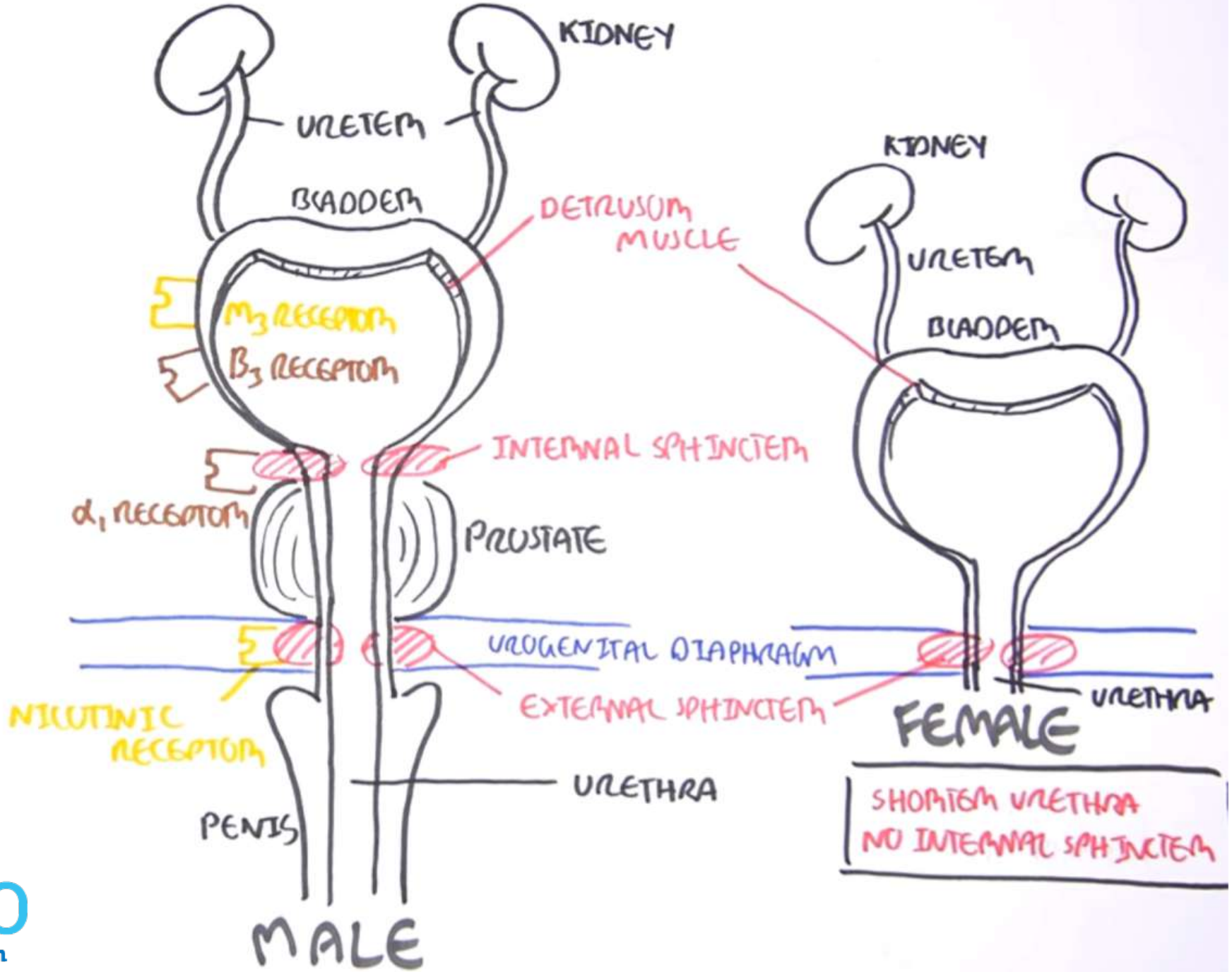
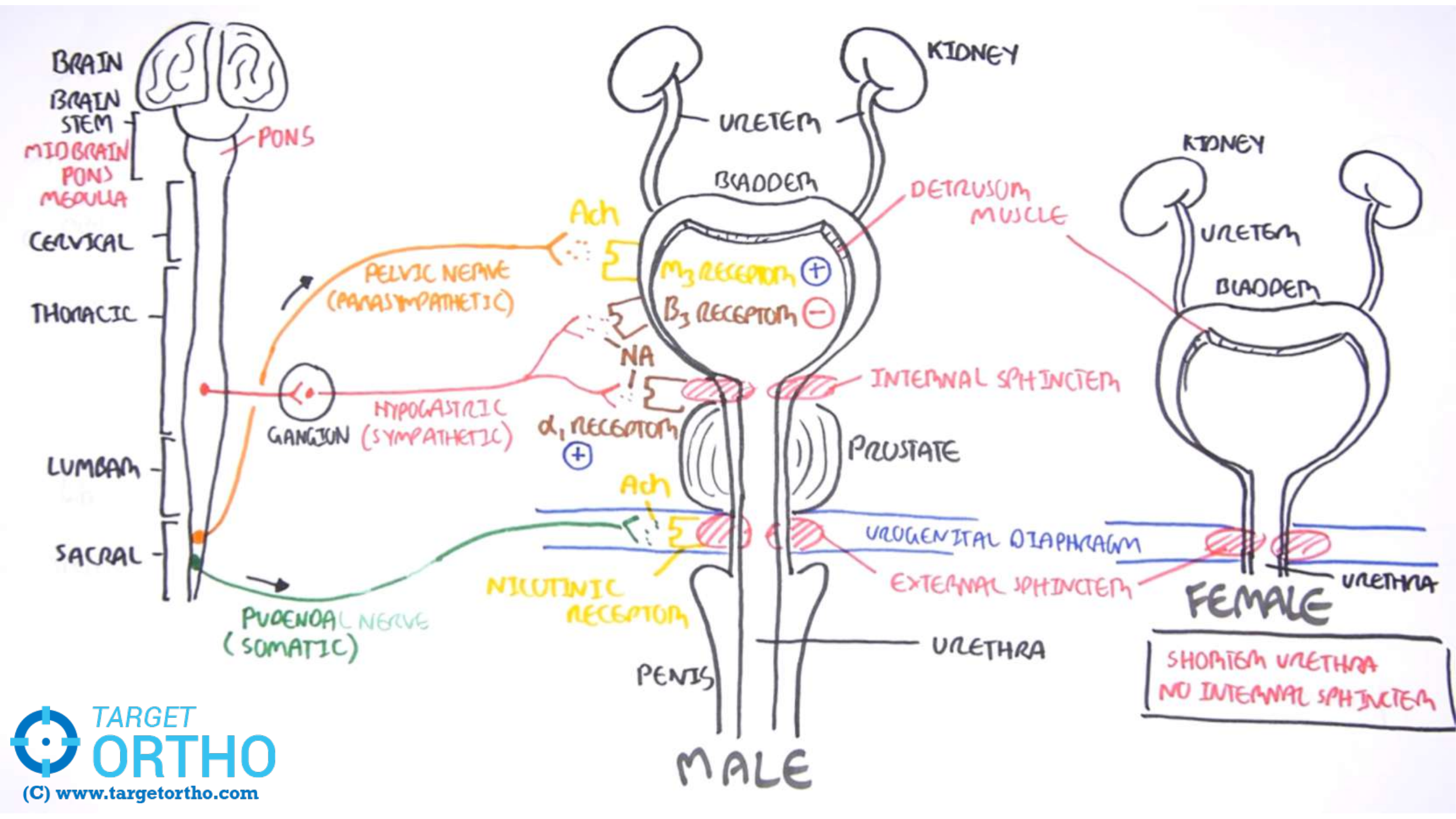
BLADDER PHYSIOLOGY & REHABILIATATION IN SPINAL CORD INJURY PATIENTS

Dr.Vishnu prasath

Spine surgeon

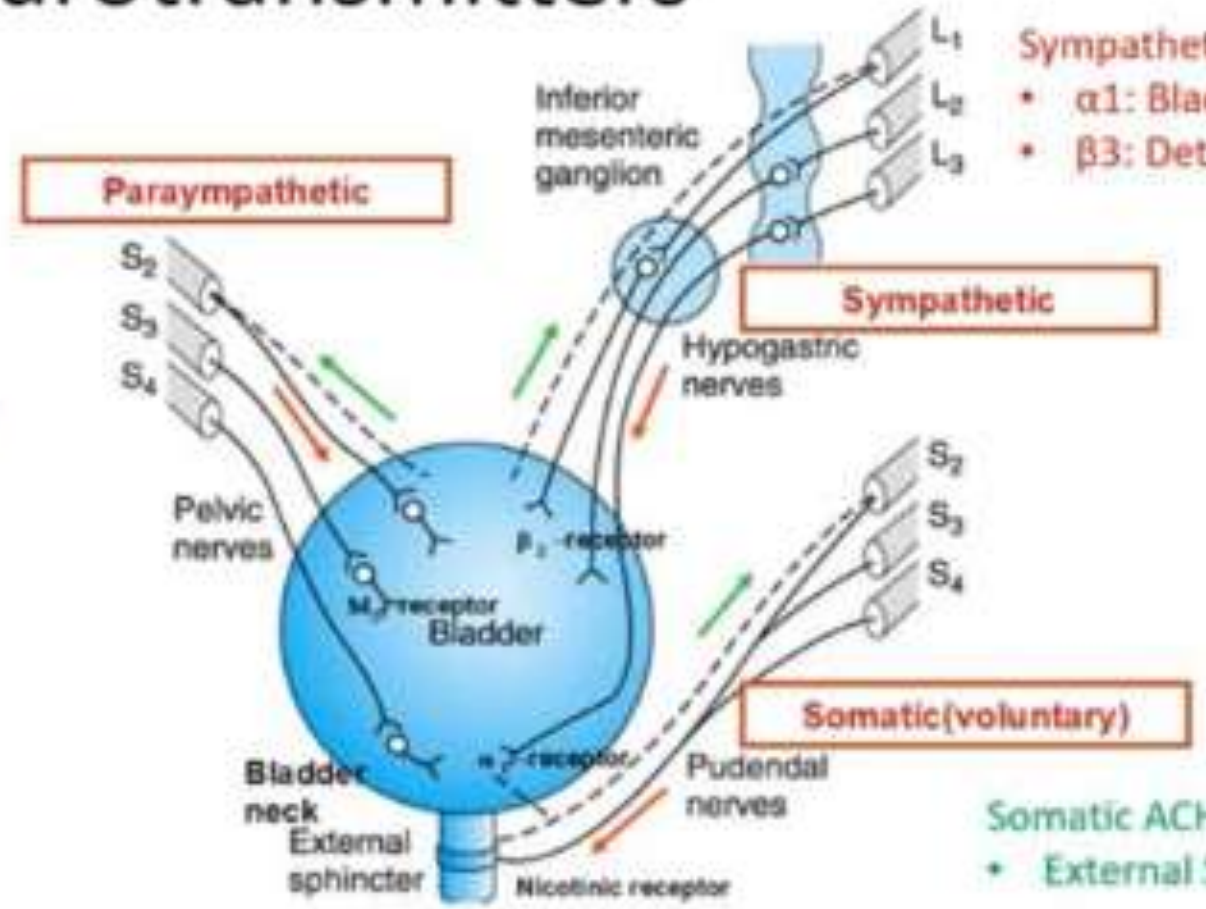




BLADDER PHYSIOLOGY

Bladder Neurotransmitters

Parasympathetic ACH Receptors
- Muscarinic 1 (M_1)
- Muscarinic 2 (M_2: (80%)
- Muscarinic 3 (M_3): 20%
  - Only M_3 mediate Detrusor contraction

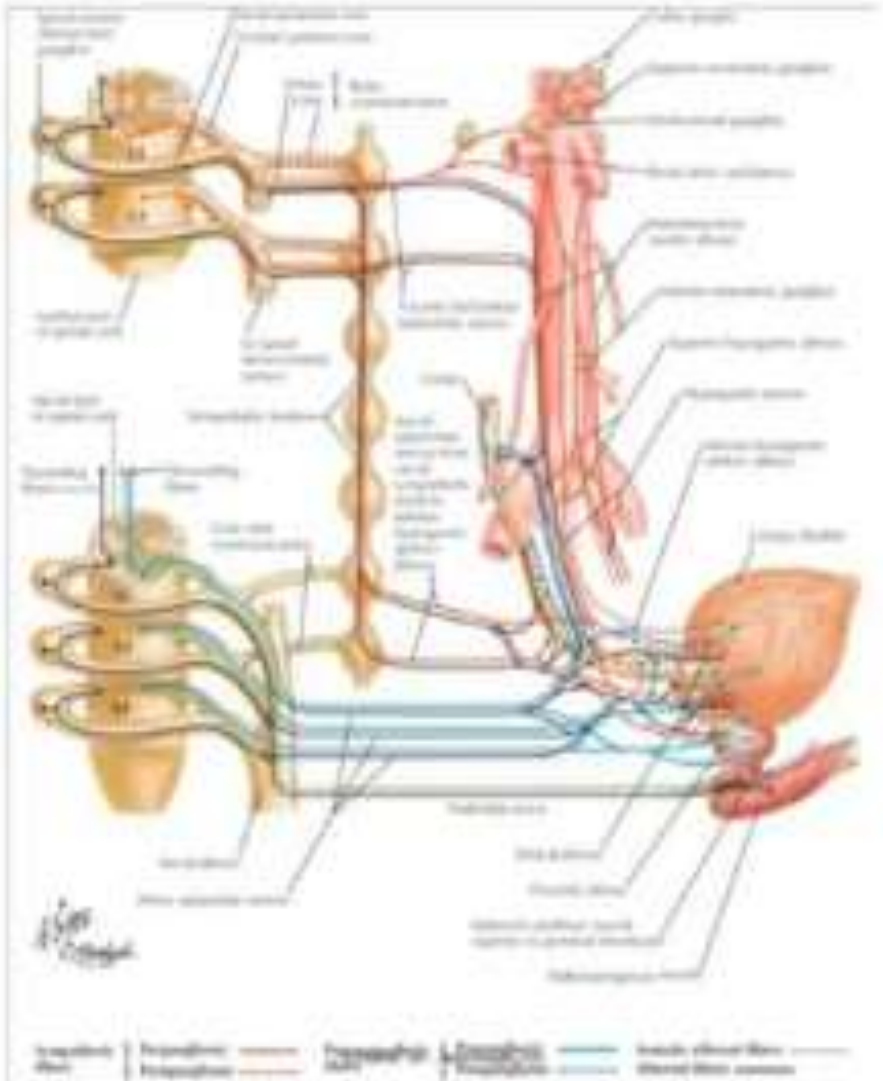


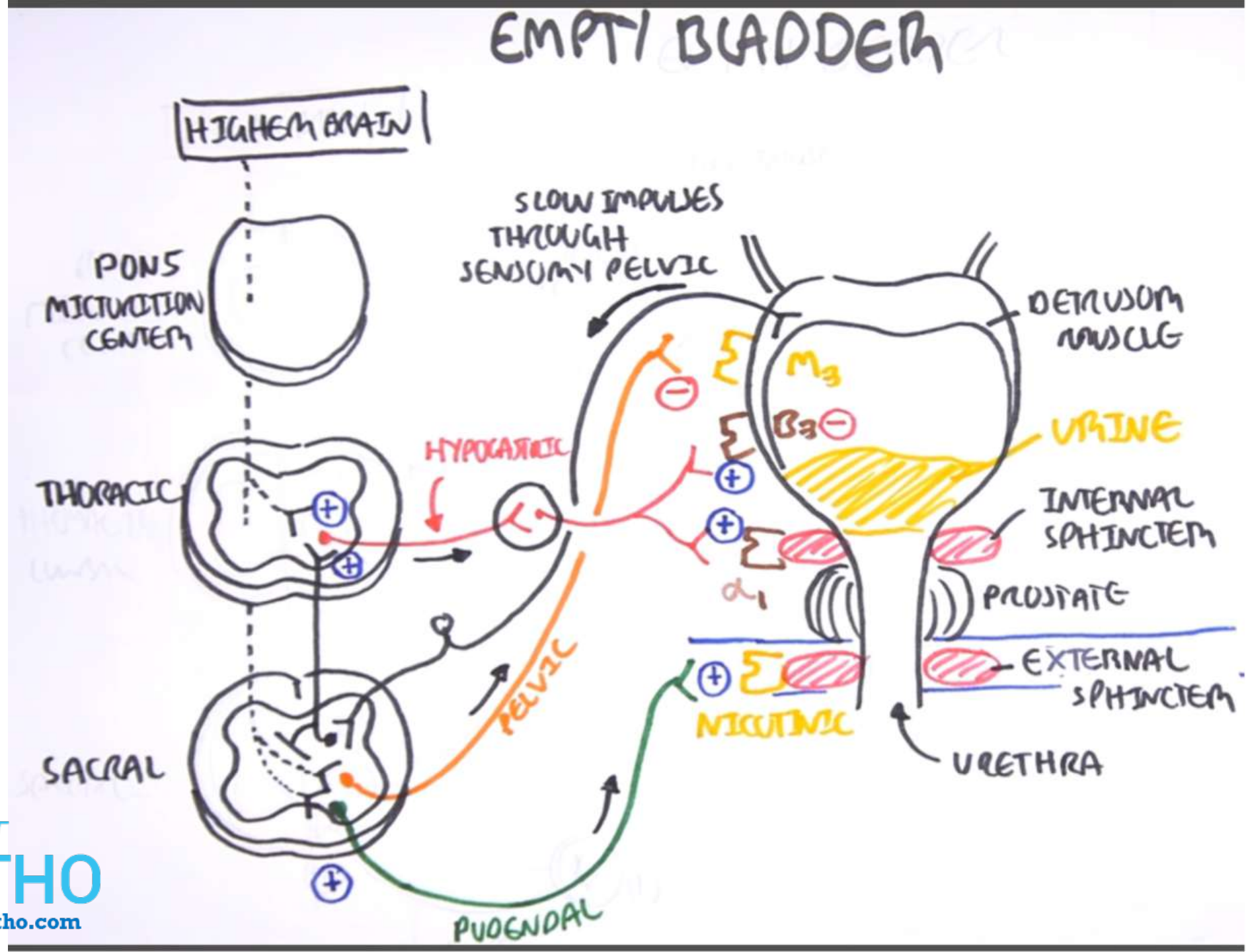
Sympathetic Adrenergic Receptors:
- α1: Bladder Neck Contraction
- β3: Detrusor Relaxation

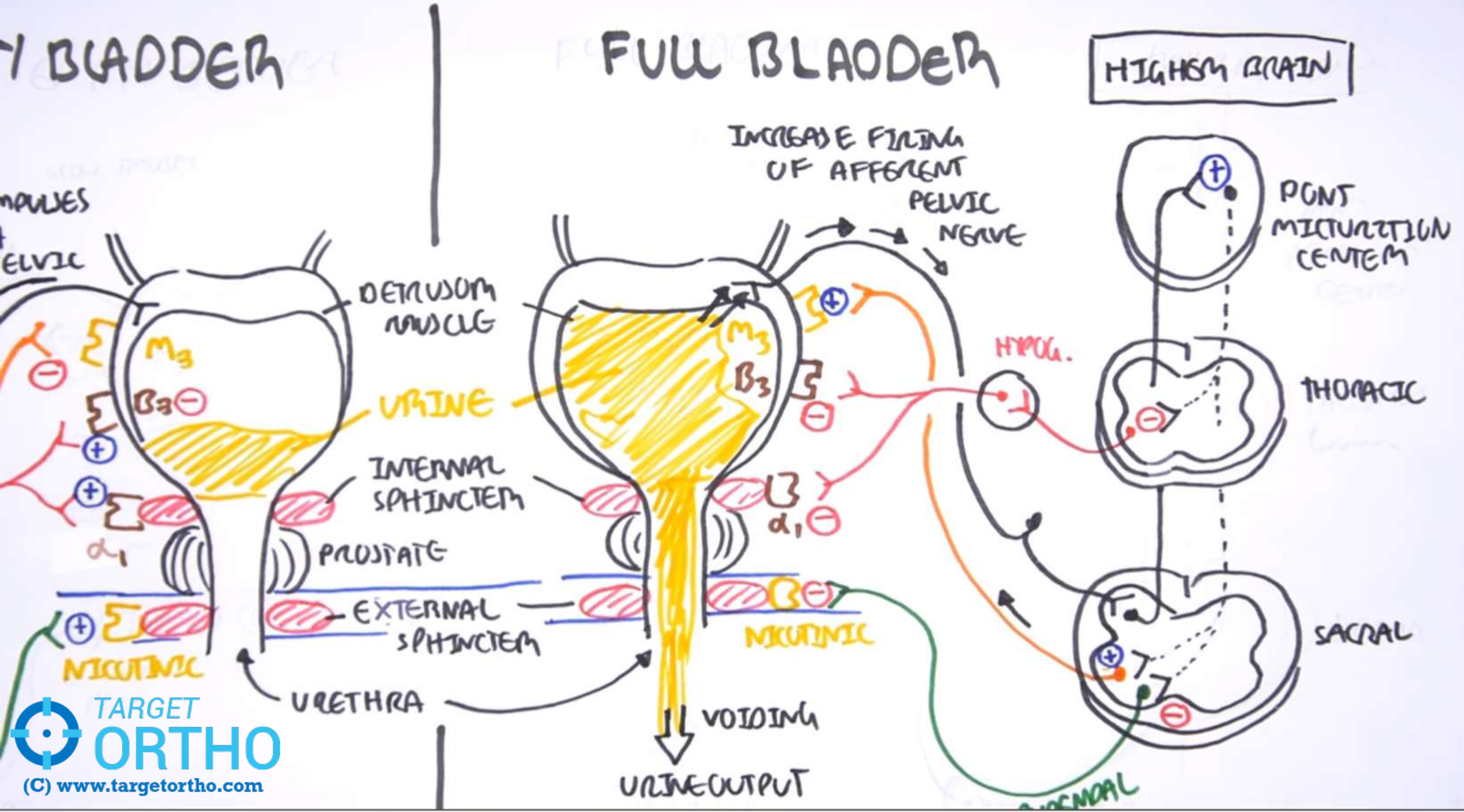
Somatic ACH Nicotinic Receptors
- External Sphincter Skeletal Muscle

Bladder Innervation

- Sympathetic NS
  - Hypogastric Nerve (T10-L2)
    - Detrusor Relaxation (β1)
    - Bladder Neck Contraction (α1)
    - Bladder Storage
- Parasympathetic NS
  - Pelvic Nerve (S2-S4)
    - Detrusor Contraction (Ach)
    - Voiding
- Somatic NS
  - Pudendal Nerve (S2-S4)
    - External Sphincter
    - Pelvic Floor Musculature

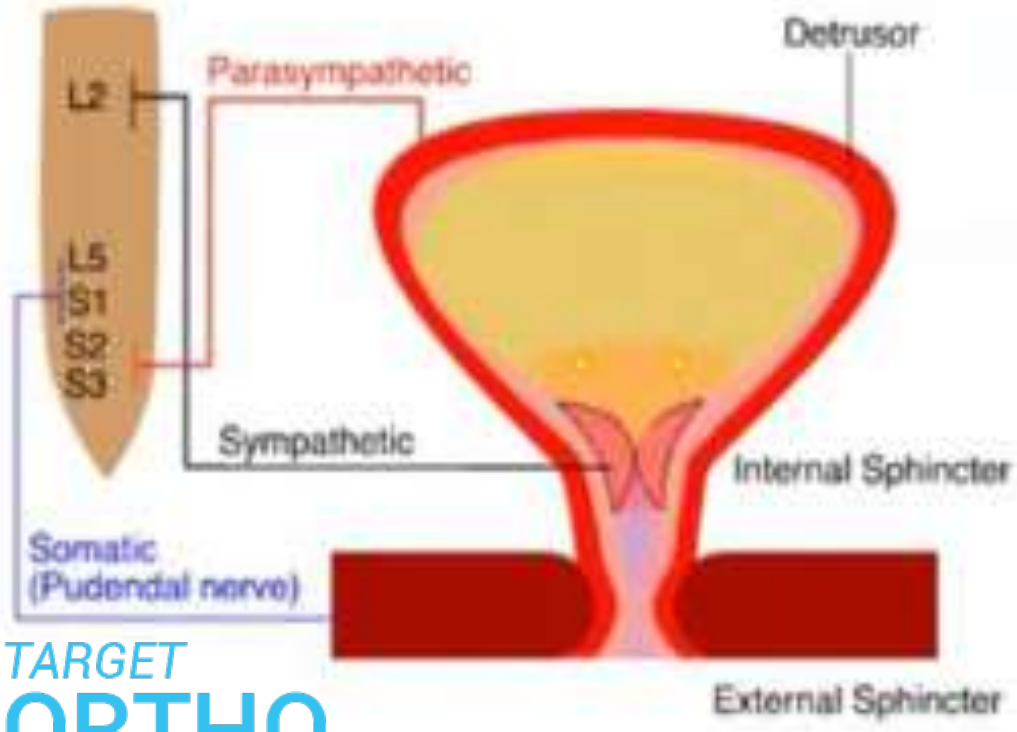






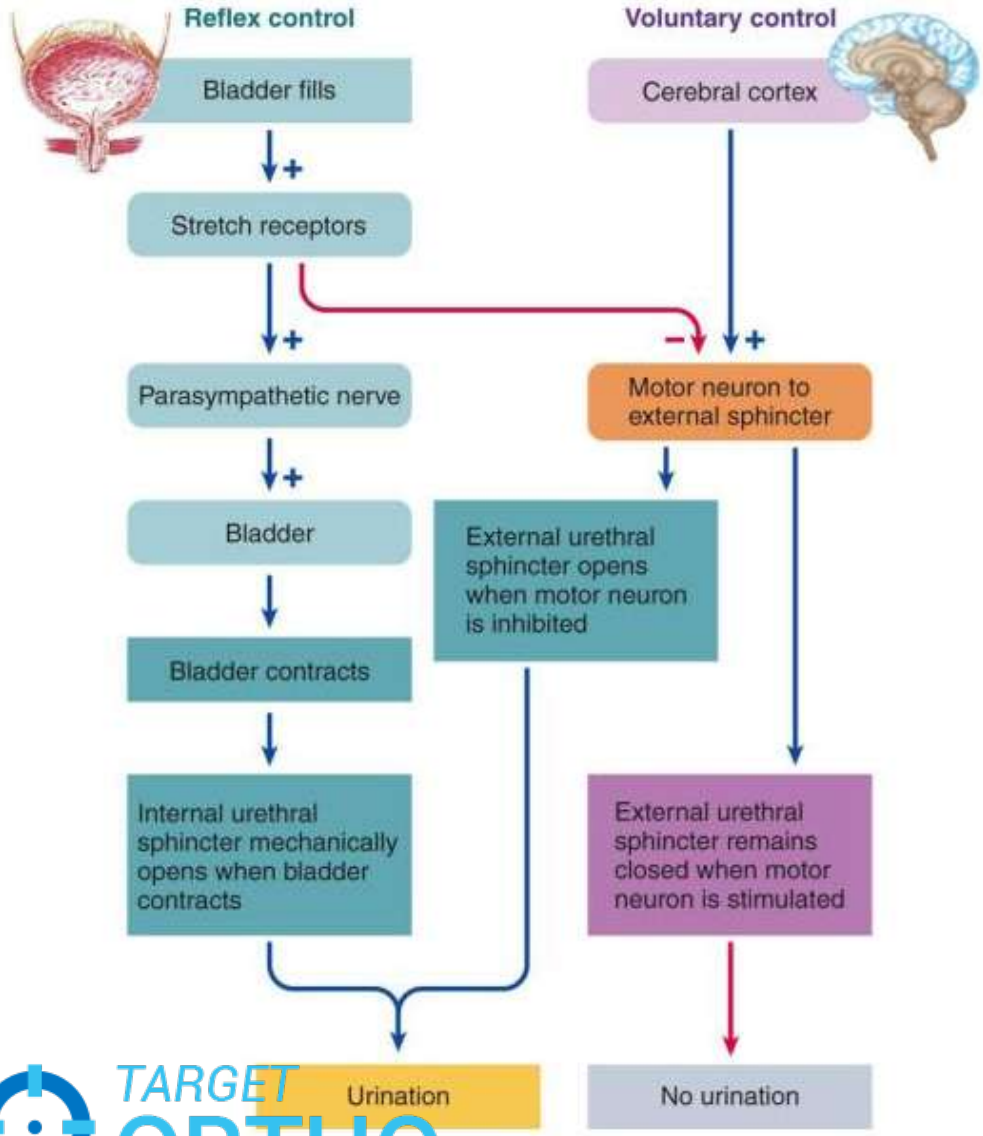
BLADDER PHYSIOLOGY

Micturition: Bladder Filling / Emptying



- Micturition Reflex
  - Bladder Filling
    - Sympathetic > Parasympathetic
      - Detrusor Relaxation
    - Internal External Sphincter Contraction
    - Detrusor Stretch: ↑ing Afferent Activation
  - Bladder Emptying
    - Parasympathetic > Sympathetic
      - Detrusor Contraction
    - Internal / External Sphincter Relaxation

REFLEX AND VOLUNTARY CONTROL OF MICTURITION



MICTURITION REFLEX

Excitation of stretch receptors when ~300ml of urine.

Pelvic nerves

Relayed to parasympathetic System

Pelvic nerves

Contraction of bladder

Bladder outlet pulled open, increase in pressure

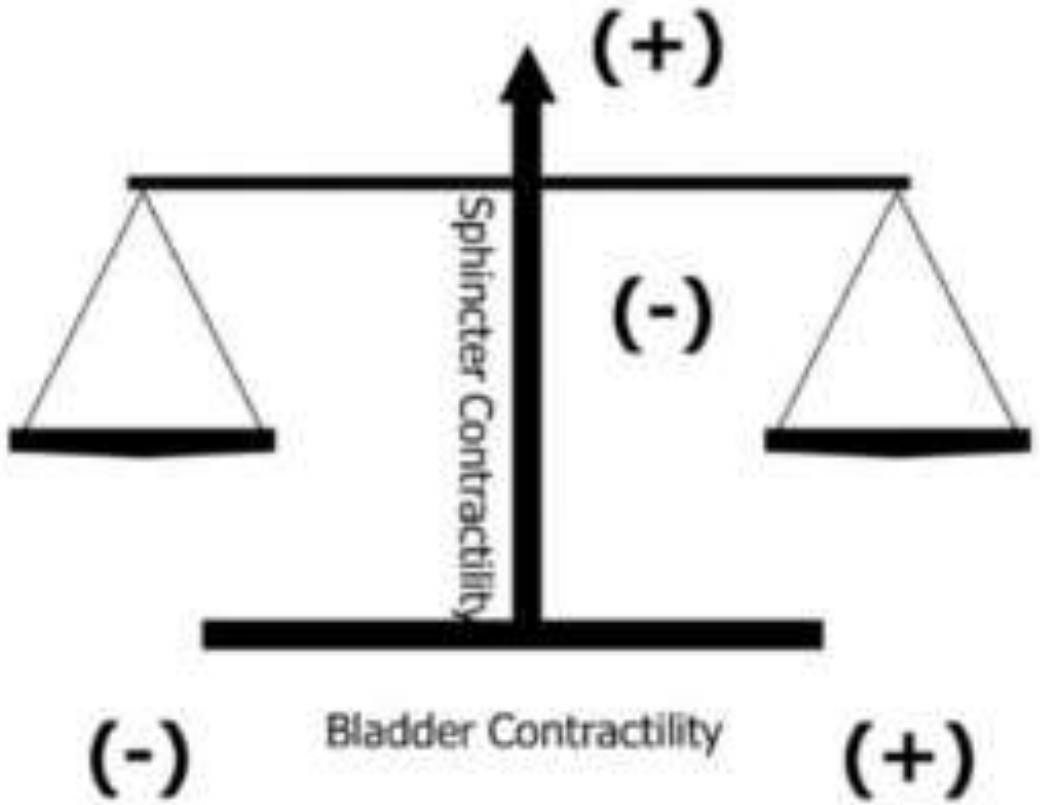
Pudendal impulses nerve inhibited

micturition

BLADDER PHYSIOLOGY

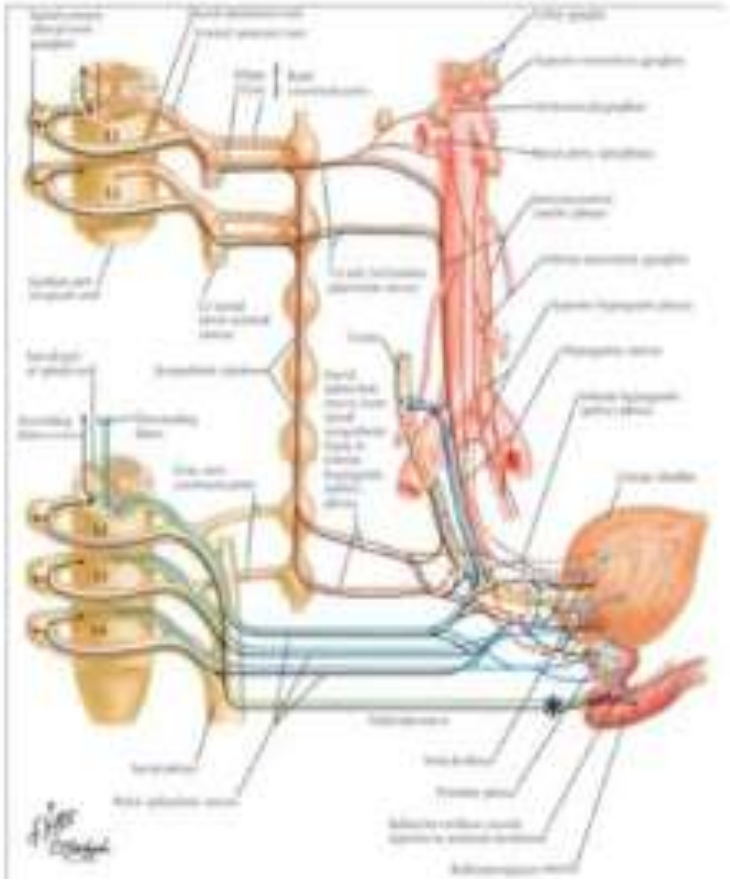
Lower Urinary Tract (2x2)

- Bladder Function
  - Too Much
    - Neurogenic Detrusor Overactivity (NDO)
  - Too Little
    - Detrusor Aconctractility
- Sphincter Function
  - Too Tight
    - Detrusor Sphincter Dyssynergia (DSD)
  - Too Loose
    - Intrinsic Sphincter Deficiency (ISD)

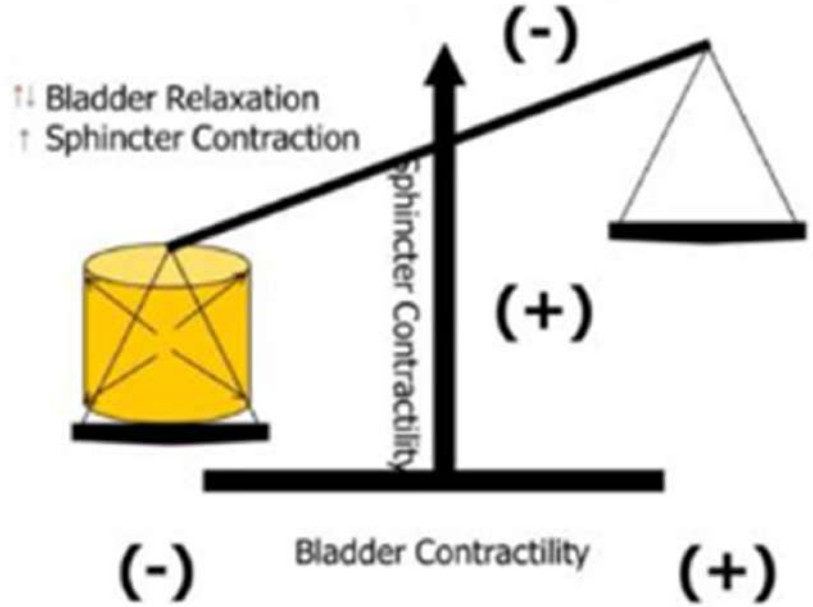


BLADDER PHYSIOLOGY

Bladder Filling Neurophysiology

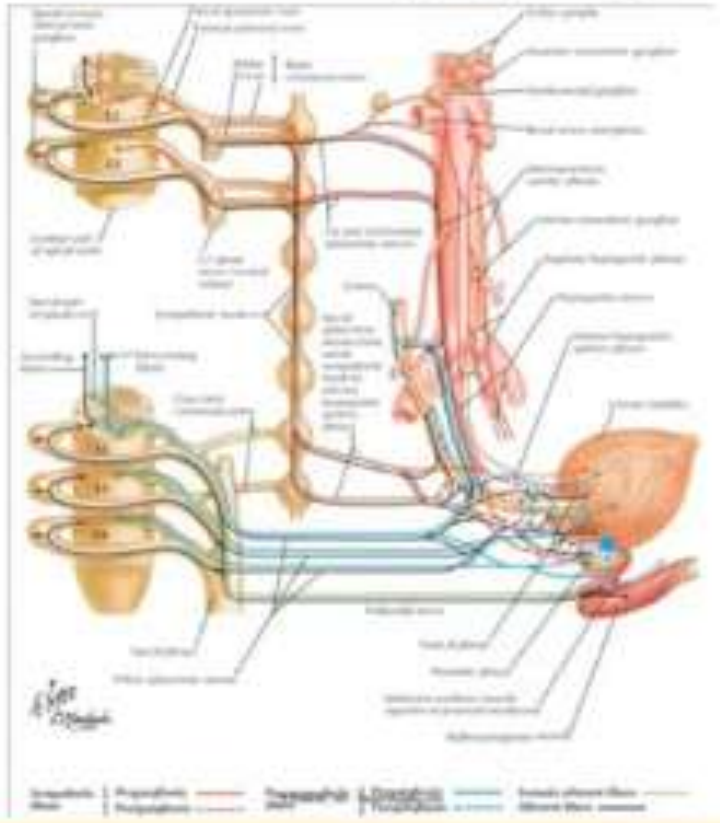


- ↑ Sympathetic NS*
  - Hypogastric Nerve (T10-L2)
    - Detrusor Relaxation (β3 Adrenergic)
    - Bladder Neck Contraction (α1 Adrenergic)
    - Bladder Storage
- ↓ Parasympathetic NS
  - Pelvic Nerve (S2-S4)
    - ↓ Detrusor Contraction (Ach Cholinergic)
    - Allows Bladder Filling
- ↑ Somatic NS*
  - Pudendal Nerve (S2-S4)
    - External Sphincter Contraction
    - Pelvic Floor Musculature Contraction
    - Bladder Filling



BLADDER PHYSIOLOGY

Bladder Emptying Neurophysiology



- ↓ Sympathetic NS
  - Hypogastric Nerve (T10-L2)
    - ↓ Detrusor Relaxation (β1)
    - Bladder Neck Relaxation (α1)
    - Facilitates Voiding
- ↑ Parasympathetic NS*
  - Pelvic Nerve (S2-S4)
    - Detrusor Contraction (Ach)
    - Facilitates Voiding
- ↓ Somatic (Voluntary) NS
  - Pudendal Nerve (S2-S4)
    - External Sphincter Relaxation
    - Pelvic Floor Musculature Relaxation
    - Bladder Voiding

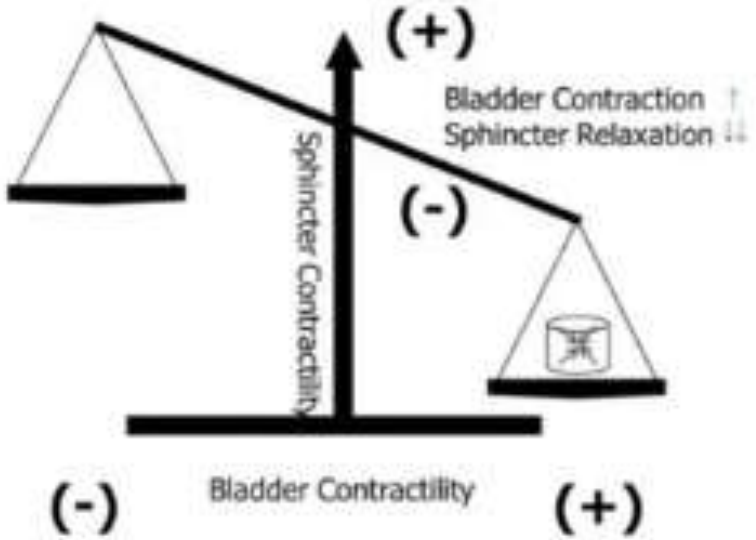
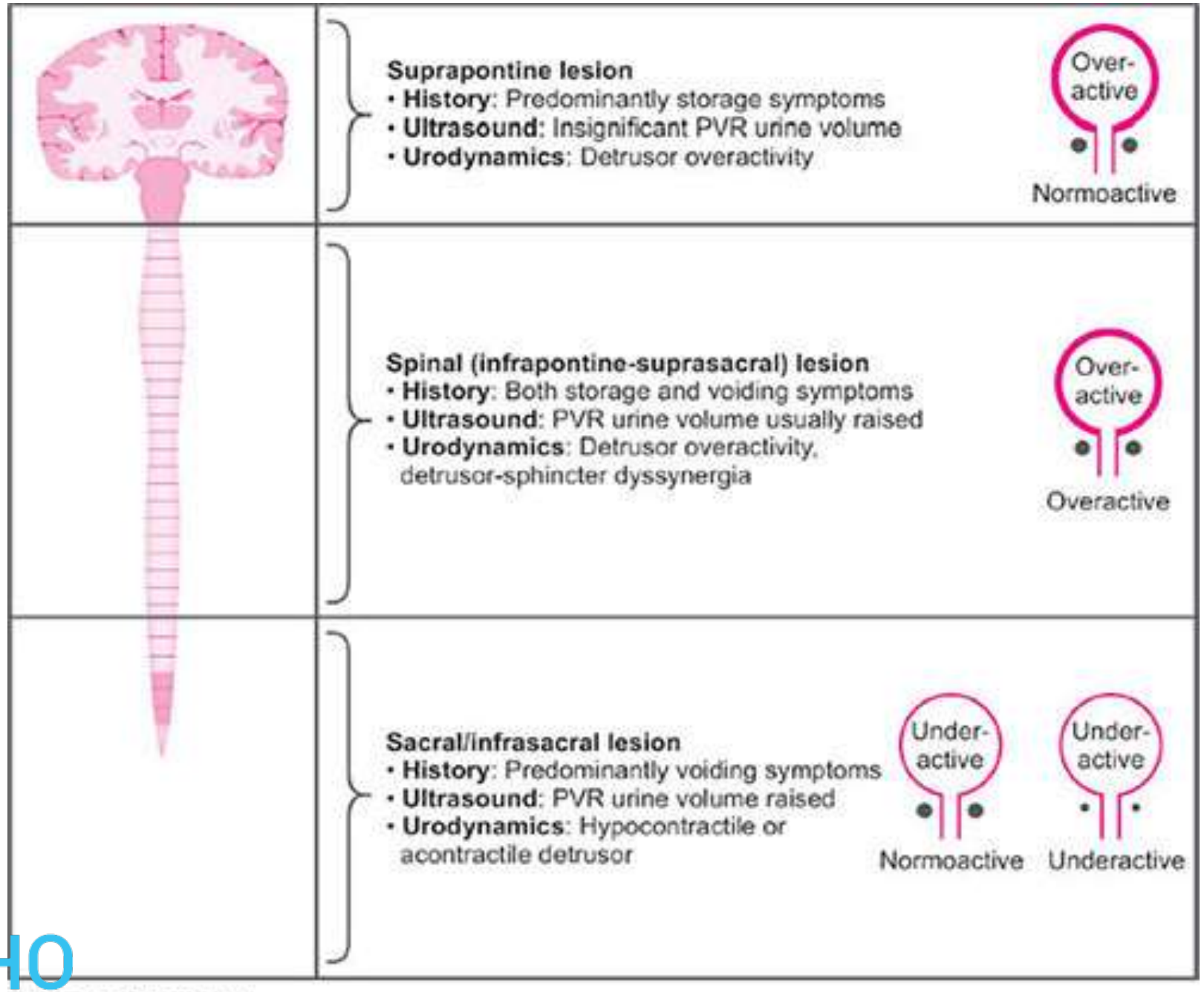


TABLE 1: Neurogenic Bladder Classification Based on Anatomic Location

Anatomic Location	*Type of Neurogenic Bladder*
Cerebral cortex *(above the pontine micturition center)*	UMN bladder with NDO
Spinal cord *(between the pontine and sacral micturition centers)*	UMN bladder with NDO and DSD
Sacrum *(at or below the sacral micturition center or cauda equina)*	LMN with DU

UMN: upper motor neuron; NDO: neurogenic detrusor overactivity; DSD: detrusor sphincter dyssynergia; LMN: lower motor neuron; DU: detrusor underactivity

	Suprapontine lesion eg. stroke, Parkinson's disease	Infrapontine-suprasacral lesion eg. myelopathy	Infrasacral lesion eg. conus medullaris, cauda equina, peripheral nerve
History/bladder diary	Urgency, frequency, urgency incontinence	Urgency, frequency, urgency incontinence, hesitancy, retention	Hesitancy, retention
Post-void residual urine (PVR)	No PVR	± Elevated PVR	PVR > 100 ml
Uroflowmetry	Normal flow	Interrupted flow	Poor/absent flow
Urodynamics	Detrusor overactivity	Detrusor overactivity	Detrusor underactivity
		Detrusor sphincter dyssynergia	Sphincter insufficiency



Suprapontine lesion
- **History**: Predominantly storage symptoms
- **Ultrasound**: Insignificant PVR urine volume
- **Urodynamics**: Detrusor overactivity

Over-active
Normoactive

Spinal (infrapontine-suprasacral) lesion
- **History**: Both storage and voiding symptoms
- **Ultrasound**: PVR urine volume usually raised
- **Urodynamics**: Detrusor overactivity, detrusor-sphincter dyssynergia

Over-active
Overactive

Sacral/infrasacral lesion
- **History**: Predominantly voiding symptoms
- **Ultrasound**: PVR urine volume raised
- **Urodynamics**: Hypocontractile or acontractile detrusor

Under-active
Normoactive

Under-active
Underactive

PVR, postvoid residual.

UMN BLADDER VS LMN BLADDER

	Spastic (automatic)	Flaccid
Vertebral level	Lesion above L1	Lesion at/below L1
Symptoms	Urgency, frequency, urgency incontinence, hesitancy, retention	Hesitancy, retention
Bladder scan	±Raised postvoid residual urine	Postvoid residual urine >100 ml
Uroflowmetry	Interrupted flow	Poor/absent flow
Bladder pressure	High	Low
Detrusor	Overactivity, detrusor–sphincter dyssynergia	Underactivity, sphincter insufficiency
Bladder capacity	Low	High
Risks	Back pressure changes	Stasis

Panicker JN, et al: Pract Neurol. 2010

- Upper Motor Neuron (Spasticity)
  - Detrusor Sphincter Dyssynergia
  - High Pressure
    - Hydronephrosis
    - Hydroureter
    - Acute Kidney Failure
    - Incontinence
- Lower Motor Neuron (Arreflexic)
  - Flaccid Bladder
  - Flaccid Sphincter
    - Overflow Incontinence

Goals of managing a neurogenic bladder

- Protecting upper urinary tracts from sustained high filling and voiding pressures (i.e. >40cm water)
- Achieving regular bladder emptying, avoiding stasis and bladder overdistension and minimising post-voiding residual volumes.
- Preventing and treating complications such as urinary tract infections (UTIs), stones, strictures and autonomic dysreflexia
- Maintaining continence and avoiding frequency and urgency
- Choosing a technique which is compatible with person's lifestyle

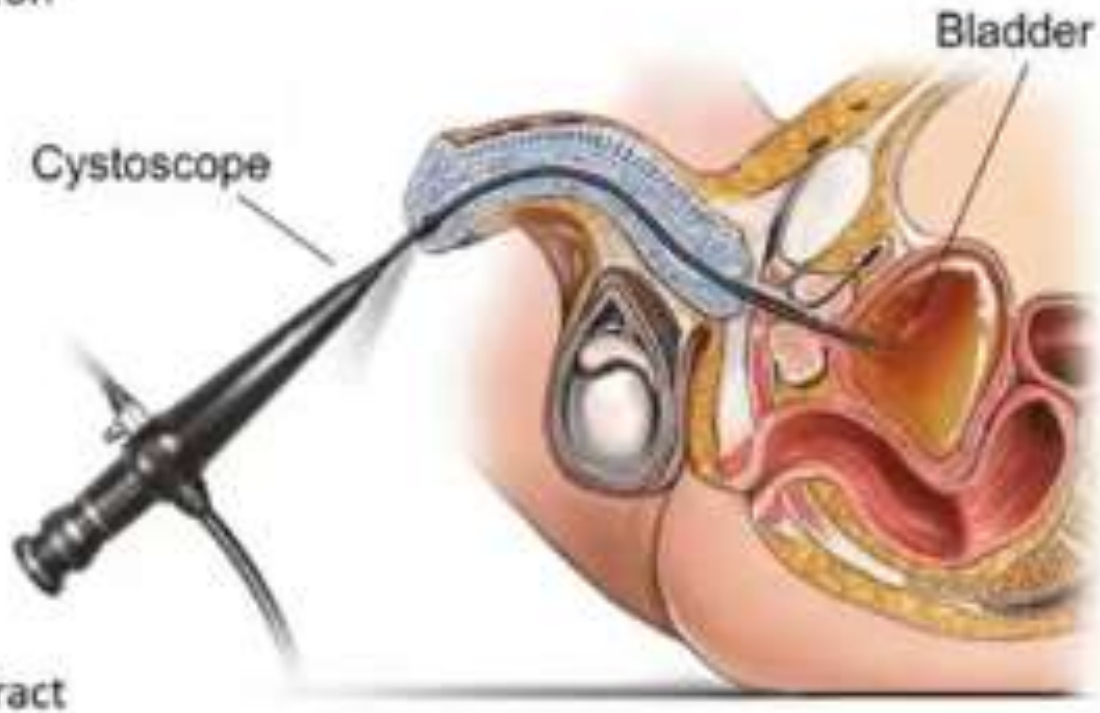
Bladder Assessment: Upper vs Lower Tracts

- Laboratory
  - Renal Panel
  - 24-hour Creatinine Clearance (Annual)
  - Cystatin C (Independent of Muscle)
  - UA, C&S PRN
- Nuclear Renal Scan PRN
- Renal Ultrasound (Annual)
  - Assess Upper Urinary Tracts
- Abdominal CT PRN
  - Renal, Ureteral or Bladder Calculi

Upper Tract Evaluation

- Cystoscopy Q5-10 years (Indwelling)
- Urodynamics (Annual or Biannual)
- Voiding Cystourethrogram

Lower Tract Evaluation



Clinical urinary tract assessment recommendation

- Bladder emptying/voiding diary
- Physical examination
- Routine urinalysis
- Urine culture and sensitivity testing
- Glomerular filtration rate
- Renal and bladder ultrasound
- Abdominal X-ray
- Abdominal computed tomography scan
- Renal scintigraphy
- Intravenous pyelography/excretory urogram
- Uroflowmetry test
- Urodynamic study
- Cystourethroscopy

NORMAL PHYSIOLOGY

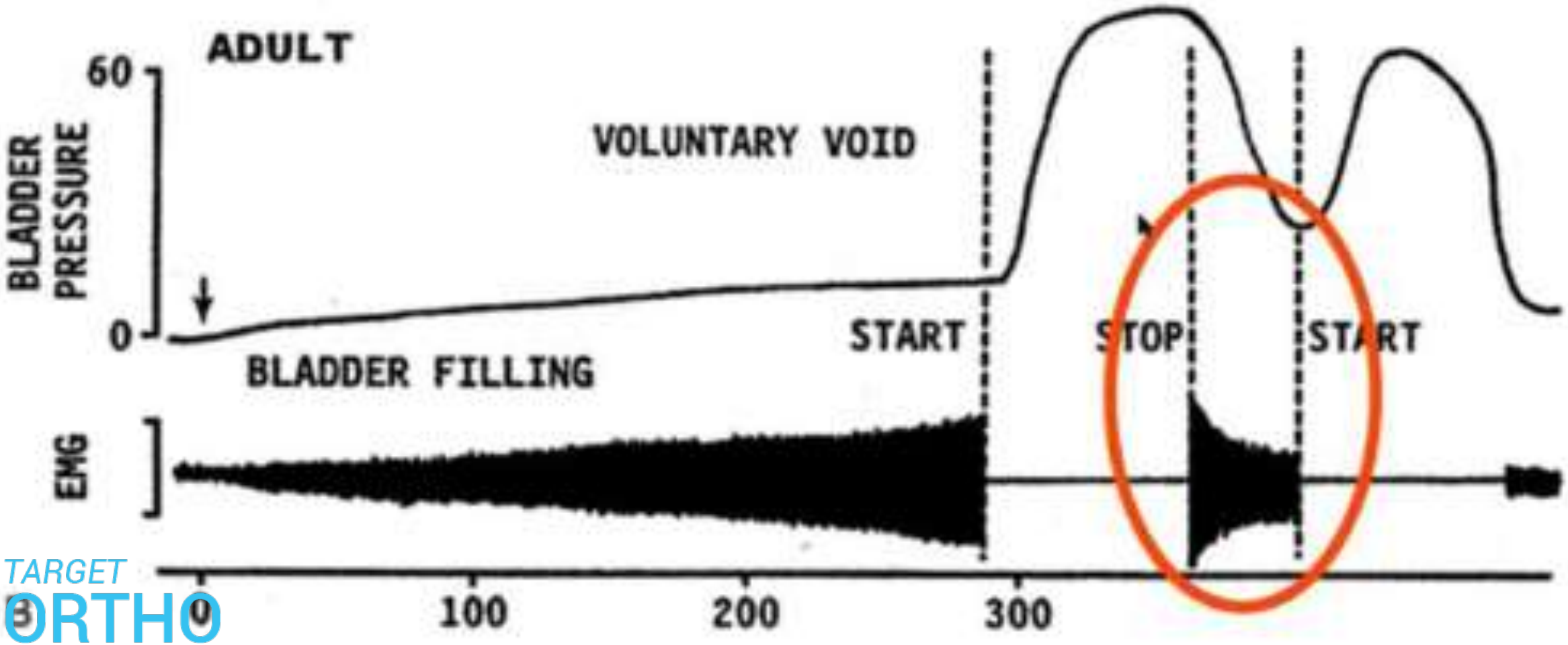
- Bladder filling rate: 20-100 ml/h
- Urethral pressure > Bladder pressure, thus maintaining continence
- Low bladder pressure during filling (0-20 cm H2O)
- Low bladder pressure during voiding (=/< 50 cm H2O)
- Bladder capacity : 400-500 ml
- Individual is continent, aware when full
- Voiding initiated voluntarily

Urodynamic study

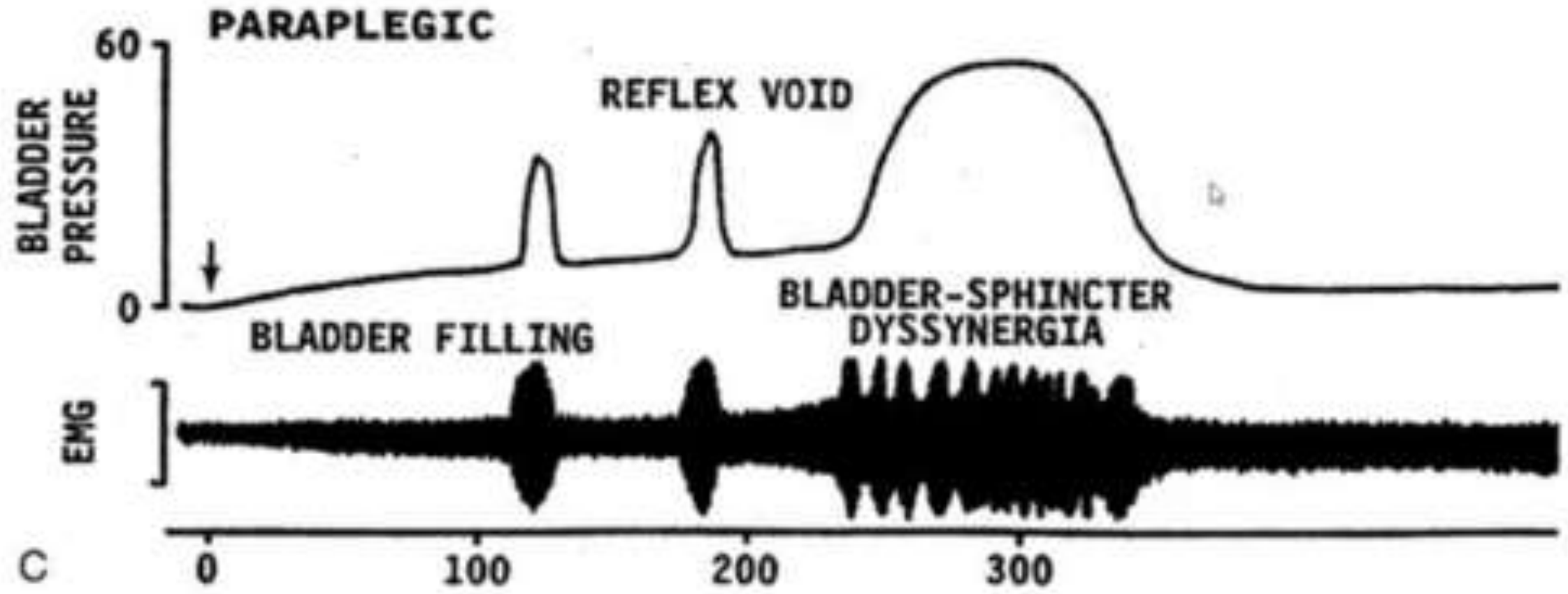
- Urodynamic study (UDS) is the gold standard - DSD and even autonomic dysreflexia.

- Every study records storage and voiding phase parameters, mainly first bladder sensation of filling, bladder capacity and compliance, do, maximum detrusor pressure (pdet-max), detrusor leak point pressure (dlpp) and flow rate.

Urodynamics (Lower Tract): Normal



Urodynamics: UMN Bladder



Loss Of Coordinated, Reciprocal Innervation

MANAGEMENT OF NEUROGENIC BLADDER

CONSERVATIVE :-

1) BEHAVIOURAL THERAPY :-EXTERNAL STIMULATION,TRIGGER REFLEX VOIDING (CREDE & VALSALVA) ,TOILETTING ASSISTANCE

2) CATHETER :- INTERMITTENT CATHETERISATION ,INDWELLING CATHETER ,CONDOM CATHETER AND EXTERNAL APPLIANCES

3)PHARMACOTHERAPY

4)ELECTRICAL STIMULATION

SURGERY :-

1)DETRUSOR ACTIVITY –INCREASING BLADDER STORAGE CAPACITY,FACILITATE BLADDER EMPTYING

2)URETHRAL RESISTANCE

3)SALVAGE PROCEDURES

Acute SCI Bladder Management Options

- Discontinue indwelling urethral catheter when daily urine output < 2,500 cc; replace with Intermittent Catheterization Protocol (ICP)
- ICP (sterile technique) q4 (or q6 hours); document volume; contact HO for volumes > 500 cc
- For Incomplete SCI, ICP (sterile technique) with lidocaine jelly q4 or q6 hours; document volume
- External Catheter if s/p Sphincterotomy and/or urethral stent; document 24-hour urine output
- Indwelling urethral catheter; document 24-hour urine output
- Suprapubic catheter to gravity; document 24-hour urine output
- Voiding Trial:
  - Offer urinal q4 (or q6) hours; q4 or q6 hours; document volume
  - Document Post-void Residual (PVR); ICP for PVR > 50cc
  - Once PVR x 3 with volume <50 cc, may discontinue around-the-clock ICP

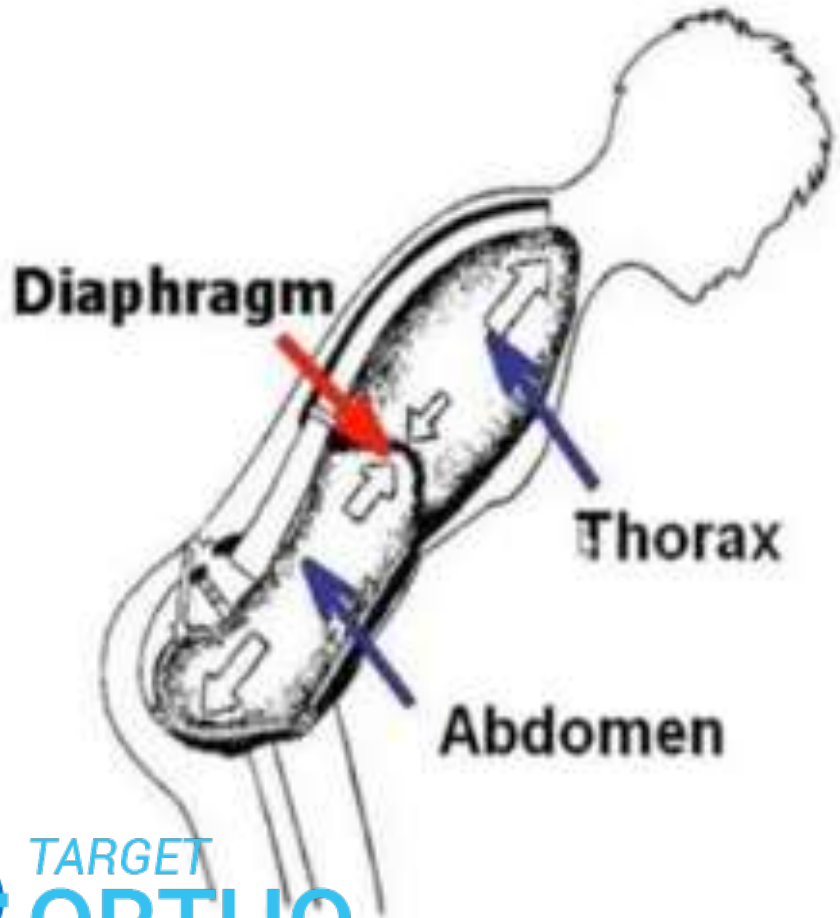
Intermittent Catheterization Considerations

- Fewer long-term complications than indwelling catheters
  - ↓ Bladder / Renal Calculi
  - ↓ Urinary Tract Infections (UTIs)
  - ↓ Transitional Cell Carcinoma
- Goal: Bladder volumes <500 cc
  - Post-Void Residual <50-100cc
- Usual Practice
  - Hospital: Sterile Technique
  - Home: "Clean" technique
  - "Touchless" Catheters Preferred

Intermittent Cath Protocol

- Desired for:
  - People who have sufficient hand skills
  - Those with caregivers willing to do it
- Consider Alternatives if:
  - Abnormal urethral anatomy (strictures, scar, etc.)
  - Bladder capacity less than 200 ml
  - Inability/unwillingness to adhere to ICP schedule
  - High fluid intake regimen
  - Tendency toward AD with bladder filling
  - Adverse reaction to passing catheter multiple times per day

Crede and Valsalva

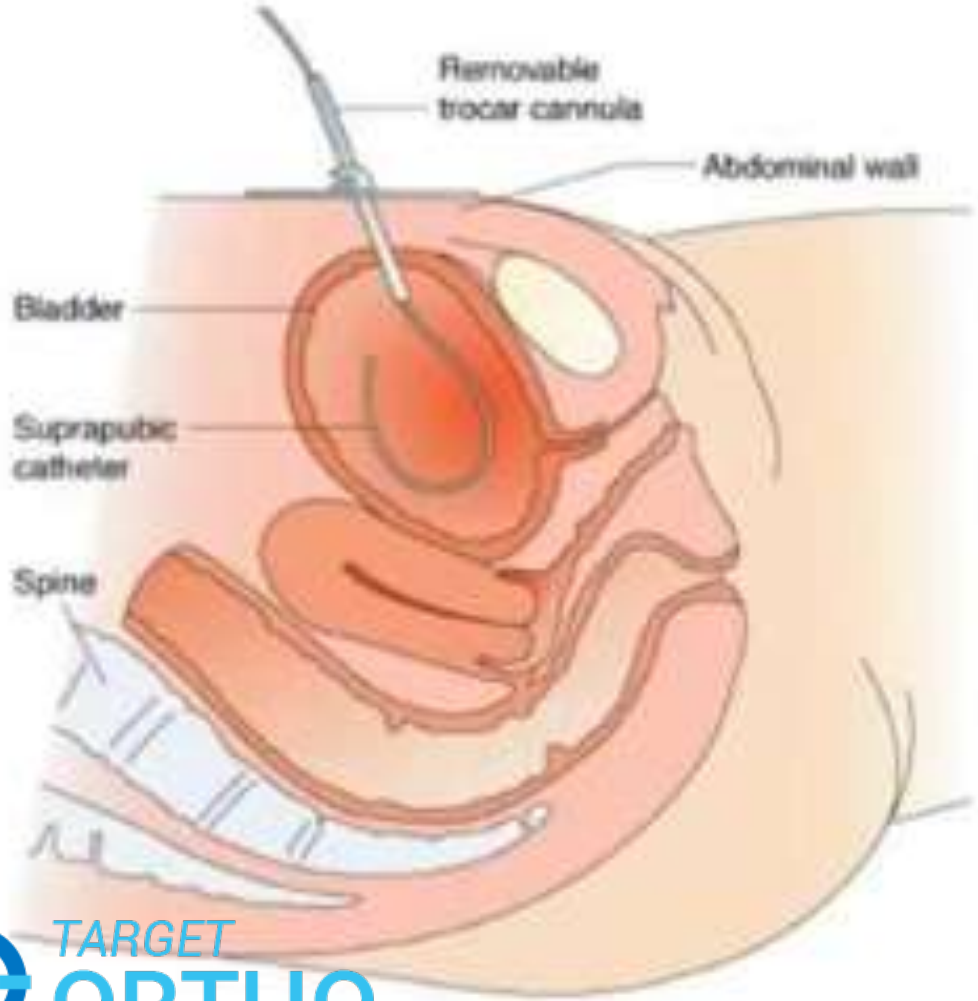


- Crede' = applying suprapubic pressure to express urine from bladder
- Valsalva = contracting abdominal muscles
- Consider in those with:
  - LMN injuries with low pressure & low outlet resistance
  - S/p sphincterotomy
- *Avoid as primary methods of bladder emptying
  - High Risk: Upper tract deterioration

Indwelling Catheters

- Consider as last resort if:
  - Poor hand skills
  - High fluid intake
  - Cognitive impairment/substance abuse
  - Elevated bladder pressures
  - Lack of success with other methods
  - Temporary management of reflux
  - Limited assistance from caregiver
- If recurrent UTIs, consider:
  - Hydrophilic Catheter
  - Silver-impregnated

Consider Suprapubic Caths:



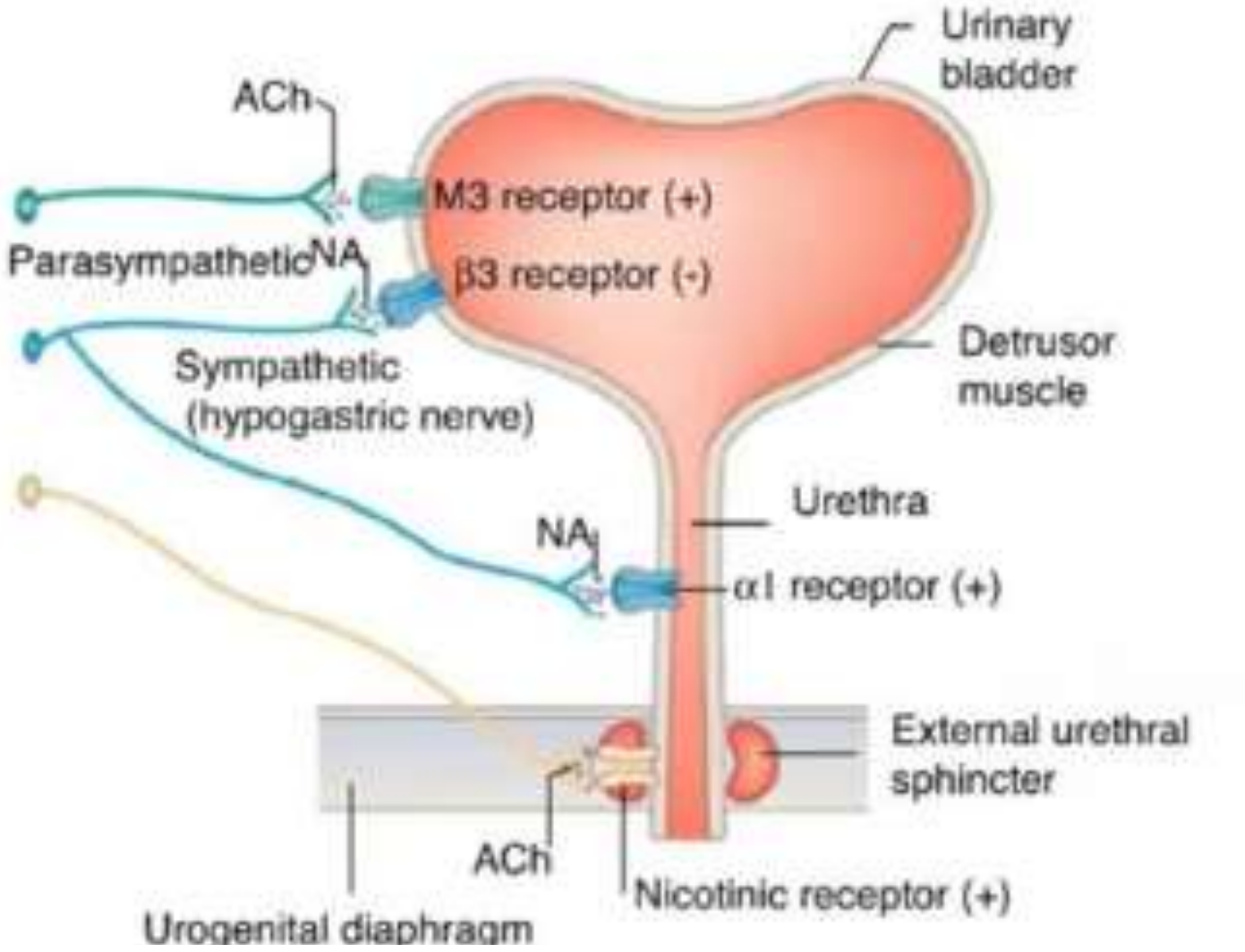
- Urethral abnormalities
- Urethral discomfort
- Recurrent catheter obstruction
- Difficulty with catheter insertion
- Skin breakdown from urethral urine leakage
- Body image/personal preference
- Desire to improve sexual function
- Prostatitis, urethritis, epididymo-orchitis

Consider Reflex Voiding

- For males with adequate bladder contractions and:
  - Hand skills or caregiver to apply condom catheter and empty leg bag
  - Poor compliance with fluid restriction
  - Small bladder capacity
  - Small post-void residual volumes
  - Ability to keep catheter in place
- Always do thorough urodynamic evaluation first

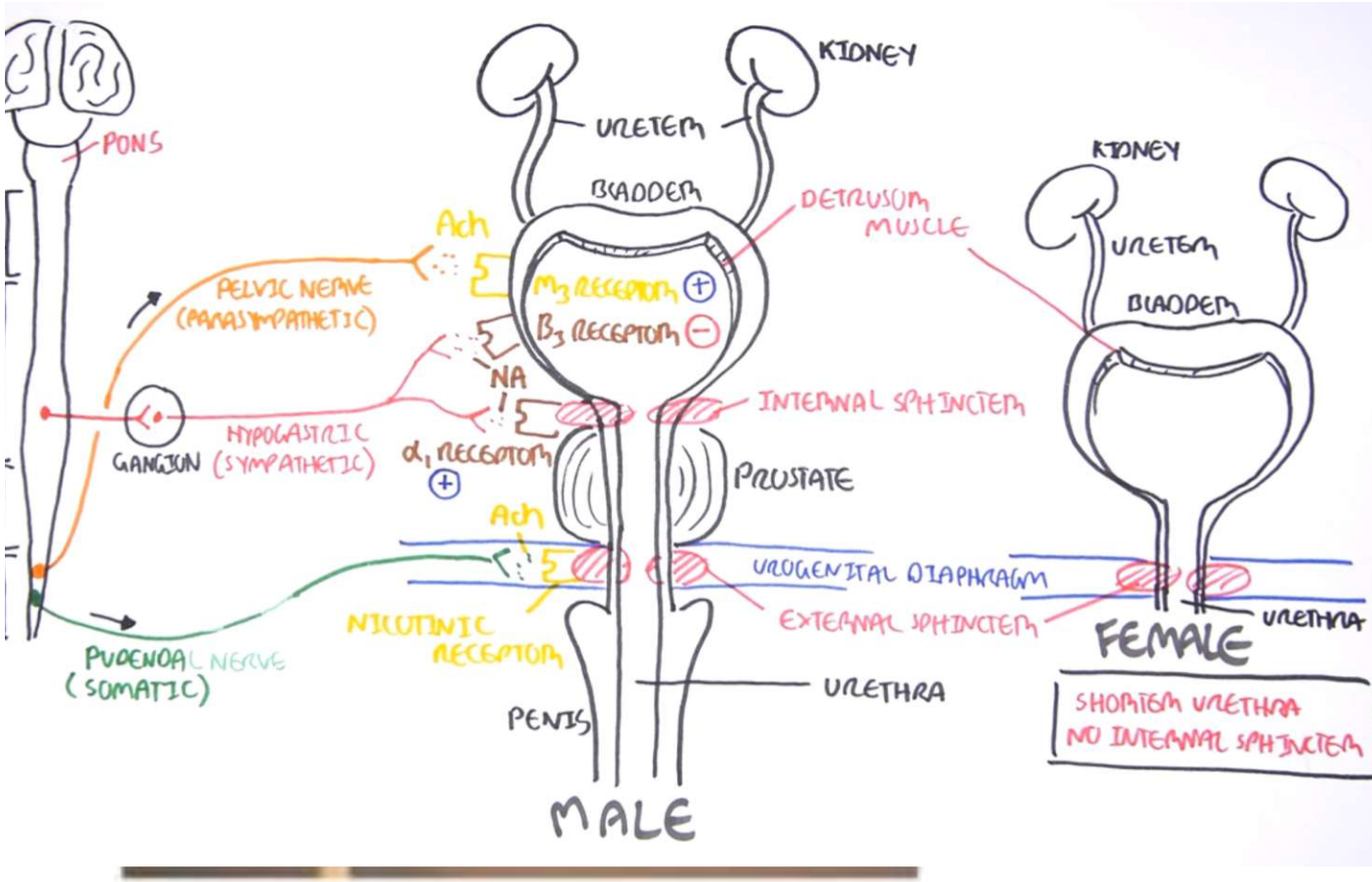
BLADDER PHARMACOLOGY

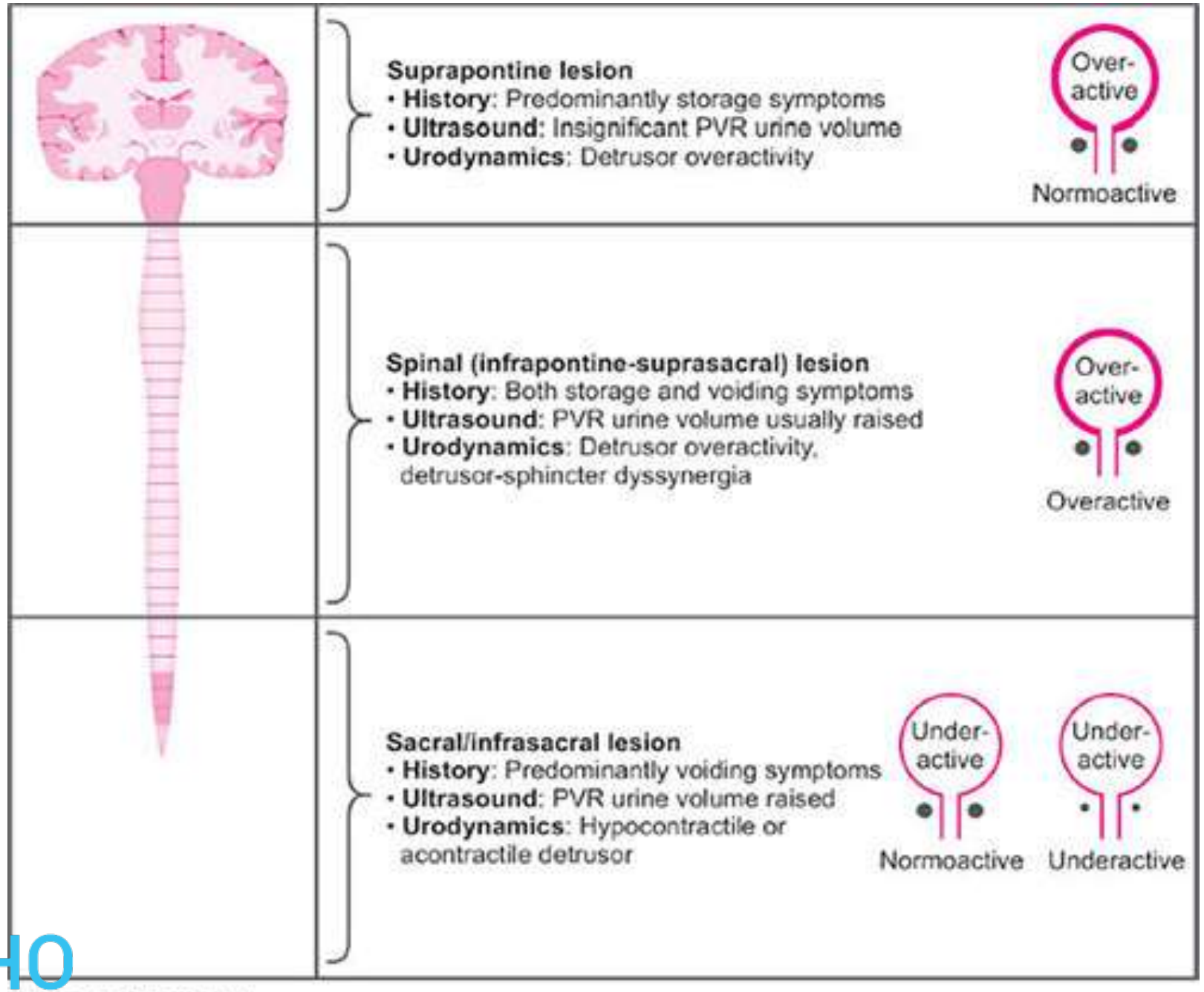
	Sympathetic	ParaSympathetic	Somatic
Detrusor Bowel	-	+ +	
Bladder neck / Internal Anal Sphincter	+	-	
External Uretheral / Anal sphincter	(?)	(?)	+
Pelvic floor			+



Pharmacological Intervention

- Alpha Blockade
  - Trigone / Urethral relaxation
- Anti-muscarinics
  - Detrusor relaxation
- Beta-3 Adrenergic Agonist
  - Detrusor relaxation
- Botulinum Toxin
  - Urethral &/or Detrusor Relaxation





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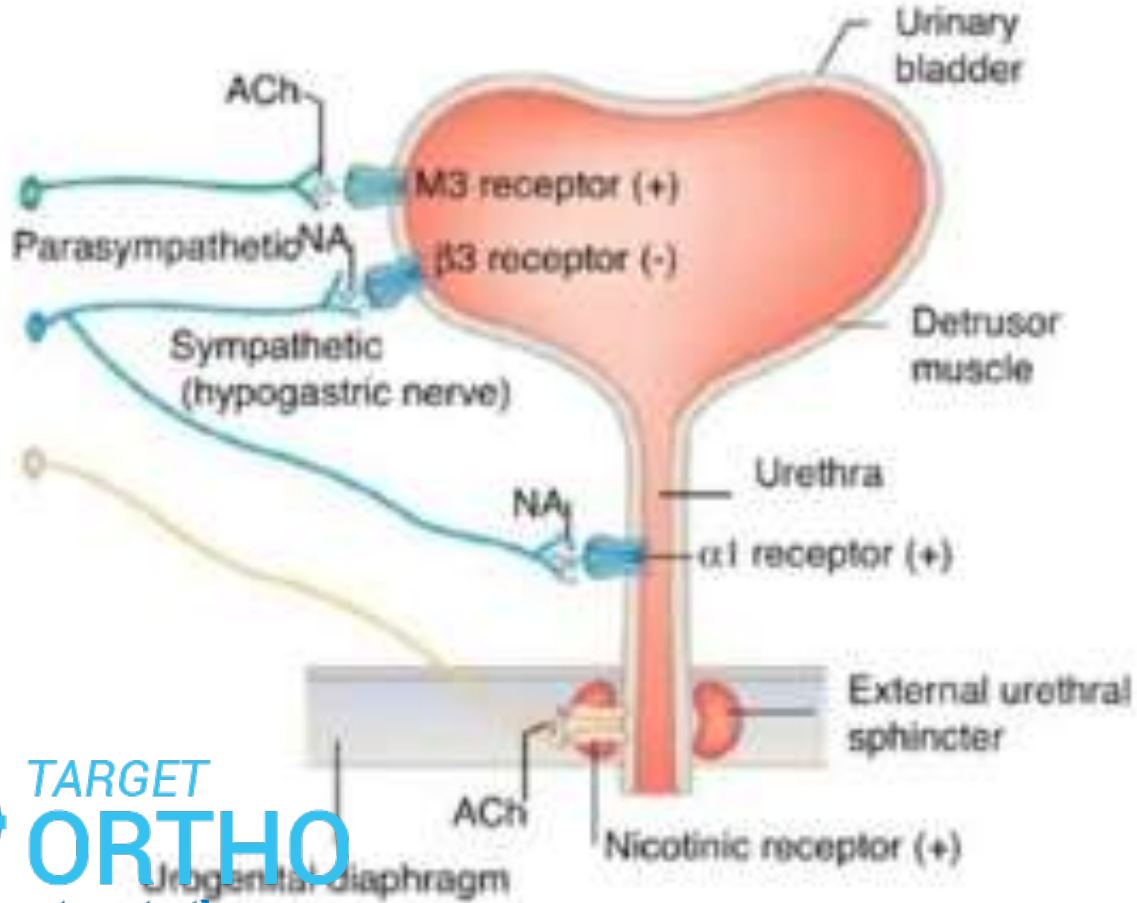
Underactive

PVR, postvoid residual.

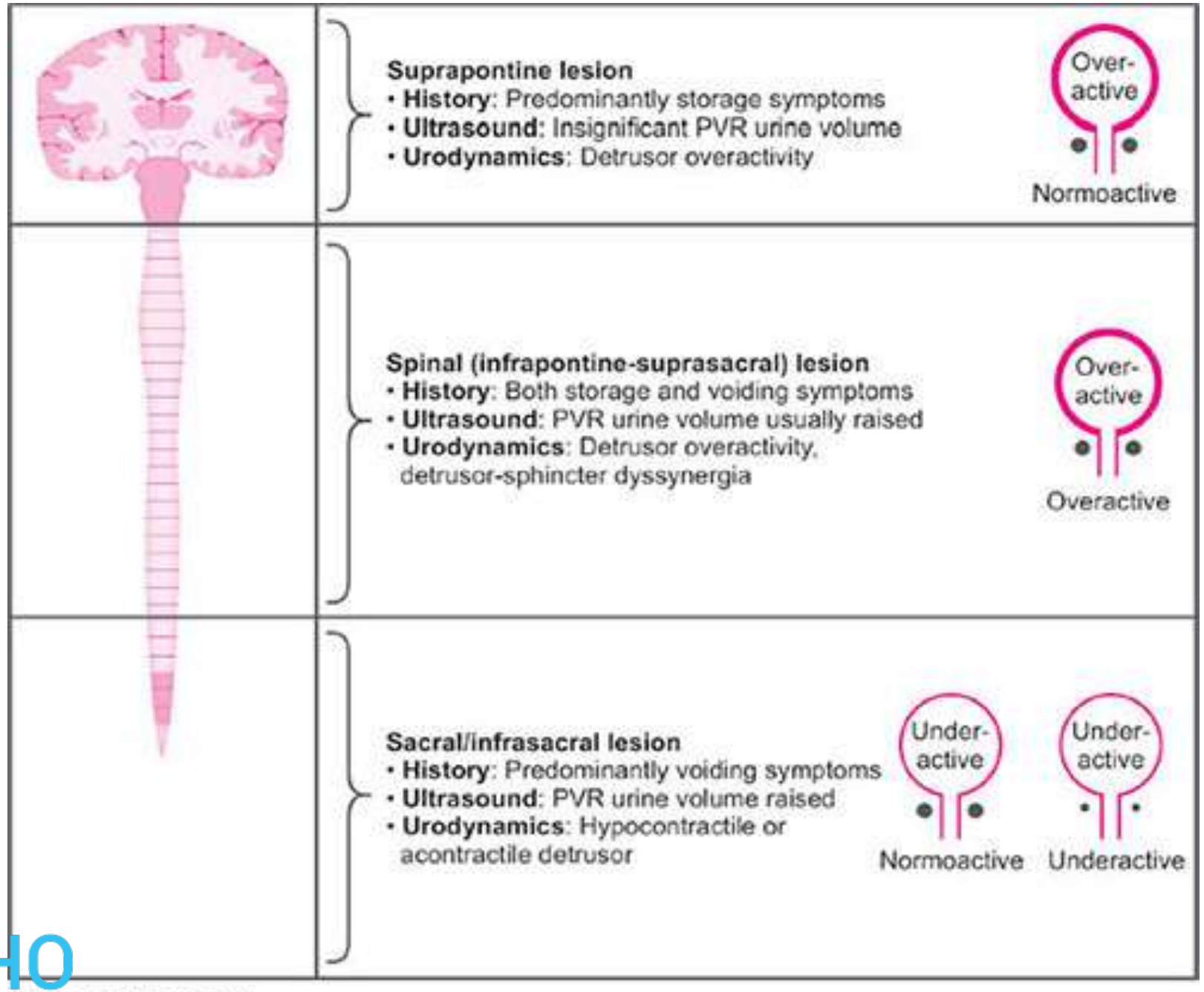
Non-Surgical Therapy for DSD: Alpha Blockers

- Terazosin
  - Alpha-1 antagonist
  - Dose- 5 to 10 mg/d
- Phenoxybenzamine
  - Alpha 1,2 antagonist
  - Dose- 30-40 mg/d
- Tamsulosin
  - Alpha 1a selective antagonist
  - Dose- 0.4 to 0.8 mg/d
- Prazosin
  - Alpha 2 antagonist
  - Dose- 5mg tid

Beta-3 Adrenergic Agonists



- Mirabegron (Myrbetriq)
  - B_3 Adrenergic Agonist
  - Detrusor Relaxation
- Clinically relevant P_{det}
  - In combination with established antimuscarinic or onabotulinum therapy
  - Improved bladder capacity and detrusor compliance



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PVR, postvoid residual.

ANTICHOLINERGIC DRUGS

- Anticholinergic drugs such as Propantheline, Oxybutynin, Tolteridone, Tropsium etc can be used orally
- Oxybutynin has some local smooth ms. relaxing and local anesthetic effect
- Tolterodine (comp. antagonist) & Tropsium (selective antagonist) have fewer anticholinergic adverse effects
- TCAs- They have additional effect on the internal sphincter by preventing NER reuptake- Caution AD
- Darifenacin- Muscarinic receptor antagonist

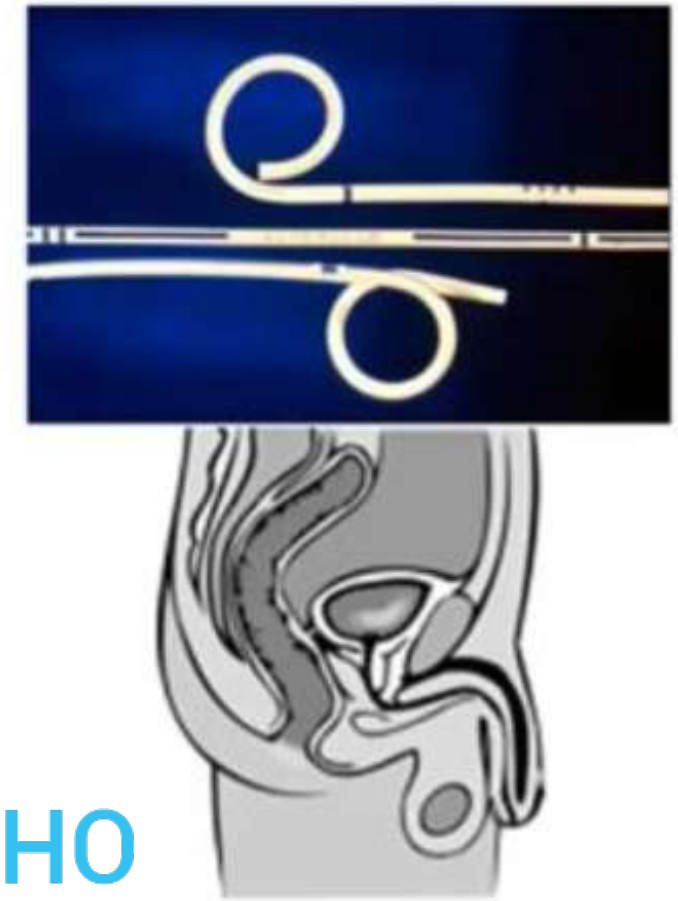
SURGERY -FACILITATES BLADDER OUTFLOW

Botulinum Toxin Injection

- Consider sphincter injection in those with detrusor-sphincter dyssynergia
- Consider injecting into detrusor muscle in those with detrusor hyperactivity
- Onset in one week; lasts 3-6 months

SURGERY -FACILITATES BLADDER OUTFLOW

Endourethral Stents



- Endourethral Stent
  - Tube holds urethra open
  - Continuous bladder drainage
  - Requires Condom Catheter
  - Alternative to External Sphincterotomy
- Consider in individuals who:
  - Can't do intermittent catheterization
  - Can use condom catheters
  - Have repeated autonomic dysreflexia
  - Experience difficult catheterization
  - Have inadequate bladder drainage
  - Have prostate-ejaculatory reflux
  - Can't use anticholinergic meds with intermittent catheterization
  - Can't use alpha blockers

SURGERY -FACILITATES BLADDER OUTFLOW

TURS (Sphincterotomy)

- Transurethral Resection of the External Urinary Sphincter
- AKA sphincterotomy
- External sphincter is cut to allow free flow of urine
- Must use condom catheter
- Same eligibility as for stent

SURGERY -FACILITATES BLADDER OUTFLOW

Electrical Stimulation

- Sacral nerve stimulation causes bladder contraction
- Electrodes are implanted surgically in the spinal canal
- Procedure usually combined with posterior sacral rhizotomy (cutting afferent nerve root)
- Useful in those with bladder hyperactivity along with catheter problems

Surgical managment

- **Surgery to promote urine storage**

-Increasing functional bladder capacity

1.Botulinum toxin-

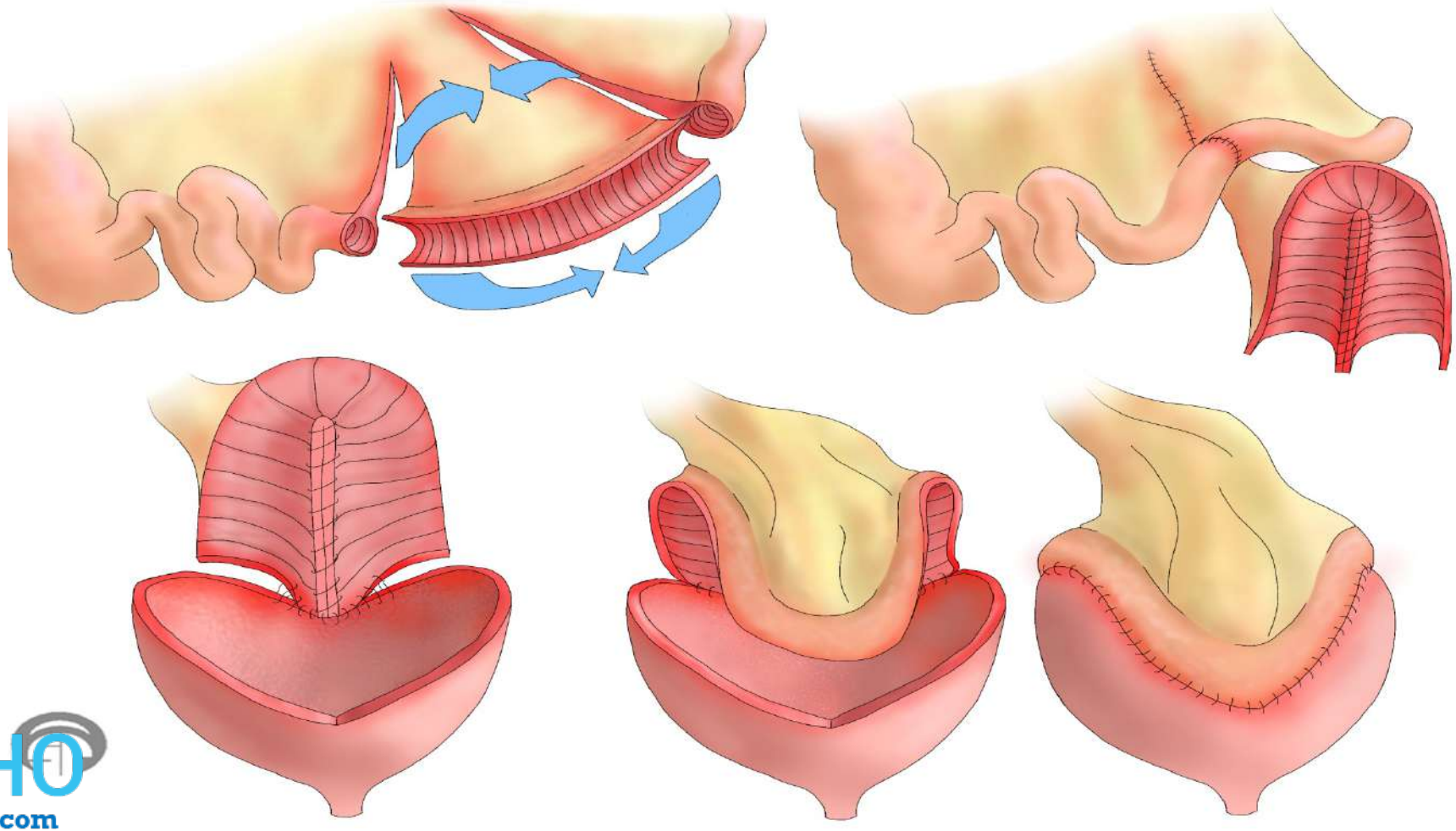
-minimum invasive.

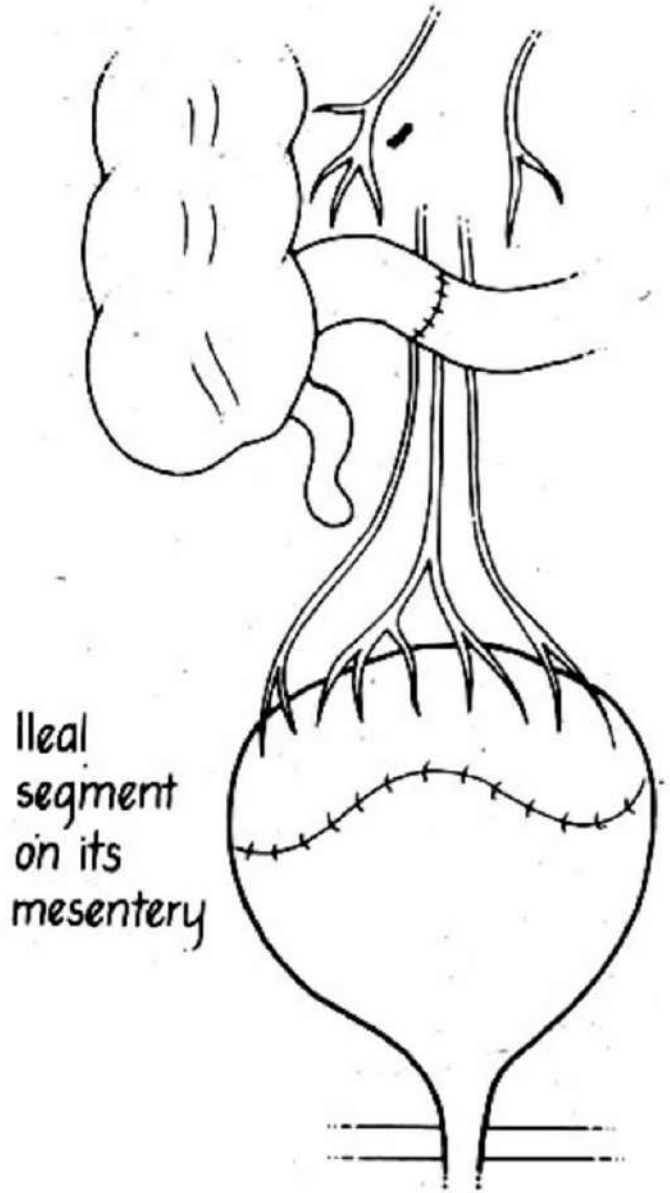
-200/300 units .

-increases reflex volumes, bladder capacities, and decreased maximum detrusor voiding pressures.

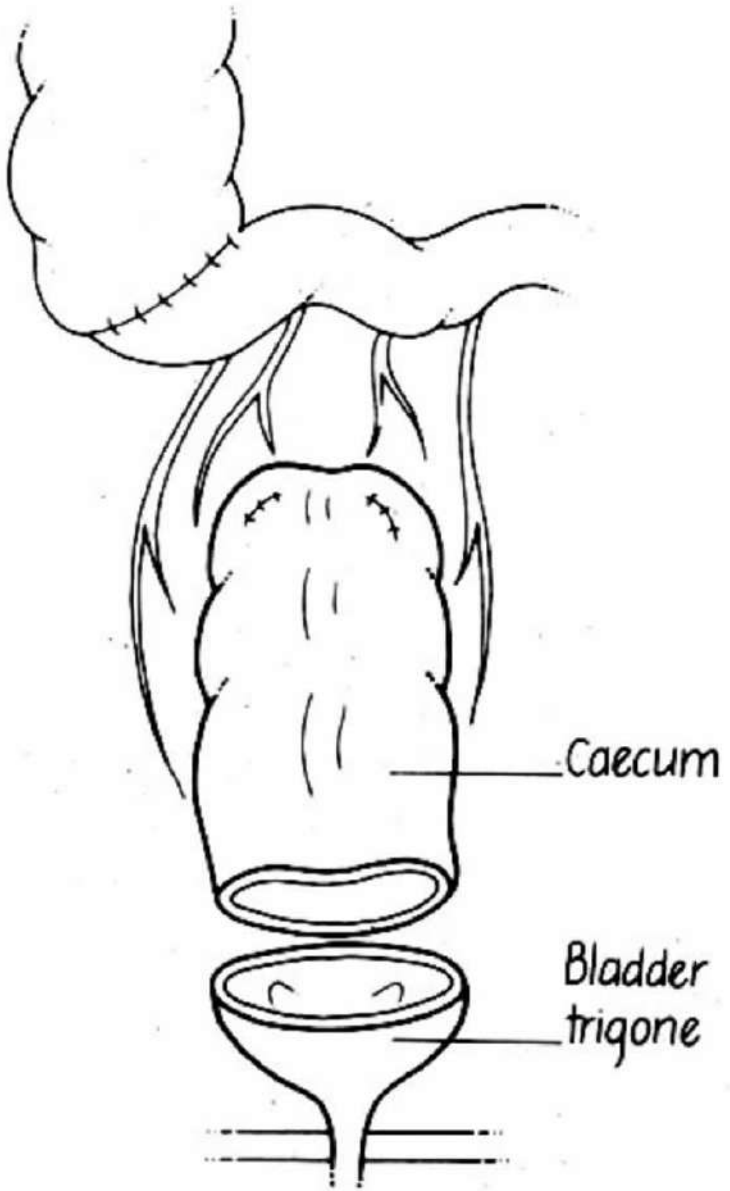
2. Cystoplasty

- A. Augmentation cystoplasty / enterocystoplasty

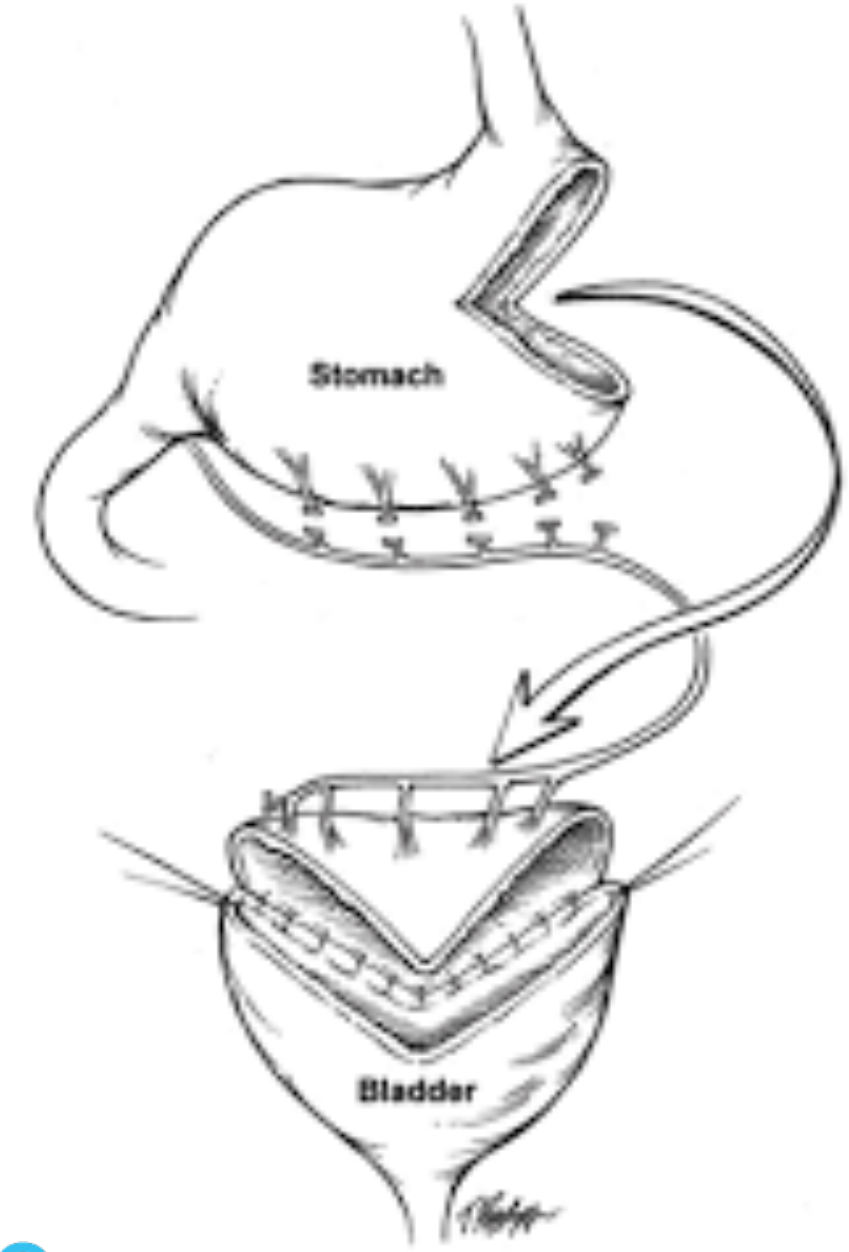




'Clam' ileocystoplasty

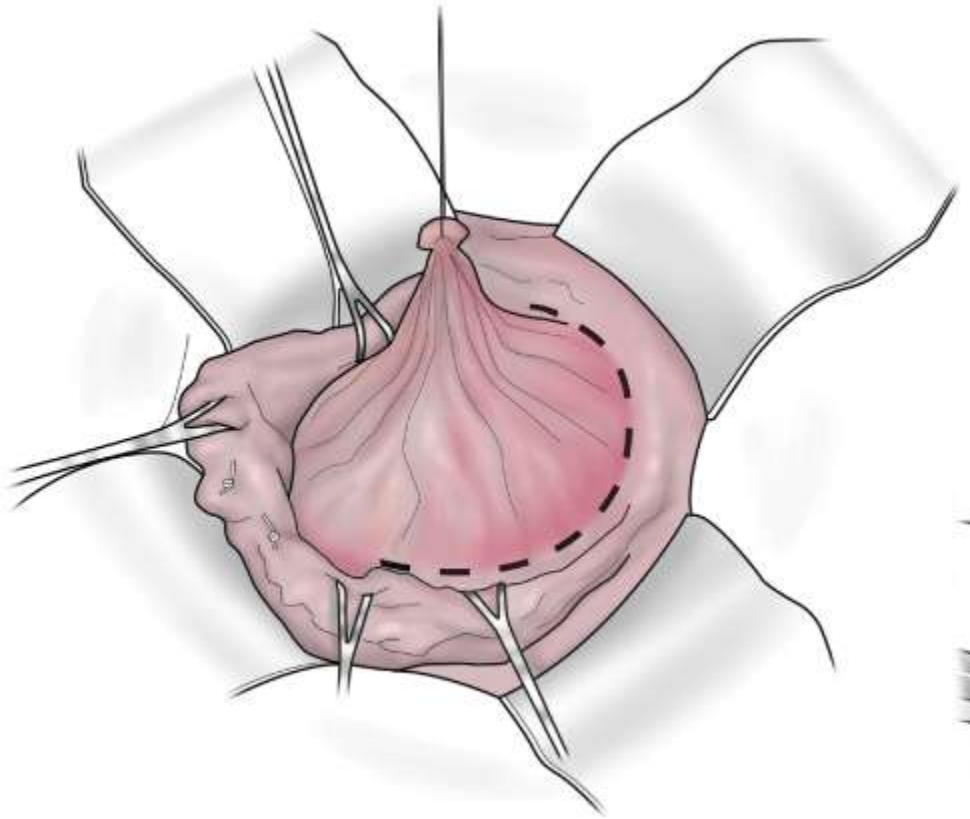


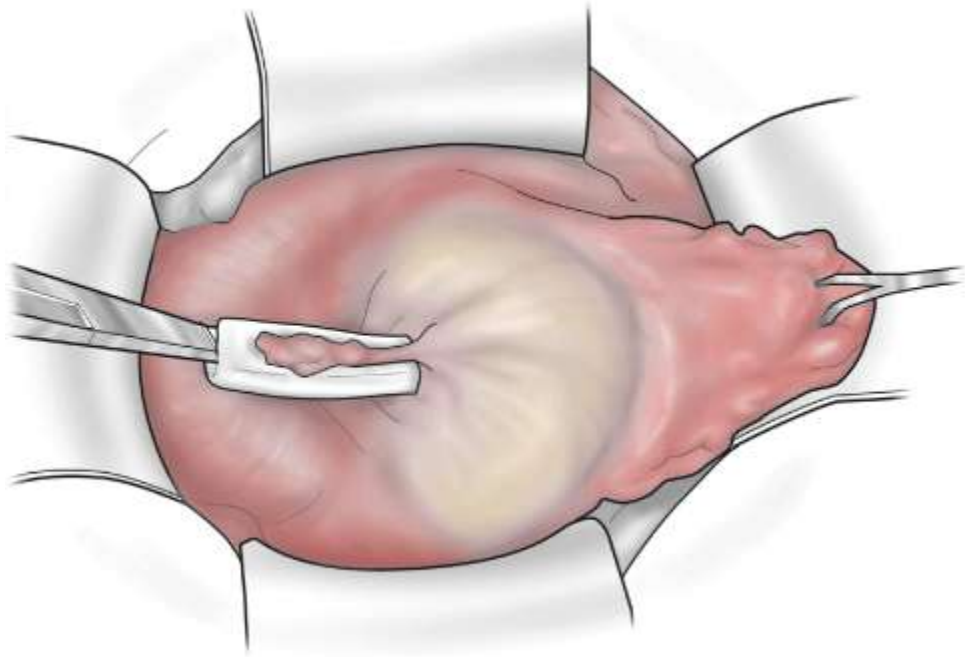
Caecocystoplasty



cystoplasty

c. Autoaugmentation (detrusor myectomy/myotomy)



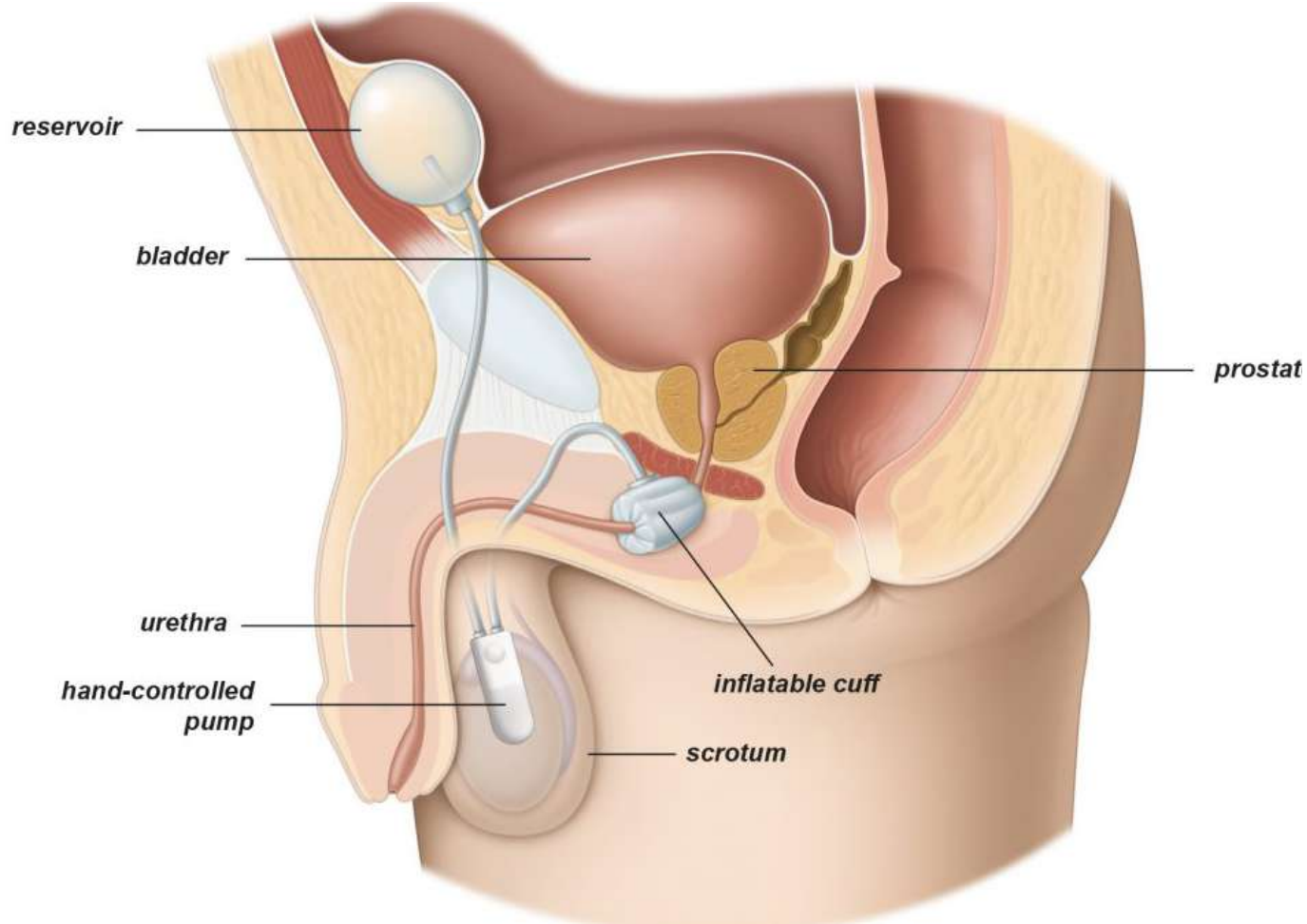


Increasing bladder outlet resistance

- Artificial urinary sphincter
- Slings :- (transvaginal tape vs. transobturator tape)
- Bulking agents :-Dextranomer, hyaluronic acid, bovine fat, polytetrafluoroethylene and collagen
- Neuromodulation

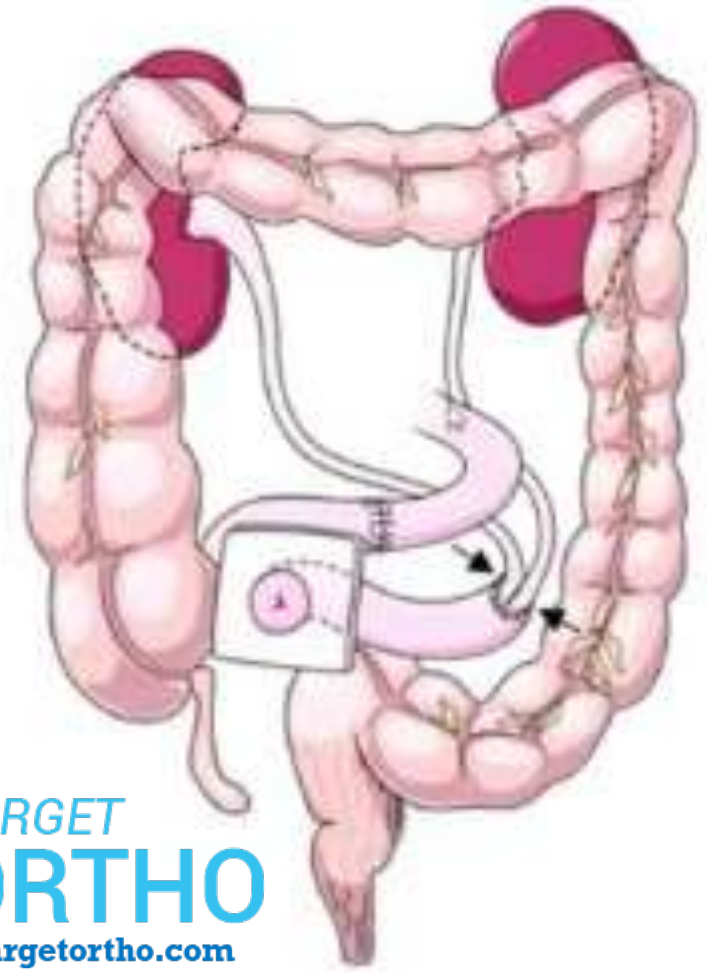
2. Increasing bladder outlet resistance

- A. Artificial urinary sphincter



SURGERY –SALVAGE PROCEDURES

Continent Urinary Diversion



- Continent Urinary Diversion
  - A segment of bowel connects ureters to abdominal wall
  - A stoma on lower abdominal wall allows catheterization
  - Useful in those who can't catheterize urethra
- Alternative: Urinary Diversion
  - As above, with external appliance
  - Ileovesicostomy
    - Bowel segment connects bladder to abdominal wall: External Appliance
    - May require 2 procedure to maintain urethral continence
  - Ureteroileostomy
    - Bowel segment connects ureters to abdominal wall

OTHER METHODS

- Microvascular transplantation of the latissimus dorsi muscle to wrap the bladder
- Nerve grafting/nerve transfer-innervate the bladder below the level of complete SCI to produce urination by Achilles tendon-to-bladder reflex contractions via an intact S1 dorsal root.
- Urethral stents-UROLUME STENTS
- Bladder tissue engineering