Neural control of the lower urinary tract in health and disease

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Outline

• The neural control of the lower urinary tract in health

• What happens following neurological injury
The neural control of the lower urinary tract...... is unique

- Dependence on the central nervous system
- Element of voluntary control
- Functions depend upon learned behaviour
- Neural circuitry: phasic vs tonic activity
Spinal control

Storage

- *Bladder-to-urethra* procontinence guarding reflex
- Sympathetic mediated detrusor relaxation

Full bladder

- *Bladder-to-urethra* inhibitory reflex
- *Bladder-to-bladder* excitatory reflex
- These form part of the spinobulbospinal reflex which allows higher centres to exert control over voiding
Emergence of central reflexes controlling LUT functions

Cortical

Sacral spinal cord
Hierarchical control of LUT functions

- **Cerebral cortex**: sensations/timing of micturition
- **Brain stem**: coordination of reflexes
- **Spinal cord**: amplification
- **Peripheral nerves**: relay

Adapted from de Groat
How full is my bladder? Is this the right time and place to void?
Functional brain imaging

SPECT
Fukuyama et al. *Neuroreport* 1996

PET
Healthy males,
Blok et al. *Brain* 1997

• Various paradigms used—repeated PFM contractions on full and empty bladder, alternating bladder filling and emptying

• Changes in cortical and subcortical activity during the micturition cycle
Perception of bladder fullness
Periaqueductal grey (PAG) of the midbrain (courtesy Holstege)

Matsuura et al, 2002
Athwal et al, 2001
Changes in brain activity with bladder filling-healthy controls

- Good bladder control
- Small volume infused
- Mild sensations

(n=6)

Changes in brain activity with bladder filling-healthy controls

- Good bladder control
- Large bladder volume
- Strong desire to void

Insula

Gray’s anatomy 1918
Insula = interoceptive or homeostatic afferent cortex

- The homeostatic afferents are the “missing” sensory limb of efferent autonomic nervous system
- Interoceptive sensations are associated with an affective, motivational aspect, hence their value in homeostasis.

- Afferents from PAG are mapped in the insula
- Basis of bladder sensations
Cingulate cortex
• ACC associated with motivation and affective aspect of interoceptive sensations
• Output correlates with sympathetic activation
• Insula = “limbic sensory cortex”
• Anterior Cingulate Cortex = “limbic motor cortex”
• Both frequently co-activated
  • Monitoring and control as bladder is filling
  • Inhibits voiding through the PAG
• With filling, activation shifts anteriorly- associated with “unpleasantness”
Changes in brain activity with bladder filling - patients with poor bladder control

Changes in brain activity with bladder filling—patients with poor bladder control

- Poor control
- Small bladder volume

- Poor control, strong desire to void, no actual DO

Changes in brain activity with bladder filling-DO during scanning

- Women with urinary urgency
- DO in the scanner

Patterns of brain activity in patients with poor bladder control

Anterior cingulate - urgency

Prefrontal cortex - continence mechanism
Pontine micturition centre = "Barrington’s nucleus"

Griffiths, Holstege et al., 1990 in cat

Blok et al, 1997
LUT control: two neural programs and a switch
Storage
PMC

S2-4 in cauda equina

pelvic & pudendal ns
Suprapontine
Stroke
Parkinson’s Disease
Tumours
Trauma
Dementias

Spinal
Multiple Sclerosis
Trauma
Tumour

Sacral / Infrasacral
Disc prolapse
Tumour
Pelvic nerve injury
Small fibre neuropathy

• Storage symptoms
• PVR: < 100mL
• Detrusor overactivity

• Storage / voiding symptoms
• PVR: usually elevated
• Detrusor overactivity, detrusor sphincter dyssynergia

• Predominantly voiding symptoms
• PVR: elevated
• Often acontractile detrusor