Physiology of ureter and renal pelvis

Transport of urine from renal pelvis to bladder active process requiring:
- Pacemaker cells
- Propagation of electrical impulse
- Adequate mucosal coaption
- Intraluminal pressure > bladder pressure

Electrical activity

Development of resting membrane potential dependent on K+
- Inside K⁺; outside Na⁺: K⁺ leaks out of cell down concentration gradient through open potassium channels.
- Electrochemical gradient thus set up with inside negative cf. outside, stopping further K⁺ efflux
- Typical resting membrane potential of ureteral cell = -30mV to -70mV

Depolarisation in pacemaker cells:
- Pacemaker cells located near pelvicalyceal border
- Pacemaker cells differ from ordinary cells in that Na⁺ permeability is unchanged by depolarisation
- Opening and slow closure of Ca⁺ channels offset by opening and slow closure of K⁺ channels alone, leading to rhythmic depolarisation and repolarisation

Believed that prostaglandins and tachykinins (prostanoids) regulate/amplify pacemaker cell activity
- Propagation of depolarisation via intermediate/gap junctions; speed 2-6cm/s [NB. ureter 22-30cm long in adults]; frequency of driven action potentials 3-5/min

Depolarisation in non-pacemaker cells:
- Opening of Na⁺ and Ca⁺ channels; closure of K⁺ channels
- Na⁺ in fast, Ca⁺ in slow – rapid depolarisation then plateau
- Raised cytosolic Ca⁺ stimulates smooth muscle contraction*
- Raised intracellular Ca⁺ re-opens voltage-gated K⁺ channels
- Rapid K⁺ efflux repolarises cell**

* depolarisation also transmitted via tubules to endoplasmic reticulum stimulating Ca release
** restoration of electrolyte balance by Na⁺/K⁺ ATPase and cAMP (drives Ca⁺ back into endoplasmic reticulum)
Mediators of peristaltic activity

<table>
<thead>
<tr>
<th></th>
<th>Contraction</th>
<th>Relaxation</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neuromodulators</strong></td>
<td>Alpha-adrenoceptor</td>
<td>Calcitonin gene-related peptide</td>
</tr>
<tr>
<td></td>
<td>Tachykinins</td>
<td>Beta-adrenoceptor</td>
</tr>
<tr>
<td></td>
<td>Histamine</td>
<td>PGE1 and PGE2*</td>
</tr>
<tr>
<td></td>
<td>Angiotensin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>? cholinergic stimulation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>? serotoninergic</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PGF2a</td>
<td></td>
</tr>
<tr>
<td><strong>Drugs</strong></td>
<td>? opiates</td>
<td>Progesterone</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Calcium channel blockers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Potassium channel openers (nicorandil)</td>
</tr>
</tbody>
</table>

* Surprisingly NSAIDs have not been shown to affect frequency of strength of ureteric contraction. They are believed to work by inhibiting prostaglandin mediated afferent arteriolar dilatation (reducing pelvic pressure and therefore pain) and reducing ureteric inflammation.

Urine transport
At normal urinary flow boluses of urine are formed by peristaltic waves
Resting ureteric pressure = 0 - 5 cm water
Peristatic waves = 20 – 80 cm water
Frequency = 2 – 6 times per minute
At very high flow rates, mucosal walls do not coapt and urine transported as a continuous column
Decompensation when bladder pressure > 40cm water
Appendix

Smooth muscle relaxation

[Diagram of smooth muscle relaxation]

Smooth muscle contraction

[Diagram of smooth muscle contraction]