Physics of Reservoir Bags
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Physics of Reservoir Bags

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Should we use the FGF of the Anesthesia Machine as a source of oxygen for Nasal Prongs or loose Mask?

No

The breathing circuit will not be ready to resuscitate from a respiratory emergency

Add a flowmeter somewhere
Temporary Solution - Flowmeter on the wall
Permanent Solution

Oxygen flowmeter on every Anesthesia Machine

Add-on
Permanent Solution

Oxygen flowmeter on every Anesthesia Machine

Add-on or Built-in

(Ohmeda Aestiva)
Should we use the **Y-piece** of the breathing circuit as a source of oxygen for Nasal Prongs?

No

The Physics does not work

* AKA Wye-piece
FGF Set to 8 LPM
Close the Relief Valve*

* AKA
Pop Off Valve,
APL (Adjustable Pressure Limiting) Valve
Insert an airway adapter to connect oxygen hose.
Oxygen hose here
But, we see and hear an alarm “Continuing Pressure”
Continuing

\[ P = 38 \text{ cmH}_2\text{O} \]
The bag grows bigger
And bigger
The FGF is still 8 LPM
So, I open the relief valve
And, I carefully adjust the relief valve to keep the bag constant and reasonable size, with No Alarm.
Pressure falls to 3 cmH2O.
I am content.
Experiment 2
How much flow was going to the nasal prongs?
I close the relief valve

I set the flow until pressure is 3 cmH$_2$O, just like before
The flow is 400 mL/min
The flow is 400 mL/min

That is what was flowing before

That is what is flowing now
The remainder of the 8 L/M Flow went out the pop off valve.
The patient was getting almost no supplemental oxygen
Flow and Pressure are related through Resistance

If the **pressure** is what it was before, and the **tubing** is what it was before, the **flow** must be what it was before.

Pressure was always 3 cmH$_2$O.
Flow was always 400 mL/min.
Remainder of the the 8 L/min flow went out the pop off valve!

Flow = Pressure / Resistance; $F = \frac{P}{R}$
When we close the relief valve

Reservoir bag properties are important

**Compliance** is the important property

Compliance = Change in Volume / Change in Pressure

\[
C = \frac{\Delta V}{\Delta P}
\]

Stiffness is 1 / Compliance

\[
S = \frac{\Delta P}{\Delta V}
\]
Bag Compliance is not constant
It varies with bag volume
Bag Compliance is not constant
It varies with bag volume

\[ C = \frac{\Delta V}{\Delta P} \]

When the bag is empty and filling \( P = 0 \)
Compliance is infinite \( C = \frac{2\ L}{0} = \infty \)

When the bag is full and stretching
Compliance has a value \( C = \frac{3\ L}{40\ \text{cmH}_2\text{O}} = .05 \)

When the bag has stretched further
Pressure does not rise
Compliance is infinite \( C = \frac{\Delta V}{0} = \infty \)
Bag Compliance is not constant

It varies with bag volume

\[ C = \frac{\Delta V}{\Delta P} \]

When the bag is empty and filling
Compliance is infinite \[ C = \frac{2 \text{ L}}{0} = \infty \]

When the bag is full and stretching
Compliance has a value \[ C = \frac{3 \text{ L}}{40 \text{ cmH}_2\text{O}} = .075 \]

When the bag has stretched further
Pressure does not rise
Compliance is infinite \[ C = \frac{\Delta V}{0} = \infty \]

How do our bags compare?
 Specifies a pressure of
35 - 60 cmH$_2$O
with bag at 4 x nominal size (4 x 3 = 12 L)
filled at 6 LPM (for 2 minutes)

Bag must revert to original size within 10%
Typical Reservoir Bags

<table>
<thead>
<tr>
<th>Product Description</th>
<th>Pressure (cmH₂O)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM Standard</td>
<td>P = 35 - 60</td>
</tr>
</tbody>
</table>
| Latex Blue                           | P = 48           | ✓
| Latex-Free Black                     | P = 54           | ✓
| Brand M Latex-free Green             | P = 46           | ✓
| Brand S Latex-free                   | P = 70           | X

X If a reservoir bag feels stiff, don’t use it.

The manufacturer voluntarily recalled this product.
Bag $P$ vs $V$ (Compliance) Curve

“3 L bag”

Pressure

42 cm H$_2$O

3 L Volume
Flow, Volume, Pressure, Time Relationship for anesthesia reservoir bag

- Flow (F)
- Volume (V): 3 L
- Pressure (P): 40 cmH₂O
- Time (t)
Bag stiffens, then softens

$S = \frac{dP}{dV}$

$42 \text{ cm H}_2\text{O}$

$3 \text{ L}$
The bag grows slowly as volume accumulates.
Pressure stays at 40 or, may fall to 30 cmH$_2$O
This bag grew to 285 L

Pressure was still 30 cmH$_2$O
Pop!
The End of the Bag
Pop!
The End of the Bag
And of this lecture
Thank you