In Vitro Performance of Long-Term Hemodialysis Catheters

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Does tip design affect the performance of a hemodialysis catheter?
- Recirculation
- Tip stability
- Blood flow turbulence

Catheter Tip Design

Step-tip

Split-tip

Tip Design to Decrease Recirculation

<table>
<thead>
<tr>
<th>A/V Offset</th>
<th>Recirculation</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0cm</td>
<td>8.4%</td>
</tr>
<tr>
<td>2.5cm</td>
<td>4.4%</td>
</tr>
<tr>
<td>3.0cm</td>
<td>2.4%</td>
</tr>
</tbody>
</table>

Separation of Inflow from Outflow

Direction of blood flow in superior vena cava

Outflow jet from venous lumen

Separation of arterial and venous end holes
Symmetric tip design
Decreases recirculation if blood lines are connected in reverse configuration

Specific Features of Hemodialysis Catheter Tip Design

Description of Hemodialysis Catheters

<table>
<thead>
<tr>
<th>Name</th>
<th>Size</th>
<th>Length</th>
<th>Tip Design</th>
<th>A/V Offset</th>
<th>Sideholes</th>
<th>Split Length</th>
</tr>
</thead>
<tbody>
<tr>
<td>ProGlide</td>
<td>14.5</td>
<td>19 cm</td>
<td>step</td>
<td>30mm</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Titan</td>
<td>15.5</td>
<td>24 cm</td>
<td>step</td>
<td>25mm</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Ultrastream</td>
<td>15.5</td>
<td>28 cm</td>
<td>step</td>
<td>20mm</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Ash Split</td>
<td>14</td>
<td>28 cm</td>
<td>split</td>
<td>30mm</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>80mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Centros</td>
<td>15</td>
<td>24 cm</td>
<td>split</td>
<td>25mm</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>25mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hemosplit XK</td>
<td>16</td>
<td>23 cm</td>
<td>split</td>
<td>30mm</td>
<td>yes</td>
<td>45mm</td>
</tr>
<tr>
<td>Equistream</td>
<td>16</td>
<td>27 cm</td>
<td>split</td>
<td>12mm</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>43mm</td>
<td></td>
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<td></td>
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<td></td>
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</tr>
<tr>
<td>Palindrome</td>
<td>14.5</td>
<td>19 cm</td>
<td>symmetrical</td>
<td>11.5mm</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Reversus</td>
<td>15.5</td>
<td>33 cm</td>
<td>symmetrical</td>
<td>8.5mm</td>
<td>no</td>
<td></td>
</tr>
</tbody>
</table>

A/V offset of step tip catheters

Split length and A/V offset of split tip catheters

A/V offset of symmetrical catheters
ASDIN2014 Scientific Meeting

**Side holes:**
- Location
- Size & Shape
- Number

**Beveled tip**

**Flow Barriers**
- Thick horizontal flow barrier
- Thin vertical barrier separates midline of arterial end hole

**ProGlide**

**Ultrasound**

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**In Vitro Test System**

3 independent circuits

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**Vertical glass column simulated SVC**
- 24mm x 350mm
- Rate of blood flow through SVC = 2400ml/min

**Viscosity of Test Fluid**

<table>
<thead>
<tr>
<th>Hematocrit (%)</th>
<th>Viscosity (cp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1.4 (plasma)</td>
</tr>
<tr>
<td>30</td>
<td>1.8</td>
</tr>
<tr>
<td>40</td>
<td>2.3</td>
</tr>
<tr>
<td>50</td>
<td>2.9</td>
</tr>
</tbody>
</table>

1.0 centipoise = water
2.3 centipoise = blood with hematocrit = 40%
- no cellular components of blood
Measurement of Recirculation

Serial dilution of blue dye used for colorimetric calibration

dual channel optical sensor calibrated for 620nm and 800nm

Measurement of recirculation using indicator dye method
% recirculation correlated to absorption of blue dye
aspirated into inflow (arterial) lumen

Catheter Testing Protocol

The 9 hemodialysis catheters underwent 72 testing procedures

Each catheter was tested four times at each viscosity:
- twice with blood lines in standard configuration
- twice with blood lines in reverse configuration

Results

Equistream
Standard configuration
- Inflow = left limb
- Outflow = right limb

Equistream
Reverse configuration
- Outflow = left limb
- Inflow = right limb

Recirculation

None of the 9 catheters had recirculation with blood lines connected in standard configuration at both 1.0cP and 2.3cP fluid viscosity (water) (40% Hct)

With blood lines in reversed configuration, catheter tip design affected the rate of recirculation
Hemodialysis machine off
Hemodialysis machine on

Ash Split
Reversed configuration
jet of blood flow directed into inflow lumen
inflow lumen

Hemosplit
Reversed configuration
jet of blood flow directed into inflow lumen
venous end hole is inflow lumen

Centros
Reversed configuration
jet of blood flow directed into inflow lumen
inflow lumen

ProGlide
Reversed configuration
Turbulence flow exiting catheter caused tip movement
rate of blood flow in SVC = 2400ml/min

Palindrome
0% recirculation with standard and reverse blood lines

Recirculation Rate
| Symmetric | Palindrome | 0% |
| Symmetric | Reversus   | 0% |
| Split tip | Equistream | 0% |
| Step tip  | Ultrasound | 8.7% |
| Step tip  | Titan      | 9.4% |
| Step tip  | ProGlide   | 16.3% |
| Split tip | Centros    | 22.3% |
| Split tip | Hemosplit XX| 33.5% |
| Split tip | Ash Split  | 39.2% |
Observations

### Ash Split

- **Standard configuration**

- **Catheter tip moves against wall of SVC**

- **Hemodialysis machine off**

- **Hemodialysis machine on**

### Hemosplit XK

- **No movement of catheter tip with standard blood lines at flow rate = 425ml/min**

- **Hemodialysis machine off**

- **Hemodialysis machine on**

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**Hemosplit XK**

- **With reversed blood lines there is significant (3+) movement of catheter tip**

- **Aspiration caused venous end hole to adhere to SVC wall**

- **Hemodialysis machine off**

- **Hemodialysis machine on**

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**Hemosplit XK**

- **With reversed blood lines there is significant (3+) movement of catheter tip**

- **Aspiration caused venous end hole to adhere to SVC wall**

- **Hemodialysis machine off**

- **Hemodialysis machine on**
Hemosplit XK
Reverse configuration

Hemosplit XK
Reverse configuration

Ash Split
Reversed configuration

Thrombus can develop on any catheter tip

Summary
Currently available hemodialysis catheters have no significant recirculation when connected in the standard configuration.

Split tip-type catheters have >20% recirculation when connected in reversed configuration.

Catheter tip design influences catheter stability and the development of catheter tip thrombus.