lee D, 1999)
### Implications for Reactive Core Activity

- Activation of reactive core
- *Anterior oblique synergist (AOS)*
  
  - abdominal oblique and contralateral adductor) follows
  
  (Lee D, 1999)
- Creates balance of extension and flexion activity

### Typical Development: 0-3 Milestones

**Motor Function:**
- Prone: head lifting
- Supported sitting: head bobbling
- Begins to swipe at objects
- Voiced sounds with movement

### Typical Development: 4-6 Months

**Symmetry**
- With increased muscle activation and independent movement, general increase in space between ribs occurs

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Implications for Anticipatory Core Activity

- Increased space between ribs supports change in rib cage shape allowing:
  - Deeper excursion of diaphragm
  - Improved activity of intercostals
  - Increased activity of PF and TA

Implications for Anticipatory Core Activity

- Increased rotation activity around hip joints contributes to activation of PF

Implications for Reactive Core Activity

- As hip flexion decreases, the POS becomes increasingly active, gains strength within the available range and contributes to anti-gravity function

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Typical Development: 4-6 Milestones

**Motor Function:**
- Supine: bridges, rolling
- Prone: propping on extended arms, superman, rolling
- Sitting with hands propped
- Beginning to reach forward (humeral flexion)
- Transfers hand to hand
- Deeper breaths, longer sounds

Typical Development: 7-9 Months

**Rotation**
- Shape of rib cage is elongating, changing alignment of shoulder girdle
- Transitional movement creates functional linkage between the shoulder girdle and pelvic girdle

Implications for Anticipatory Core Activity

- Increased hip ROM and capacity to maintain midline hip rotation ramps up activation of PF
- Increased differentiation of control of diaphragm for postural stability, air flow and sound for speech
  (Alexander R, 1991)
Implications for Reactive Core Activity

- POS contributes hip extension for active base of support (anti-gravity extension)
- AOS contributes to increased active rotation (protective reactions and transitional movement)

Crawling and ½ kneeling positions reflect activity in reactive core Lateral Synergist (LS = Contralateral Glute Med/Min and Adductors) Lee D, 1999
- and Rotational Synergist (Ipsilateral Hip Lateral Rotators and Adductors) Wiebe J 2013

Typical Development: 7-9 Milestones

Motor Function:
- Pushing up into sitting, creeping/crawling, kneeling, pulling to stand, cruising
- UEs for play, maturing grasp pattern
- Produces sound independent of movement
Typical Development: 10-12 Months

Gross Motor Independence
- Rib cage becoming more rectangular in shape
- Movement begins in all planes against gravity

Implications for Anticipatory Core Activity
- Trunk movement in all planes increases activation of diaphragm
- Increased demand on mid-range hip control in standing contributes to activation of PF

Implications for Anticipatory Core Activity
- Diaphragm, pelvic floor and TA partnership provides increased stabilization of lumbar spine and pelvis allowing initiation of movement from pelvis rather than upper trunk

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### Implications for Reactive Core Activity

- Increased activity in all postural synergists in tandem with anticipatory core team

### Typical Development: 10-12 Milestones

**Motor Function:**
- Climbing stairs, taking first steps
- Manipulates and combine fine motor in play, dressing and feeding
- Increased air intake, decreased respiratory rate
- Abdominal-thoracic breathing pattern begins

### Typical Development: 12-24 Months

**I Can Do It Myself**
- Effective Core muscle activation now in place for maintenance of stable trunk with simultaneous movement of the body in all planes

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Typical Development: 12-24 Milestones

Motor Function:
- continued refinement in all areas of development

Effective Core Strategy

Core Strategy:
- stable head mobile trunk stable pelvis
- dynamic postural control within function

Q and A
What Happens to Core Function When Development is Atypical?

Atypical Development

Motor development can be impacted by difficulties in either the motor or the sensory systems.

- Ultimately, lack of physiological flexion at birth fundamentally impacts alignment.
- This negatively impacts the development of Core Strategy.
Atypical Development

Movement patterns develop to compensate for this inefficient postural control:
✓ Breath holding
✓ Head/neck extension
✓ Stabilization by using end ranges

Atypical Development: Breath holding

Task:
Stabilize body against gravity

Compensation:
Breath holding

Implications for Anticipatory Core Activity

- Rib cage remains high and compact
- Decreased activation of respiratory diaphragm
### Atypical Development: Breath holding

#### Functional Consequences:
- Poor midline head control
- Dislikes prone, unable to push off surface with UE s
- Compromised movement – moving for as long as breath holding
- Decreased sounds
- Monocular fixation retained

### Atypical Development: Neck Hyperextension

#### Task:
Stabilize head to provide stable base for eyes

#### Compensation:
Neck hyperextension possibly combined with active tongue retraction

### Implications for Anticipatory Core Activity

- Rib cage remains high and compact secondary to shoulder elevation
- Decreased activation of respiratory diaphragm
### Atypical Development: Neck Hyperextension

**Functional Consequences:**
- Poor midline head control
- Dislikes prone
- Decreased ability to pair UE function or movement with vision
- Belly breathing
- Voiced sounds with movement
- Monocular fixation retained

### Atypical Development: Dynamic Holding

**Task:**
Stabilizing the trunk against gravity

**Compensation:**
Active holding with rectus abdominus, iliopsoas and diaphragm

### Implications for Anticipatory Core Activity

- Muscles used isometrically for stabilizing during movement and against gravity
- Substituting phasic muscle activity for postural muscle activity
- Anticipatory core offline

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Atypical Development: Dynamic Holding

Functional Consequences:
- Supine preferred
- Sitting with posterior pelvic tilt
- Humerus remains internally rotated w/elbow, wrist and hand flexed
- Breath holding with movement
- Difficulty with development of binocular vision

Muscle Tone

Neurological (spasticity or hypotonia)  Mechanical (stiffness)  Dynamic Holding

• Changing alignment and muscle activation alters dynamic holding
• Can improve postural control

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An Evidence-Based Pediatric Model for Dynamic Core Stability

Pop Quiz

Name that alignment?

K Pre-Botox

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K 8 Weeks Post-Botox

Alignment: Function follows Form

Ribcage position dictates:
- Excursion and contribution of the diaphragm to physiologic priorities, postural control and movement support
- Impacts the capacity of the diaphragm to set up the IAP pressure system

Alignment

- Posterior Thoracic Cage Translation
  - Decrease lumbar lordosis (7.4)
  - S-curve L-S (T-12-L2 flex) *apex*
  - Increase pelvic posterior tilt (15.9)
  - Sacral base posterior tilt (13.1), closer to horizontal

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Posterior Ribcage Translation

Position of the ribcage relative to the pelvis

Part 1: Military

Posterior Ribcage Translation

Position of the ribcage relative to the pelvis

Part 2: Slouch

Rib Cage Tip

Lower Ribcage: Anterior/Superior (Top of the RibCage behind pelvis)

Lower Ribcage: Post/Inf (Bottom of the Ribcage behind pelvis)

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Dixie Cup on a Stick

Lower Ribcage: Anterior/Superior

Named by lower rib cage

Dixie Cup on a Stick

Lower Ribcage: Posterior/Inferior

Named by lower rib cage

Let's play

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Seated Lab

Make your rib cage tip Ant/Sup

Named by lower ribcage

Seated Lab

Make your rib cage tip Post/Inf

Named by lower ribcage

Defining Neutral Alignment

Neutral Ribcage/Pelvis
- Position of optimum recruitment of the Diaphragm/Pelvic Floor Piston
- Balance of flexors and extensors
- “Sweet Spot” within neutral range, balancing their structure, muscular forces, and pressure

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Breathing and Rib Cage Position

Diaphragm: Dysfunction

Breath Holding:
- Valsalva: large loads
- Substitution for the Core in postural control, movement strategies, transitions and prepping for small exertions
- Repeated high intra-thoracic (ITP) and IAP can contribute to incontinence and constipation

Chest and Belly Breathers:
- Lateral component dysfunction (lower 6 ribs)
- Keeps ribs high and flared or fixed
- Core disconnected/IAP potential is reduced
- Both use breath holding as a stability strategy
Diaphragm: Intervention

Umbrella Inhale

Close the Umbrella Around the Handle

Umbrella Breathing

Shelley’s Cues for Umbrella Breathing

- Alignment is the key!
- Teach using an actual umbrella
- Use visual of diaphragm action

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Shelley’s Cues for Umbrella Breathing

- Place your hands around ribs 8-10 and provide gentle resistance throughout breath:
  - “Breathe into my hands”
  - “Make my hands move out”
- Use Theraband around ribs 8-10 and provide resistance (home program)
- Emphasize gentle breath in
- Breathe out “through a straw”; some children may need a straw to work with
- Some children may have increased difficulty with lip pursing (orbicularis oris = flexion activity)

Alignment is the key!
Standing Lab

Let's Play

Pelvic Floor

Anatomy 101: Action
- Anticipatory contraction to stabilize lumbo-sacral, SI, pelvic-hip, and PS joints
- Force couple with multifidus to control the sacrum
- Synergist with TA (1° Anterior)
- Ebbs and flows with the Diaphragm (1-7 mm)
- Supports pelvic viscera
- Pelvic floor (slow twitch) and urogenital diaphragm (fast twitch)
- S2,3 nerve roots for PF and foot intrinsics


Pelvic Floor: Function

Function:
- Needs to be integrated into Core recruitment, and functional patterns
- Anticipatory, balanced contraction between:
  - anterior/posterior
  - Right (R)/Left (L)
- Spine length remains the same:
  - No pelvic movement
- Concentric/Eccentric
- Creating a motor program, strategy, and resting tone


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Pelvic Floor: Dysfunction

Dysfunction:
- Bum gripping
- No link to the rest of Core
  - No TA
  - Breath holding
- Movement
  - Hollowing
  - Pelvic rocking
  - Ribcage elevation/depression
  - Teeth gritting


Pelvic Floor: Tricks

Tricks:
- Ski Jump
- Pursed lips/open mouth
- Turn feet in/out
- Lift your arches

Pelvic Floor and Kids

Primarily look at PF in function - pelvic stability in:
- Crawling
- Standing
- Moving from bilateral to unilateral stance
- Unilateral stance

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Palpation

- Generally don’t palpate for motor function – observation!
- Dealing with continence, always palpate

Permission

- Ask permission of child and/or adult
- Explain why
- “I need to put my hand here (demonstrate on yourself) to feel what your PF is doing. Is that OK with you?”
- Document, have another person present, use TA

Pelvic Floor Cues

- Alignment is key!
- Gently “stop a toot”

Break sequence down:
- Practice PF
- Inhale, extend the exhale
- Blow before you go
- Then practice movement
- “Beans” for teens

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Client Scenario: CP Hemiplegia

- MD born at 25 weeks, 971 grams
- Dx R hemiplegia CP

At 12 years old:
- Decreased range and strength
- Difficulties with visual scanning, attention
- Altered sitting and standing posture
- Altered gait pattern

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Client Scenario: CP Hemiplegia

Functional limitations:
- Sit to stand transition with UE support
- Decreased sitting tolerance
- Decreased standing balance

Client Scenario: CP Hemiplegia

Anticipatory Core Deficit:
- Breath holding for transitional movement or challenging tasks
- Indicated poor diaphragm function

Client Scenario: CP Hemiplegia

Anticipatory Core Deficit:
- Inability to hold midrange posture in any position, stabilizing in end range
- Indicated deficit in all four anticipatory core elements
Client Scenario: CP Hemiplegia

Anticipatory Core Deficit:
- Pelvic retraction and poor hip control in midstance gait
- Indicated poor pelvic floor integration to stabilize pelvis and anchor hip during gait

Client Scenario: CP Hemiplegia

Anticipatory and Reactive Core Integration:
- Poor anticipatory postural control in sitting, standing and gait
- Indicated poor timing of recruitment of both anticipatory and reactive core components

Client Scenario: CP Hemiplegia

Pre-Treatment Sitting

Pre-Treatment Standing

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Client Scenario: CP Hemiplegia

First Intervention Block:
- Ability to maintain bench sitting for 20 minutes to meet demands of classroom organization and transitions.
- Increase dynamic postural control as demonstrated by transitioning from sit-stand without the use of arms in order to carry school materials while moving and no loss of balance when stance is achieved.

First Intervention Block:
- Taught neutral alignment of rib cage and pelvis in supine
- Taught full utilization of diaphragm in supine “umbrella breathing”
- Progressed to sitting with postural supports (wedge) and standing

Client Scenario: CP Hemiplegia
- Taught proper diaphragm engagement before transitional movement
- “Blow before you go”

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In supine and sitting:
  • Paired optimized alignment with breathing with movement exercises for inside-out recruitment pattern
  • Variety of exercises and movement patterns targeted prioritized postural synergists

Client Scenario: CP Hemiplegia

Pre-Treatment  Post-Treatment (first block)  Post-Treatment w/ wedge

Second Intervention Block:
  • Increase trunk muscle coordination, strength and stability in a more demanding position against gravity as demonstrated by standing in a more neutral alignment with ribs over pelvis and reduced reliance on extreme anterior tilt.
  • Increase standing balance as demonstrated by maintaining standing in the same place for 30 seconds to facilitate safety in standing and social interaction.

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Client Scenario: CP Hemiplegia

Second intervention block:
In sitting and standing:
• Paired optimized alignment with breathing with movement exercises for inside-out recruitment pattern
• Increased awareness of alignment in standing
• Variety of exercises and movement patterns targeted prioritized postural synergists

Pre-Treatment 2009  Post-Treatment 2010  2013

Client Scenario: CP Hemiplegia

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Client Scenario: CP Hemiplegia

Treatment in Different Populations

- Cerebral Palsy
- Developmental Coordination Disorder
- Autism Spectrum Disorder
- Down Syndrome
- Varied Chromosomal Anomalies
- Organ Transplant
- Sensory Processing Disorder
- Anxiety Disorder
- Pediatric and Adolescent Stroke

Q and A

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References


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