What is Industry Doing to Help Us?
Filtration, **Oxygenators**, Monitoring

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Disclosure

- Employee of Sorin Group
- Engineer by training, not a clinician
Reducing Air Emboli via Oxygenator Design

Emboli and Perfusion Circuit: A Long History of Improvement:

- Bubblers and Disks
- Antifoam Agents
- Cardiotomy Filters
- Oxygenator Membranes
- Emboli reduction flow paths
- Centrifugal pumps
- Arterial filter technology
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What is Industry Doing to Help Us?

- Providing significant design improvements
- Review of relevant physics of emboli
- Information on optimal use techniques for specific products
- Broad perspective of clinical application & experience
- Support for specific clinical situations
- Conduit for sharing information and references
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Sources for Air Emboli in the Bypass Circuit:

<table>
<thead>
<tr>
<th>External:</th>
<th>Internal:</th>
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</thead>
<tbody>
<tr>
<td>– Venous line</td>
<td>– Splashing</td>
</tr>
<tr>
<td>– Sample manifold</td>
<td>– Turbulence / entrainment</td>
</tr>
<tr>
<td>– Suction blood</td>
<td></td>
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<tr>
<td>– Trans-membrane</td>
<td></td>
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<tr>
<td>– Incomplete priming</td>
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**Understanding Emboli Behavior:**

- **Size:**
  - Macro (visible): >100 microns?  Micro (not visible): <100 microns?

- **Forces: Volume, Buoyancy & Viscous Drag:**
  - Volume = \( \frac{\pi \cdot d^3}{6} \): Function of diameter cubed
  - Buoyancy: Proportional to emboli volume
  - Forces of fluid flow can negate buoyancy
    - Forces increase with square of velocity
  - Centrifugal forces and separation

- **Wall Thickness and Diameter:**
  - Ratio of \( t \) (thickness) to \( D \) (diameter)
  - Aggregation
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Reducing Embolic Load:

- **Entry reduction**
  - Minimize air from cannulation site
  - Avoid dry venous line
  - Appropriate use of vacuum
  - Monitor air in the circuit

- **Removal**
  - Devices with smaller pore size venous filter
  - Appropriate venous reservoir volume

- **Retention**
  - Centrifugal pumps
  - Arterial filters
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Understanding Design Differences:

• Venous Reservoir
  – Flow path and filter pore sizes
  – Volume for optimal air removal for flow rate
  – Low level vortexing characteristics

• Cardiotomy Filter
  – Flow path and pore sizes
  – Tendency to entrain from splashing or recirculation
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- **Oxygenator bundle**
  - Opportunity for air to move across membrane
    - TMP, membrane matrix, flow path
  - Membrane purge
    - Purge location and flow rate
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Ultimate Defense: A Combined Approach: Device + Technique

1. Understand physics of emboli and performance of your devices
2. Work with surgical team to minimize air entry at the table.
3. Carefully manage sample ports.
4. Sequester suction volume when possible.
5. Use venous reservoir with small pore size venous filter.
6. Increase volume in reservoir when not detrimental.
7. Use a centrifugal pump.
8. Understand oxygenator design and performance characteristics. Use them to advantage.
9. Use small pore size arterial filters.
10. Monitor and improve your technique.