Long Term Catheter Maintenance

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Aims and Introductions

Aims

1. Discuss basics of catheter design and use
2. Discuss common catheter complications and their management
3. Discuss the science behind infection and encrustation in detail

Who am I?
Section 1

The basics
Catheter Design

Lengths are standard (~40cm) or female (~25cm)

Width measured in the Charrière or French scale, which is three times the diameter in mm
Usually available in even numbered widths from 6 to 24
Smaller paediatric catheters introduced on stilets

Fig. 1. Schematic, perspective and sectional drawing showing the design of the “self-retaining bag catheter.” The distention duct lies in the catheter wall, opens within the bag cavity and has a proximal end extension for convenience in attaching a syringe to distend the bag.
Catheter Materials

Some PVC models available, but usually constructed from natural rubber latex or silicone.

Silicone becoming more popular as do not have same allergy problem as latex.

Compared to latex, silicone:

- Stiffer, so thinner walls and wider lumen
- Permeable, so balloon spontaneously deflates
- Deformable, so balloon does not deflate flat
- Expensive
Catheter Manufacture

Latex catheters formed by repeated dipping of former rod into liquid latex. Balloon added before final dipping

Silicone catheters extruded as continuous tube, cut to length, and the tip and drainage connectors bonded to each end. Balloon attached to the outside of the tube, so this is widest part of catheter even when deflated.

Before and after use picture of silicone catheters showing the deflated balloon
Silicone catheters have good surface properties and are usually not modified.

Modern latex catheters are usually coated, largely to reduce friction, using:

- PTFE (Teflon)
- Silicone elastomer
- Hydrogels

Siliconised latex catheters treated with silicone oil as a temporary lubricant - they’re basically plain latex.

Antibacterial agents can be added to coatings.
Catheter Uses

Short term:

- Temporary bladder drainage during illness
- Usually in hospital
- PTFE coated latex or antimicrobial coated catheters
- Major complication is catheter associated urinary tract infection (CAUTI)

Long term:

- Varily defined as > 1 month or > 3 months, but essentially permanent
- Usualy in community
- Hydrogel or silicone coated latex and 100% silicone catheters
- Major complication is catheter encrustation
Catheter Complications

Usually of more concern in long term catheterisation:

- Traumatic hypospadias
- Urethral stricture - *use an SPC in those expected to void normally again*
- Frank haematuria - *30% of LTC users*
- Pain - *70% uncomfortable, 20% worse than 50% on visual analogue scale*
- Overactive bladder
- Bladder stones - *50% of those with encrustation*
- Encrustation - *40-50% of LTC users*
- Catheter associated urinary tract infection - *universal*
Section 2

Diagnosing and referring complications
Communication

Be assertive and proactive when dealing with doctors – they’re not the experts

Ask for more detailed discharge summaries
Tell the GPs what to write
Explain diagnoses (with reasons)
Suggest investigation and treatment plans
The ‘Blocked’ Catheter

Causes of a non-draining catheter:

- Twisted tubing
- Siphon effects
- Mucus plugging
- Catheter encrustation
- Bladder spasm

History is useful, pH isn’t, but gold standard is *cut the catheter open*. 
Section 3

Non-infective complications
Bladder Spasm

Overactive bladder
Older people
Neurological disease
Spinal cord injury

Some catheter users have a catheter fitted because of an overactive bladder - it hasn’t cured the problem
Bladder Spasm

May respond to:

- Caffeine and alcohol avoidance
- Bowel care
- Softer or smaller catheter or catheter balloon

Often needs anticholinergics at high doses

If that fails, could consider:

- Botulinum toxin
- Urinary diversion
Other Catheter Blockages

Siphon effects
Tube kinking or compression
Mucus plugging
Visible Haematuria

Only 3% of referrals
Occurs in 30% of long term catheter users

Ignore invisible haematuria
Don’t treat as UTI without systemic signs
New, recurrent, visible haematuria is worth investigating once

If no serious cause, 5ARIs or suprapubic catheterisation work in men
Discomfort

69% of users rate catheters ‘uncomfortable’

19% rate pain >50% on Visual Analogue Scale

Best solution is an SPC...
Discomfort

Suprapubic sites also often very tender
Catheter Expulsion

Recurrent spontaneous expulsion of a fully inflated catheter balloon needs a suprapubic catheter or pads…

…and often both
Suprapubic Catheters

SPCs don’t:

• Prevent most infections
• Prevent encrustation and stone formation
• Prevent bladder spasm

They’re useful for:

• Reducing discomfort and easing catheter changes (usually)
• Extending catheter life with wide bore catheters
• Preventing urethral damage and expulsion
• Preventing haematuria in men
• Reducing scrotal infections in men

May still have problem with urethral leakage in women:

• Try bladder spasm strategies
• Otherwise need a urethral closure procedure
Difficult Catheter Changes

Unable to insert

- Where’s it getting stuck - prostate or stricture, skin or linea alba?
- In general, go stiffer for SPCs and floppier for urethral catheters
- Go thinner for skin or meatal problems, then refer to hospital for dilatation electively
- If that doesn’t work, refer to hospital, sometimes as an emergency – put in a urethral catheter for SPC users if possible
- Next time, remember it’s always easier to insert into a slightly filled bladder

Unable to deflate balloon

- Does the valve work? Can you put more fluid in?
- No - remove the valve (don’t cut the catheter)
- Yes - leave a syringe attached
- If that doesn’t work, refer to hospital non-urgently
Difficult Catheter Changes

Balloon deflated, still stuck

- Often silicone catheters used suprapubically, rarely external encrustation
- Refill and empty balloon slowly
- Leave 1-2 ml in balloon
- Pull and twist
- If that doesn’t work, refer to hospital non-urgently, with balloon refilled if it’s an SPC

- Long term, consider latex catheters, integral balloons, or more frequent changes
Section 4

Infected complications
Catheter Associated Infection

Assuming closed drainage is used...

Asymptomatic bacteriuria increases in frequency with length of catheterisation:

- Cumulative incidence ~ 3-10% per day
- ~ 50% at 10 days
- > 90% at 28 days
- Essentially 100% in long term users

Urinary catheters leading source of nosocomial UTI, because very commonly used devices (~10% inpatients)

Possibly around 5% of those catheterised in hospital develop symptomatic UTI
Mechanics of Colonisation

Bacteria move up the catheter as an extending biofilm (shown in green)

- This is slow normally, such as on the external surface of the catheter
- In the catheter lumen, turbulent flow of the urine seeds bacteria ahead of the main biofilm - these form microcolonies which eventually fuse and speed up extension of the biofilm

A closed drainage system eliminates the intraluminal route
Planktonic Bacteria

Free floating planktonic bacteria
Bacterial Biofilm

Sheets of bacteria in a matrix on catheter surface
Forms a layer with a controlled local environment
Phenotypically distinct, slow growing bacteria
Catheter Encrustation

40-50% of all long-term catheter users
Urinary tract colonisation with urease positive bacteria
Rise in urinary pH
Precipitation of calcium and magnesium containing crystals
Blockage of catheter with crystalline deposits
Crystalline Bacterial Biofilm

Formation of crystals within the biofilm matrix
Protected from changes in urine chemistry
# Urease Producers

### Gram-negative bacteria
- Bacteroides corrodens
- Helicobacter pylori
- Bordetella pertussis
- Bordetella bronchiseptica
- Haemophilus influenzae
- Haemophilus parainfluenzae
- Proteus species
- Providencia stuartii
- Klebsiella species
- Pasteurella species
- Pseudomonas aeruginosa
- Aeromonas hydrophilia
- Yersinia enterocolitica
- Brucella species
- Flavobacterium species
- Serratia marcescens
- Ureaplasma urealyticum
- Mycoplasma T-strain

### Gram-positive bacteria
- Staphylococcus aureus
- Staphylococcus epidermidis
- Corynebacterium species
- Mycobacterium rhodochrous group
- Micrococcus varians
- Bacillus species
- Clostridium tetani
- Peptococcus asaccharolyticus

### Yeast
- Cryptococcus species
- Rhodotorula species
- Sporobolomyces species
- Trichosporon cutaneum
- Candida humicola

Catheter encrustation most strongly associated with *Proteus* species
Urease catalyses the hydrolysis of urea

\[
\text{H}_2\text{NCONH}_2 + \text{H}_2\text{O} \rightarrow 2\text{NH}_3 + \text{CO}_2
\]

\[
2\text{NH}_3 + \text{H}_2\text{O} \leftrightarrow 2\text{NH}_4^+ + 2\text{OH}^-
\]
Struvite and Carbonate Apatite

**Struvite:** MgNH$_4$PO$_4$

**Carbonate apatite:** Ca$_5$(PO$_4$,CO$_3$)$_3$
Infecting Organisms

Short term catheterisation organisms:

- 50% *E coli*
- Remainder a mix of *Staphylococcus, Enterococcus, Pseudomonas, Klebsiella* and *Proteus*

All long-term catheterised individuals have positive urine cultures

- 95% with more than one organism
- Up to 40% with *Proteus* species

Need to be sure of difference between:

1. Asymptomatic urinary tract colonisation
2. Symptomatic urinary tract infection
Section 5

Strategies for controlling infection
Preventing Infection

Shown to reduce infection rates:

• Closed drainage system

Shown to not reduce colonisation rates:

• Daily meatal or perineal antibacterial washes*
• Adding antibacterials to drainage bags*
• Antibacterial catheter/bladder washouts*

Shown to reduce colonisation rates but not infection:

• Systemic antibiotics* - delay colonisation a few days but rates catch up to same level as if no treatment

* promote emergence of multi drug resistant organisms
Antimicrobial Catheters

Two main types available:

- Silver Alloy
- Nitrofurazone

Aimed at short term hospital market to reduce nosocomial CAUTI

- Both types of catheter show reductions in asymptomatic bacteriuria in those catheterised less than one week (relative risks around 0.5-0.6).
- Silver catheters may have more prolonged effect than nitrofurazone, but no head to head (yet).
- Small trial of nitrofurazone catheter long term shows no benefit.

- Trials show economic benefit from silver alloy catheters.

- Trials not looked at emergence of resistance
Nitrofurazone

Mechanism of action

• Similar to nitrofurantoin
• Reduced intracellularly, with multiple target sites in bacterial metabolic pathways

Long use topically with no evidence of increasing resistance. Similar results with nitrofurantoin.

Several common urinary organisms intrinsically resistant:

• *Proteus*
• *Pseudomonas*
• *Klebsiella, Serratia, Enterobacter*

Bacterial overgrowth has been noted in topical treatment
Silver

Mechanism of action

• Multiple sites of action
• Binds to sulphur, oxygen and nitrogen containing groups
• Displaces other metal ions

Bioavailability reduced by many factors in urine

Resistance well recognised

• Plasmid mediated and linked to other resistance genes
• Porin modifications and efflux pumps implicated
• Resistance lost rapidly on removal of silver
• Not known to be clinically important
Symptomatic CAUTI

Really need to measure symptomatic CAUTI

<table>
<thead>
<tr>
<th>Symptom</th>
<th>No Infection (n=945)</th>
<th>Bacteriuria (n=89)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td>5.9 %</td>
<td>4.8 %</td>
</tr>
<tr>
<td>Urgency</td>
<td>7.6 %</td>
<td>6.0 %</td>
</tr>
<tr>
<td>Dysuria</td>
<td>8.0 %</td>
<td>6.0 %</td>
</tr>
<tr>
<td>Temp &gt; 38.5 °C</td>
<td>19.8 %</td>
<td>17.7 %</td>
</tr>
</tbody>
</table>

Difficult to diagnose UTI on symptoms
Has implications for economic evaluations

Tambyah & Maki (2000)
Antimicrobial Long Term Catheters

For both types of catheter:

Biofilms can be effectively grown on them in in vitro bladder models

Catheters removed from long term catheter users show normal levels of biofilm development
Investigations and Treatment

Most febrile episodes settle in less than 24 hours without antibiotics.

Do not need to treat:

- discoloured or foul smelling urine
- Haematuria
- positive urine cultures (even if an ESBL producer)
- feeling a bit off.

Those with recurrent, prolonged, febrile infections need investigating for treatable causes such as bladder or staghorn renal stones.

Otherwise, can treat the more severe cases as per normal recurrent UTIs, but beware higher risk of resistance emerging, or turning someone into an encruster.

For epididymitis or periurethral abscess, fit an SPC.
Section 6

Strategies for controlling encrustation
Current Treatment Strategies

Can we cure encrustation?

Eradicate bacteria
Acidify urine
Inhibit urease
Increase catheter lumen
Pre-empt blockage
Increase urine output
Eradicate bacteria

Antibiotics do not remove biofilm resident organisms
They do promote emergence of resistance

<table>
<thead>
<tr>
<th>bacteria isolated before</th>
<th>antibiotic</th>
<th>bacteria isolated after</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Pr. mirabilis</em>, <em>Ent. faecalis</em>, <em>E. coli</em></td>
<td>amoxicillin</td>
<td><em>Ent. faecalis</em></td>
</tr>
<tr>
<td><em>Ent. faecalis</em>, <em>E. coli</em>, <em>Kl. pneumoniae</em>, <em>Staph. aureus</em></td>
<td>minocycline</td>
<td><em>Pr. mirabilis</em>, <em>Ent. faecalis</em>, <em>Staph. aureus</em></td>
</tr>
<tr>
<td><em>Pr. mirabilis</em>, <em>Ps. aeruginosa</em></td>
<td>co-amoxiclav</td>
<td><em>Pr. mirabilis</em>, <em>Ps. aeruginosa</em></td>
</tr>
<tr>
<td><em>Pr. mirabilis</em>, <em>Ps. aeruginosa</em></td>
<td>ciprofloxacin</td>
<td><em>Pr. mirabilis</em>, <em>Ps. aeruginosa</em></td>
</tr>
<tr>
<td><em>Pr. mirabilis</em>, <em>Ent. faecalis</em>, <em>Ps. aeruginosa</em>, <em>E. coli</em></td>
<td>ciprofloxacin</td>
<td><em>Pr. mirabilis</em>, <em>Ent. faecalis</em>, <em>Ps. aeruginosa</em>, <em>E. coli</em></td>
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<td><em>Pr. mirabilis</em>, <em>Ent. faecalis</em>, <em>Ps. aeruginosa</em>, <em>E. coli</em></td>
<td>clarithromycin, ciprofloxacin</td>
<td><em>Pr. mirabilis</em>, <em>Ent. faecalis</em>, <em>Ps. aeruginosa</em></td>
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<tr>
<td><em>Pr. mirabilis</em>, <em>Ent. faecalis</em>, <em>Kl. pneumoniae</em>, <em>Ps. aeruginosa</em></td>
<td>trimethoprim</td>
<td><em>Pr. mirabilis</em>, <em>Ent. faecalis</em>, <em>Kl. pneumoniae</em>, <em>Ps. aeruginosa</em></td>
</tr>
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</table>
Urinary acidification

Cranberry juice and ascorbic acid
Cannot acidify urine orally

Acidic catheter maintenance solutions
Some effect in *in vitro* trials
No effect in clinical trial
Biofilm protected crystals do not dissolve in acid conditions
Possible damaging effects on urinary tract
Urease inhibitors

Acetohydroxamic acid
Works, but very high side effect profile

Other, newer inhibitors may be a promising strategy in the future
Pre-emptive catheter changes

*Whatever else you do, recognise that the catheter will eventually block*

1. Work out an expected catheter lifespan
2. Change the catheter more often than this
3. Plan strategies to cope with unexpected blockage
Bladder calculi

50% of encrusters have stones
All stone formers have encrustation

Most bladder stones will show up on plain X-ray, some on USS, and all on CT or cystoscopy
Treating bladder calculi

Debris is common
Small stones can be removed with a basket at cystoscopy (73%)
Larger stones require (usually endoscopic) surgery

How much does it help?
Variation Between Heavy Encrusters and Light Encrusters

What is responsible for the differing encrustation rates between catheter blockers?
Voided pH

Catheter blockers tend to have a higher voided pH than non-blockers

Encrusts do not always void at an alkaline pH

Non-encrusts do not always void at an acidic pH
Nucleation pH

Urinary pH above which crystals precipitate
Nucleation pH variation

Not always 6.8
Varies from <6 to >10
Varies from week to week in some patients
Significance of variability

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Patient category</th>
<th>p value for difference between the mean values for slow and rapid encrusters</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rapid encrusters</td>
<td>Slow encrusters</td>
</tr>
<tr>
<td>mean $pH_v$</td>
<td>7.20</td>
<td>6.91</td>
</tr>
<tr>
<td>mean $pH_n$</td>
<td>7.32</td>
<td>8.08</td>
</tr>
<tr>
<td>mean safety margin</td>
<td>0.13</td>
<td>1.17</td>
</tr>
</tbody>
</table>

The graphs show the relationship between catheter lifespan (days) and voided pH, as well as nucleation pH.
Increase urine output

Should work, but difficult
Probably need to ensure consistently high output 24 hourly
Future Strategies

Probably won’t work:

• Antimicrobials
• Acidification

Worth a closer look:

• Novel urease inhibitors
• Physical properties of catheter coatings
• Bacterial interference
• Chelation