Understanding & Managing Urine & Chest Drainage Systems

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Medical Update
University of Mauritius, Le Réduit, Mauritius
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Dedicated to the memory of Wilhelm (Bill) Schwab, PhD

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Disclosures

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- *As co-inventor of the Human Patient Simulator mannequin, I receive a fraction of the royalties that the University of Florida collects from the licensee CAE/METI*
- *As co-inventor of the Temperature Management System (TMS) cooling football pads, I receive a fraction of the royalties that the University of Florida collects from the licensee*

Undrained dependent loops in chest and urine drainage systems (clinical)

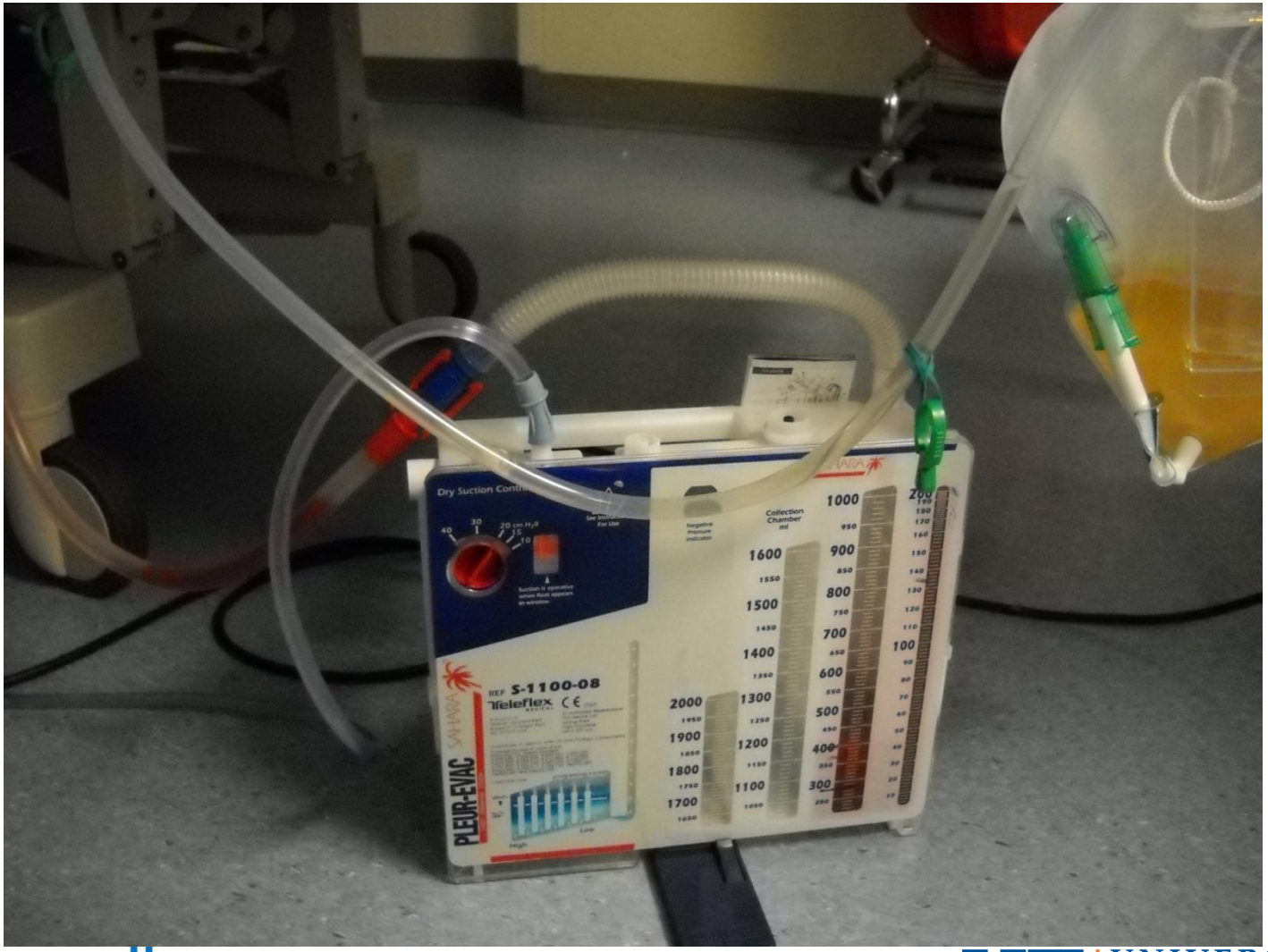
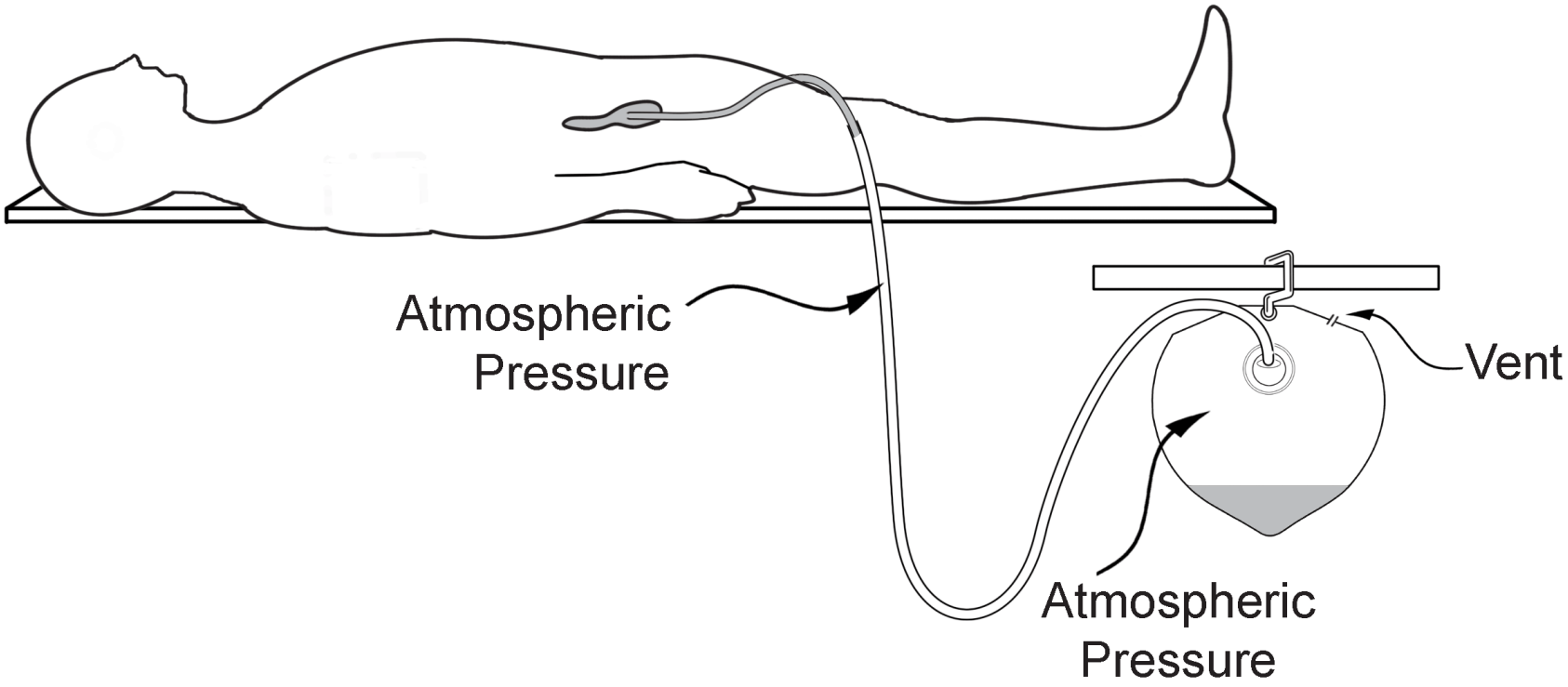


Photo by Nikolaus Gravenstein, MD, 2010

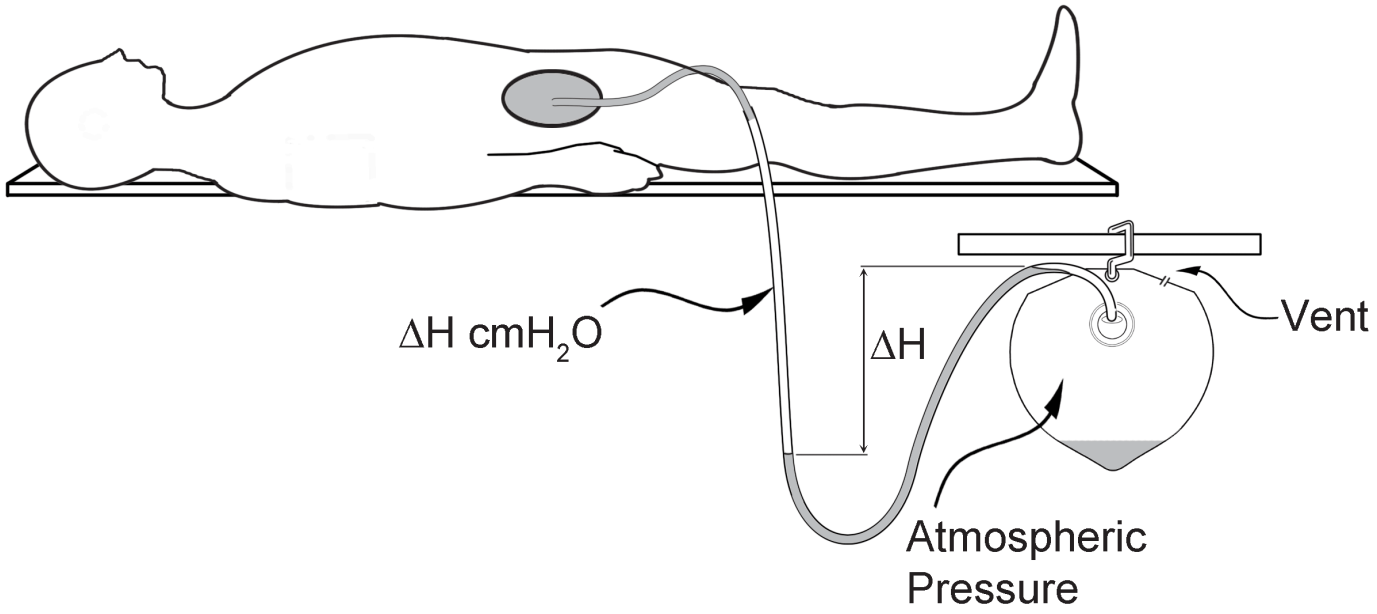
Urine drainage system

(as intended to be used; drained tubing, emptied bladder)



Urine drainage system

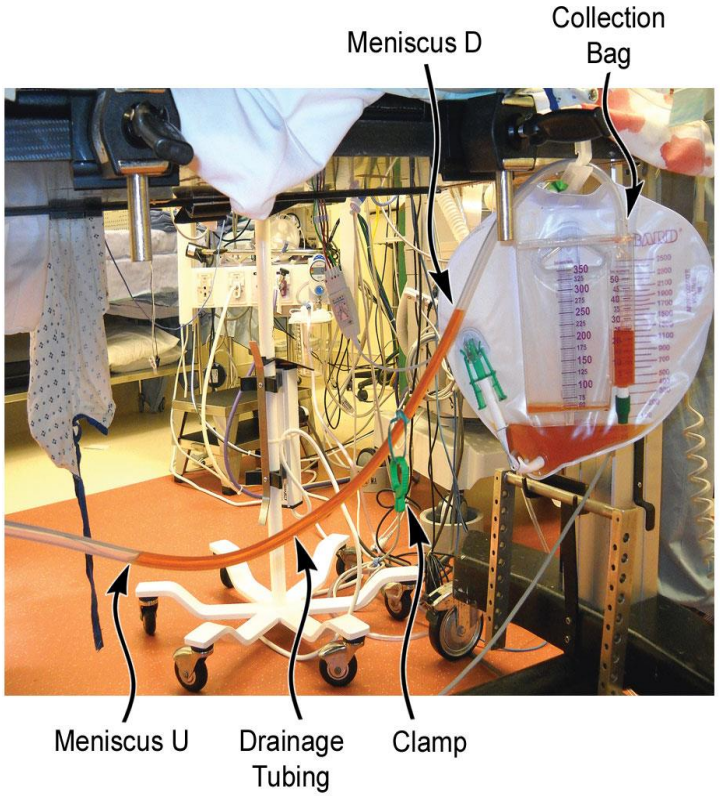
(as used; undrained tubing, distended bladder)



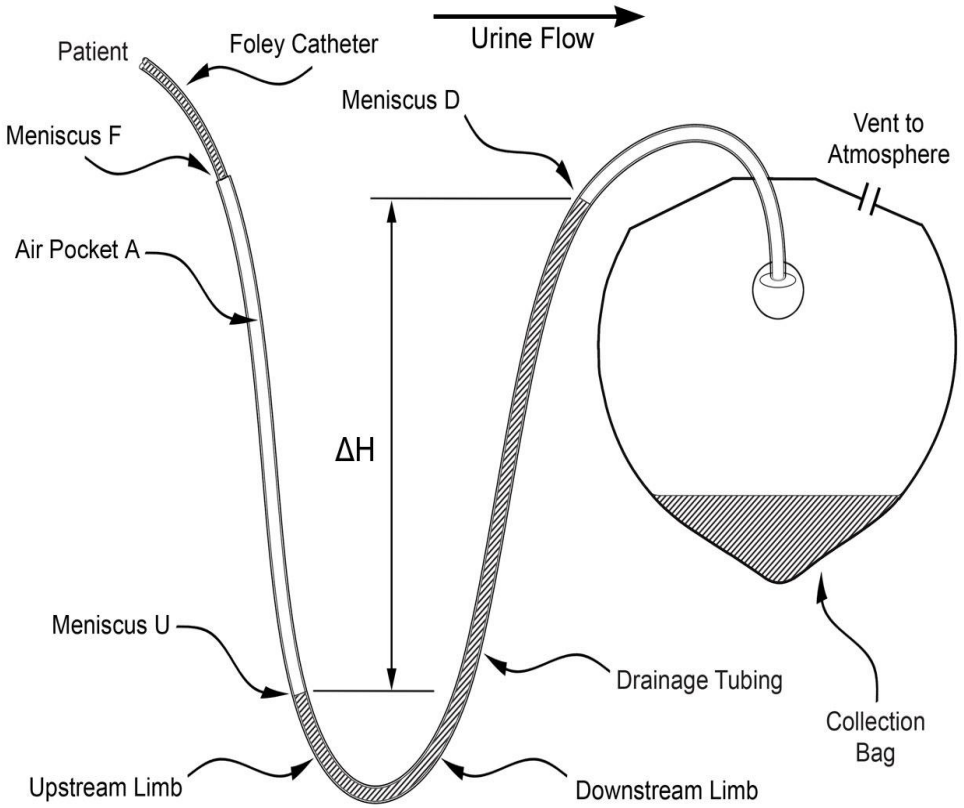
Nurse:Patient ratio in Mauritius?

- Are traditional urine drainage system designs vestiges from a bygone era with actual or assumed 1:1 nurse:patient ratios?

Dependent loops in urine drainage systems



Clinical Environment



Schematic Diagram

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Hypothesis

- Dependent loops in urine drainage systems behave as U-tube manometers
- Difference in meniscus heights Δh (in cm) is equal to the difference in pressures (in cm H_2O) across the dependent loop, according to the hydrostatic equation:

$$p = \rho.g.h$$

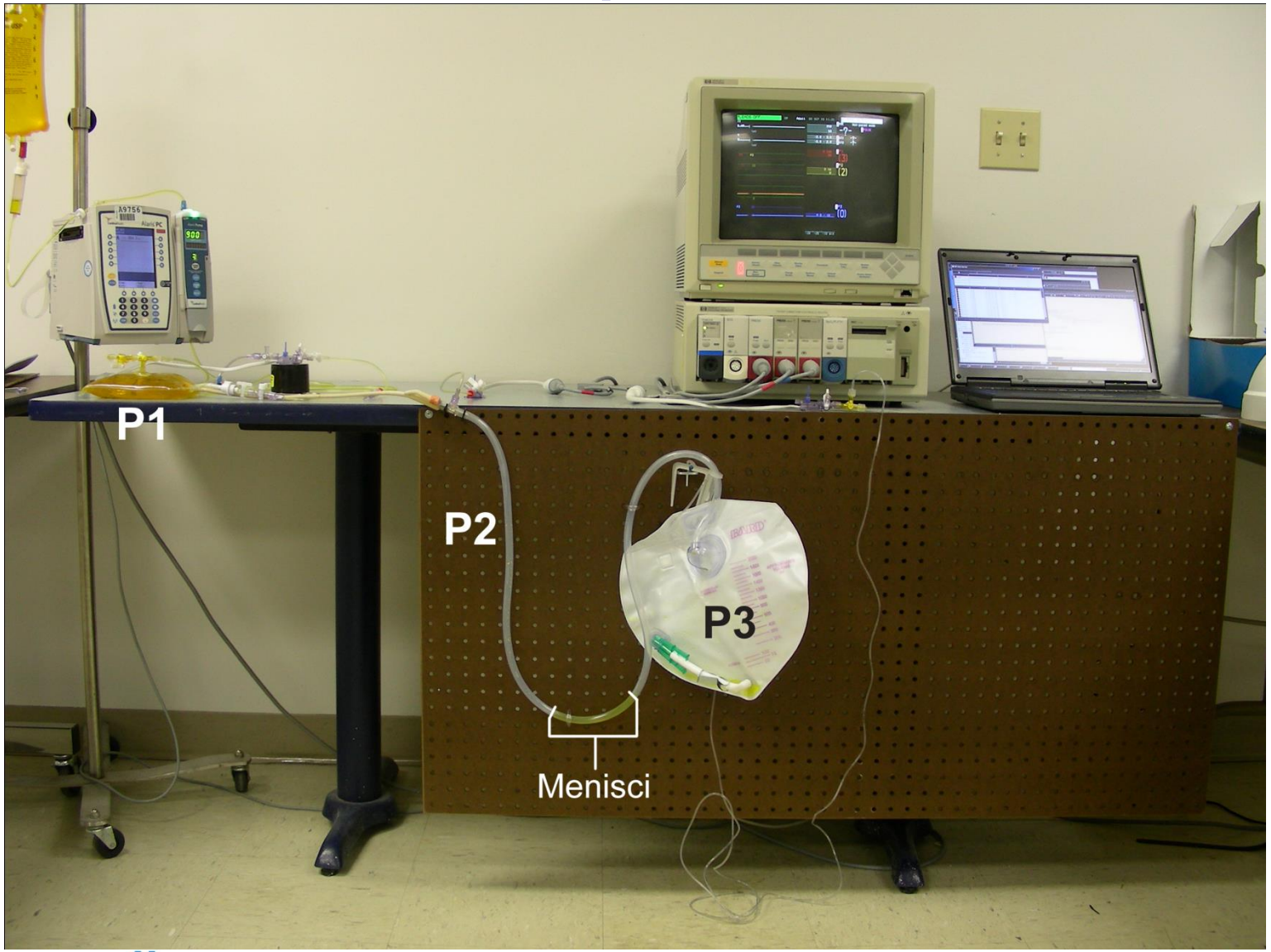
$$\Delta p = \rho.g.\Delta h$$ where

p = pressure, ρ = density of fluid

g = acceleration due to gravity

h = height of a column of fluid

Bench Model Experimental Set-Up



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Bench model experimentation

- Video A – conventional urine drainage configuration with dependent loop
- Video B – urine drainage system without dependent loops

Research

Foley Drainage Tubing Configuration Affects Bladder Pressure: A Bench Model Study

Wilhelm K. Schwab, David E. Lizdas, Nikolaus Gravenstein, and Samsun Lampotang

In a recent surgery, one author of this study noted poor urine flow after kidney reperfusion in a liver-kidney transplant patient; however, after straightening the urine

Schwab, W.K., Lizdas, D.E., Gravenstein, N., & Lampotang, S. (2014). Foley drainage tubing configuration affects bladder pressure: A bench model study. *Urologic Nursing, 34*(1), 33-37. doi:10.7257/1053-816X.2014.34.1.33

A bench model was created to measure and analyze pressures in a simulated

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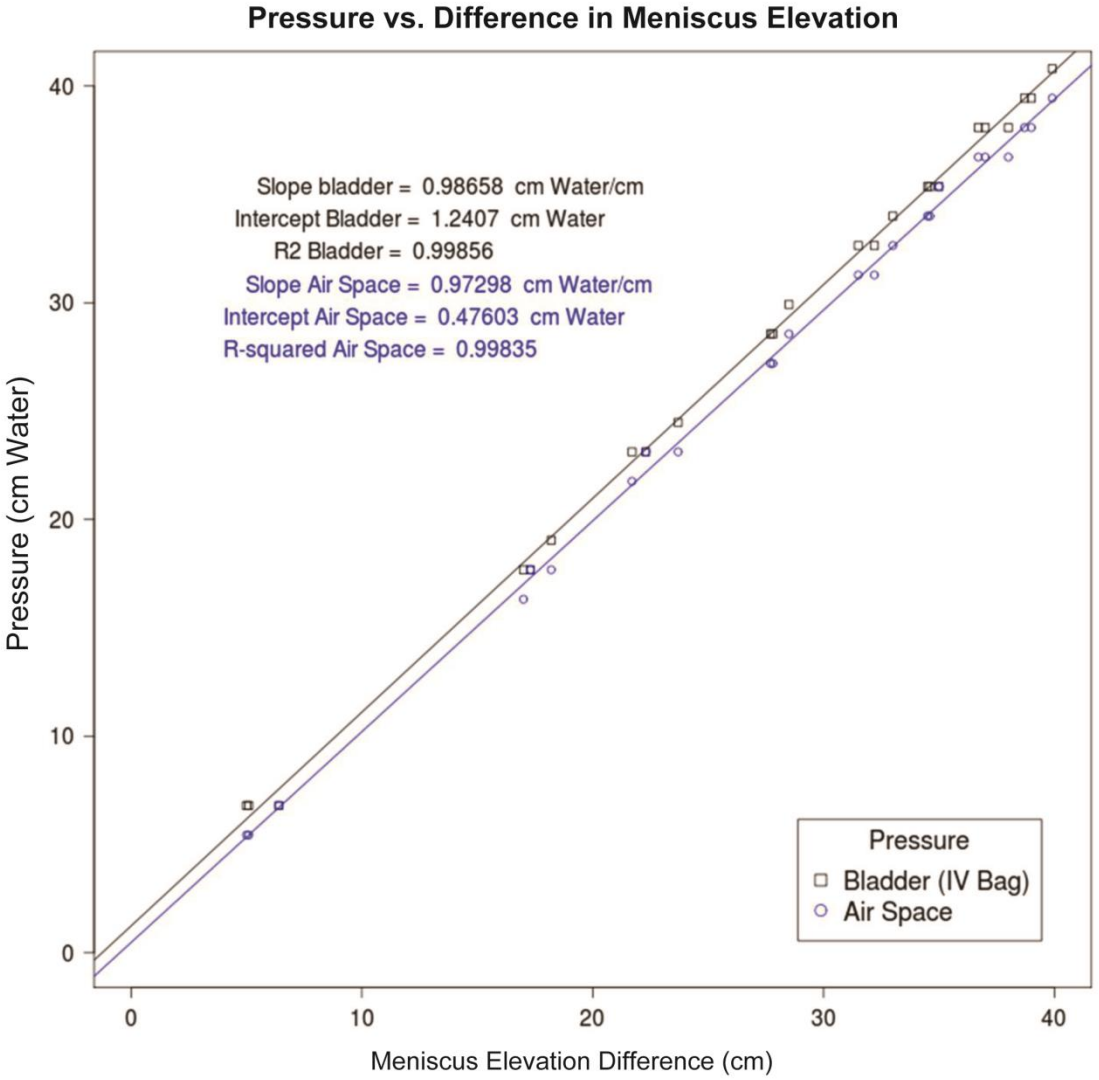
UF Bench Model Experimental Results



Schwab WK, Lizdas DE, Gravenstein N, Lampotang S: Foley Drainage Tubing Configuration Affects Bladder Pressure: A Bench Model Study. *Urologic Nursing* 34(1):33-37, 2014

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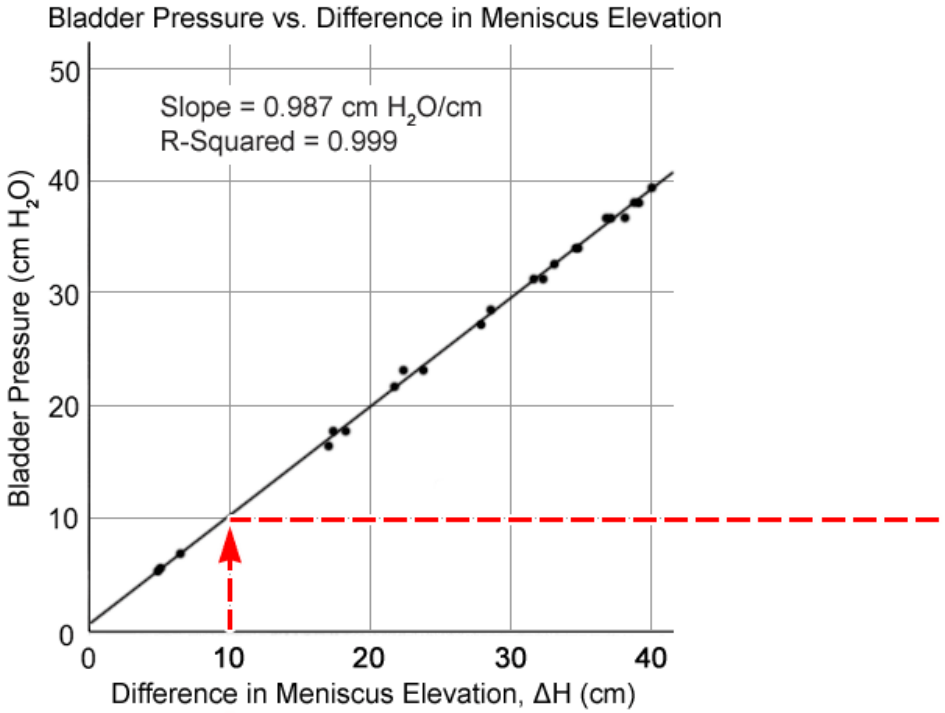
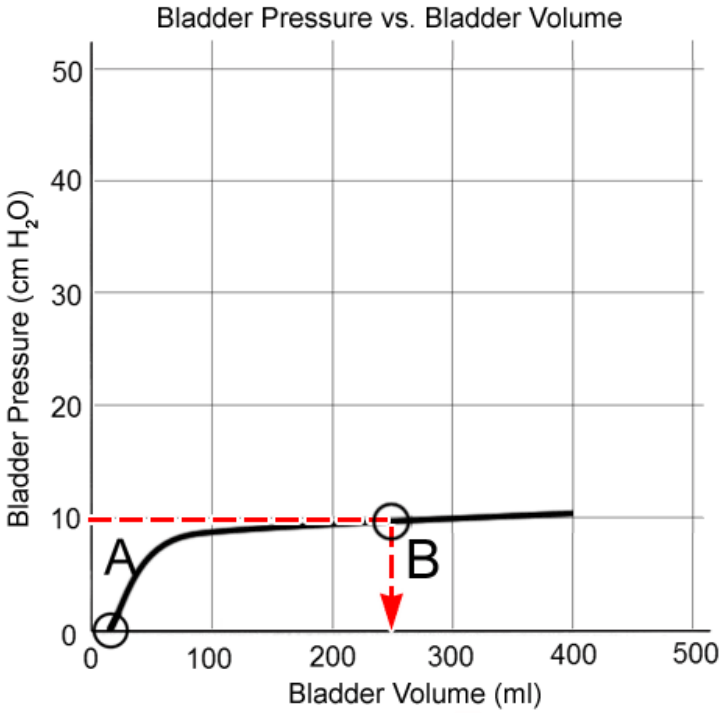
Physiological Effect





University of Florida in vitro data

Graph adapted from Giebisch & Windhager in Boron & Boulpaep, Medical Physiology, 2003

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Prevalence study

- Prevalence of urine-filled dependent loops over 3 weeks in summer 2011 in 141 patients hospitalized at an academic health center

J Wound Ostomy Continence Nurs. 2015;42(3):273-278.
Published by Lippincott Williams & Wilkins

CONTINENCE CARE

Prevalence of Dependent Loops in Urinary Drainage Systems in Hospitalized Patients

Gale Danek ■ Nikolaus Gravenstein ■ David E. Lizdas ■ Samsun Lampotang

■ ABSTRACT

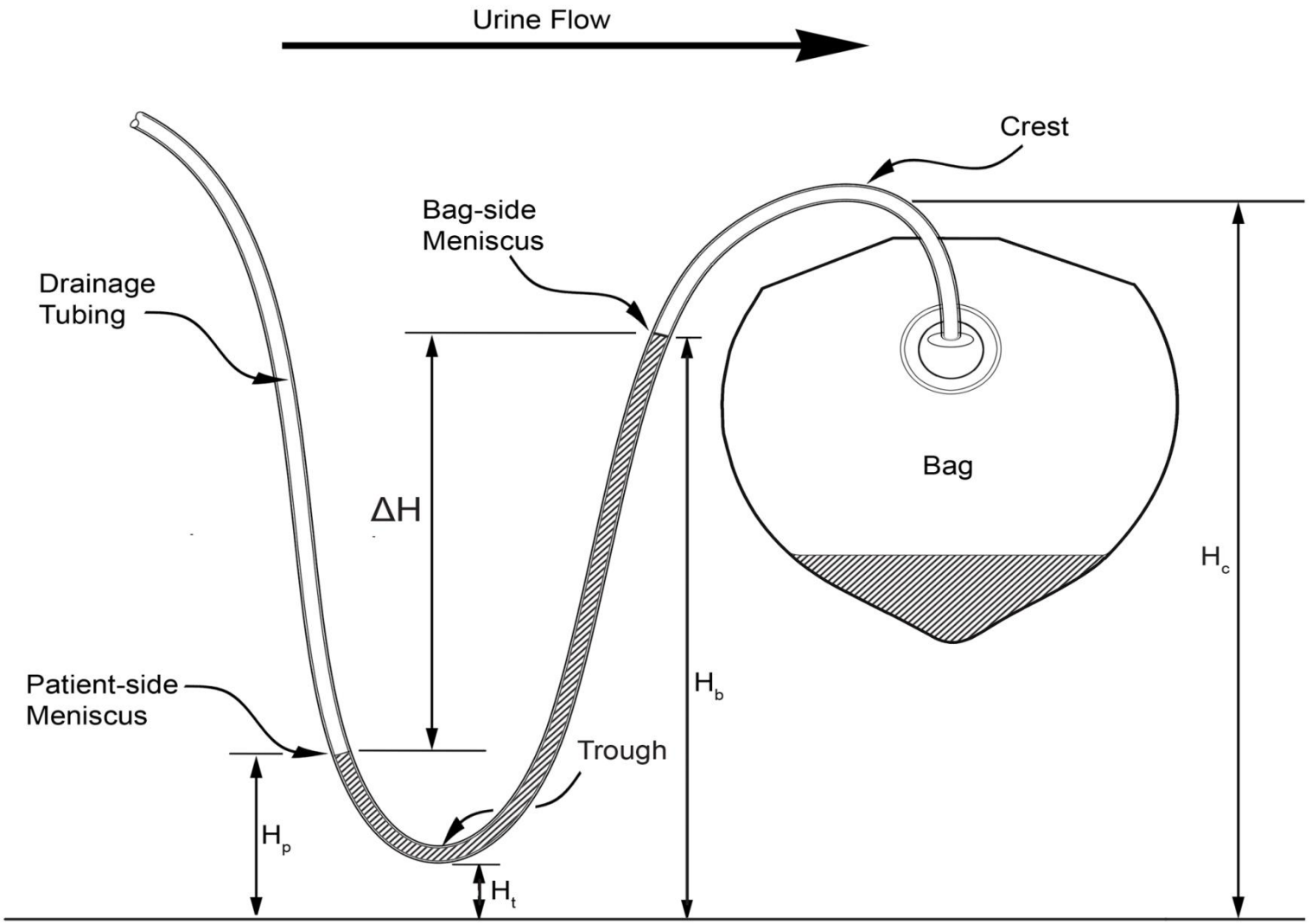
PURPOSE: The purpose of this study was to measure the prevalence and configuration of dependent loops in urinary drainage systems in hospitalized, catheterized adults.

SUBJECTS: The study sample comprised 141 patients with indwelling urinary catheters; subjects were hospitalized at an academic health center in northern Florida.

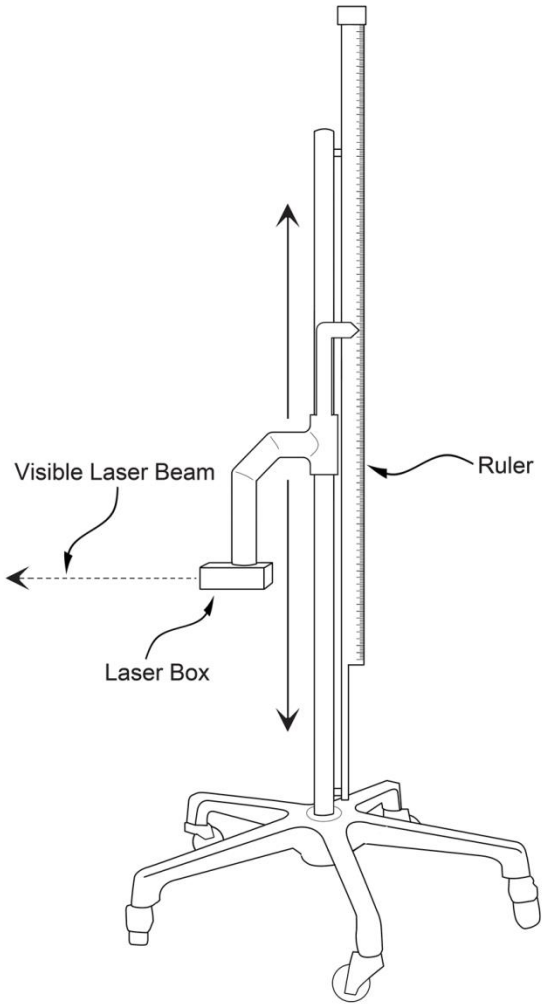
METHODS: We measured the prevalence of dependent

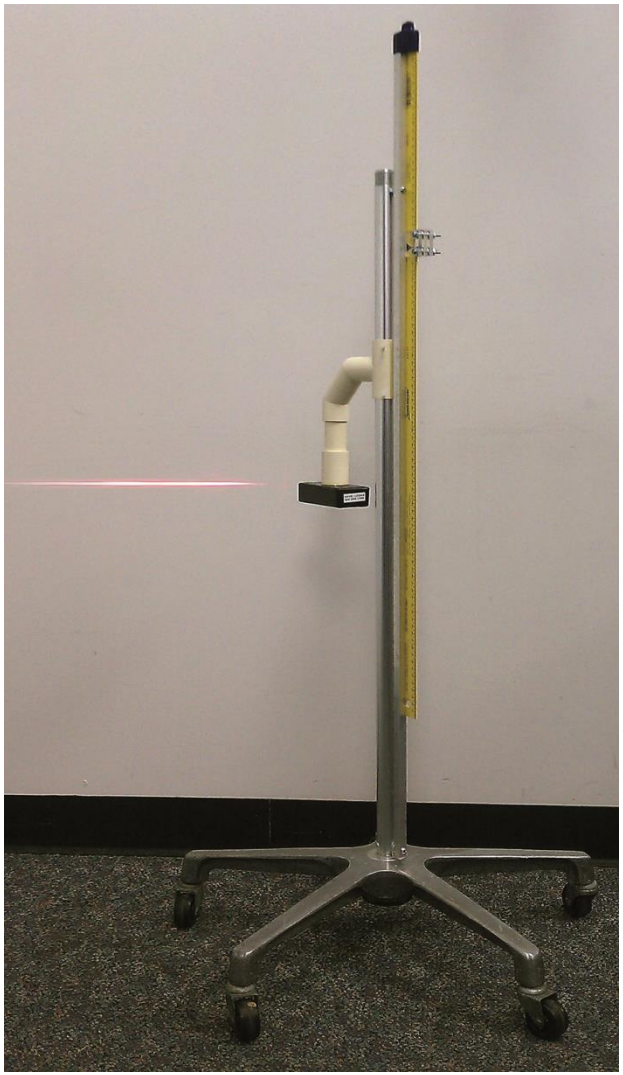
drained urine and are suspected of impeding bladder drainage and increasing the residual volume of retained urine in the bladder.[1] Dependent loops have been associated with an odds ratio of 2.1 for developing catheter-associated urinary tract infection (CAUTI).[2,3] Our hospital's procedure manual,[4] CAUTI prevention guidelines from the Wound, Ostomy and Continence Nurses Society,[5] and manufacturer instructions for the urine drainage system used at our hospital[6] recommend avoiding dependent loops in urine drainage tubing.

Meniscus height definitions



Experimental equipment





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Results (Danek et al 2015)

	No Urine in Dependent Loop	Urine in Dependent Loop	Total	% with Urine in Dependent Loop
ICU	7	72	79	91.14%
IMC		9	9	100%
MS		25	25	100%
Total	7	106	113	93.81%

Results (Danek et al 2015)

	H_c	H_t	Bed Height	H_b	H_p	$H_b - H_p$ ($H_b > H_p$)	$H_b - H_p$ ($H_p > H_b$)	$H_p = H_b$
Average (cm)	45.13	27.77	71.94	39.52	38.38	8.22	-12.24	0
SD (cm)	11.13	16.72	11.98	15.19	18.01	5.84	9.87	0
Minimum (cm)	25.2	0	47.5	25.2	2.9	0.2	-0.2	0
Maximum (cm)	93.7	83	97	89	83	25.9	-39	0
Median (cm)	43.1	27.3	72.62	38.1	36.8	7.55	-8.8	0
% subjects						65.3%	32.7%	2%
N	110	110	73	102	99	64	32	2

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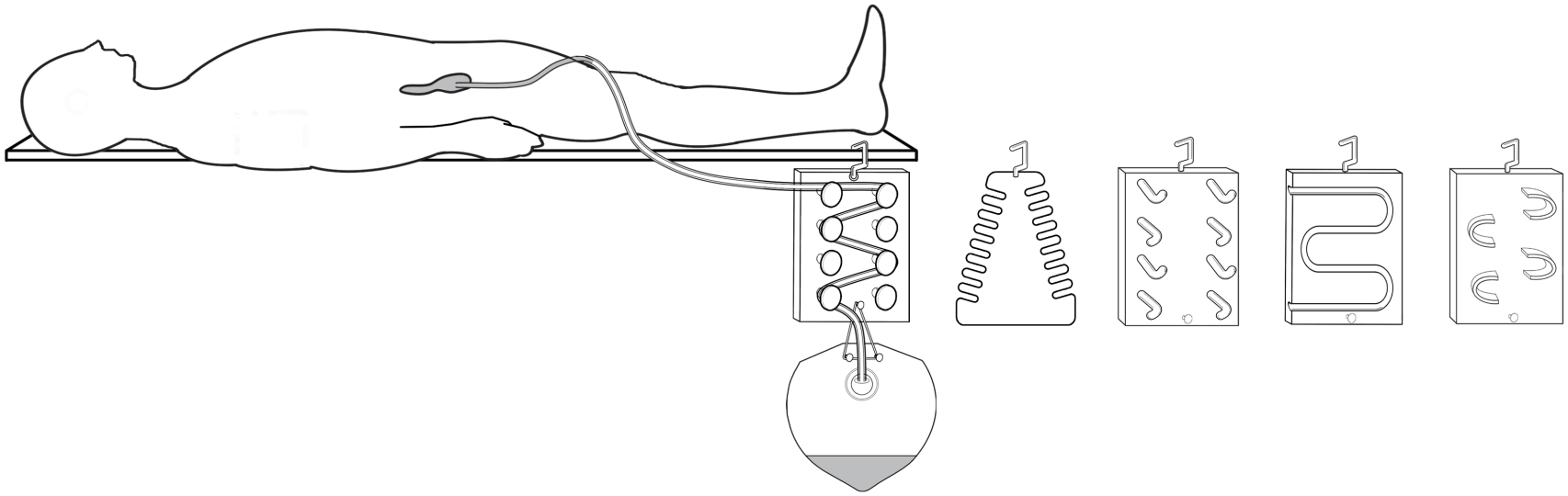
Clinical Implications

- Bench model data and clinical prevalence data about dependent loops are consistent with the findings from Garcia *et al*, *Journal of Urology*; Vol. 177, 203-207, January 2007; DOI:10.1016/j.juro.2006.08.101

Garcia et al 2007

- Bedside bladder ultrasound volumetric studies performed on patients hospitalized in ward and ICU before first morning ambulation
- In 75 ICU patients, mean residual volume was 96 ml (range 4 to 290)
- In 75 patients in the hospital ward mean residual volume was 136 ml (range 22 to 647).

Solution 1: Template Remove Dependent Loop



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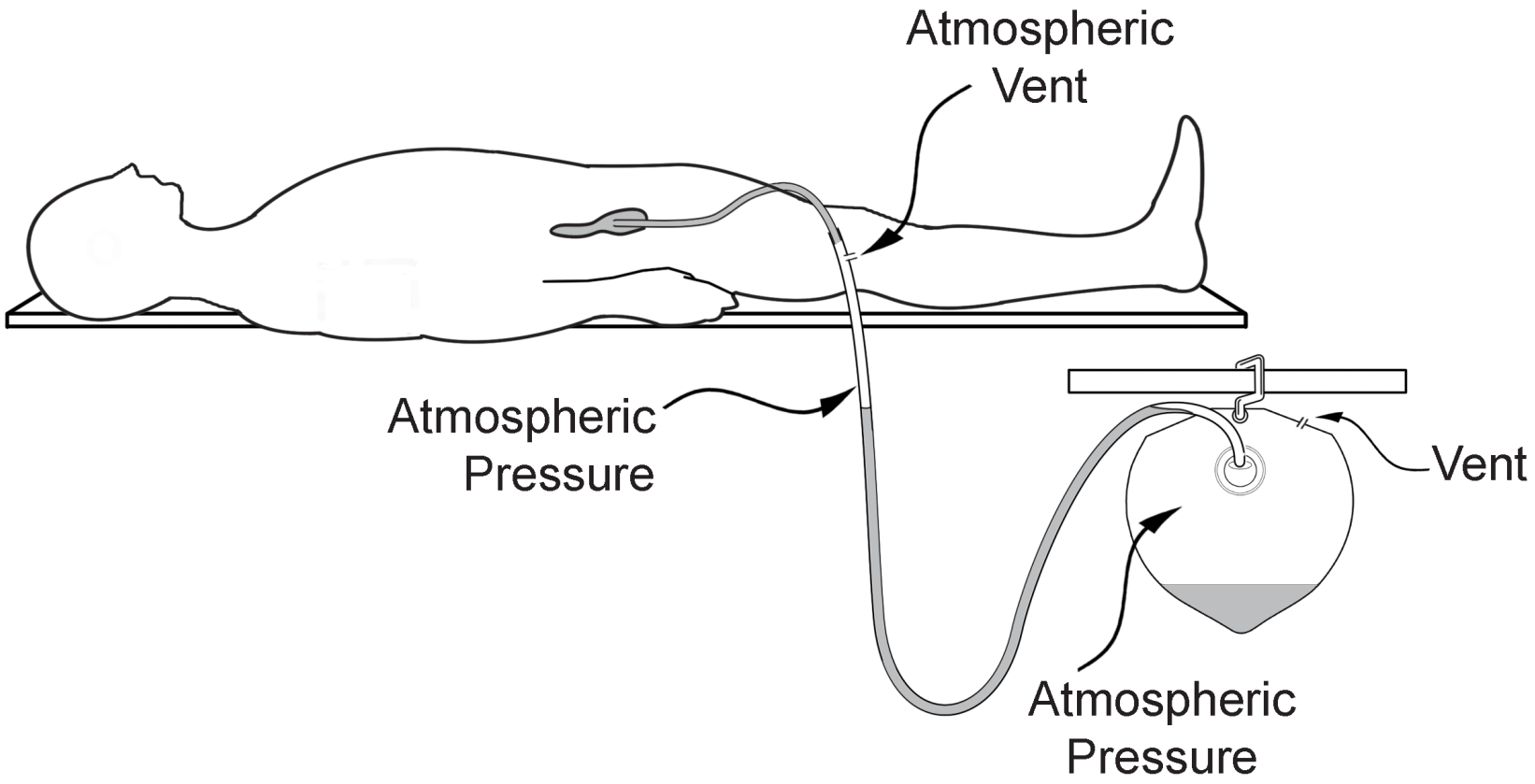
Solution 2: Vent
Remove Effect of Dependent Loop



Hypothesis/Clinical Implications

- Undrained urine-filled dependent loops impose a back pressure of ΔH cm H_2O on the bladder, resulting in large residual urine volumes trapped in the bladder
- Large residual urine volumes distend the bladder and may promote Catheter Associated Urinary Tract Infection (CAUTI)
- Research impacts standard of care for more than 1 million US patients per year who acquire CAUTI (most common HAI)

Mauritius context

- Do urine drainage systems in Mauritius have a valve to prevent backflow of urine from the collection bag back to the bladder?
- Should UltraSound BladderScan be performed for patients with in-dwelling urinary catheters too?

Clinical implications for Mauritius

- Actionable items:
  - Prevent/remove dependent loops (it's hard)
  - Always empty dependent loops; be careful to avoid back flow of stagnant urine accumulated in the dependent loop back to the bladder
  - UltraSound BladderScan performed for patients with in-dwelling urinary catheters too?
  - Do not place a urine-containing urine collection bag on the belly of the patient during transport!!!
  - Hang urine bag at foot of bed instead of side

Questions on enhanced urine drainage system?

Undrained dependent loops in chest and urine drainage systems (clinical)

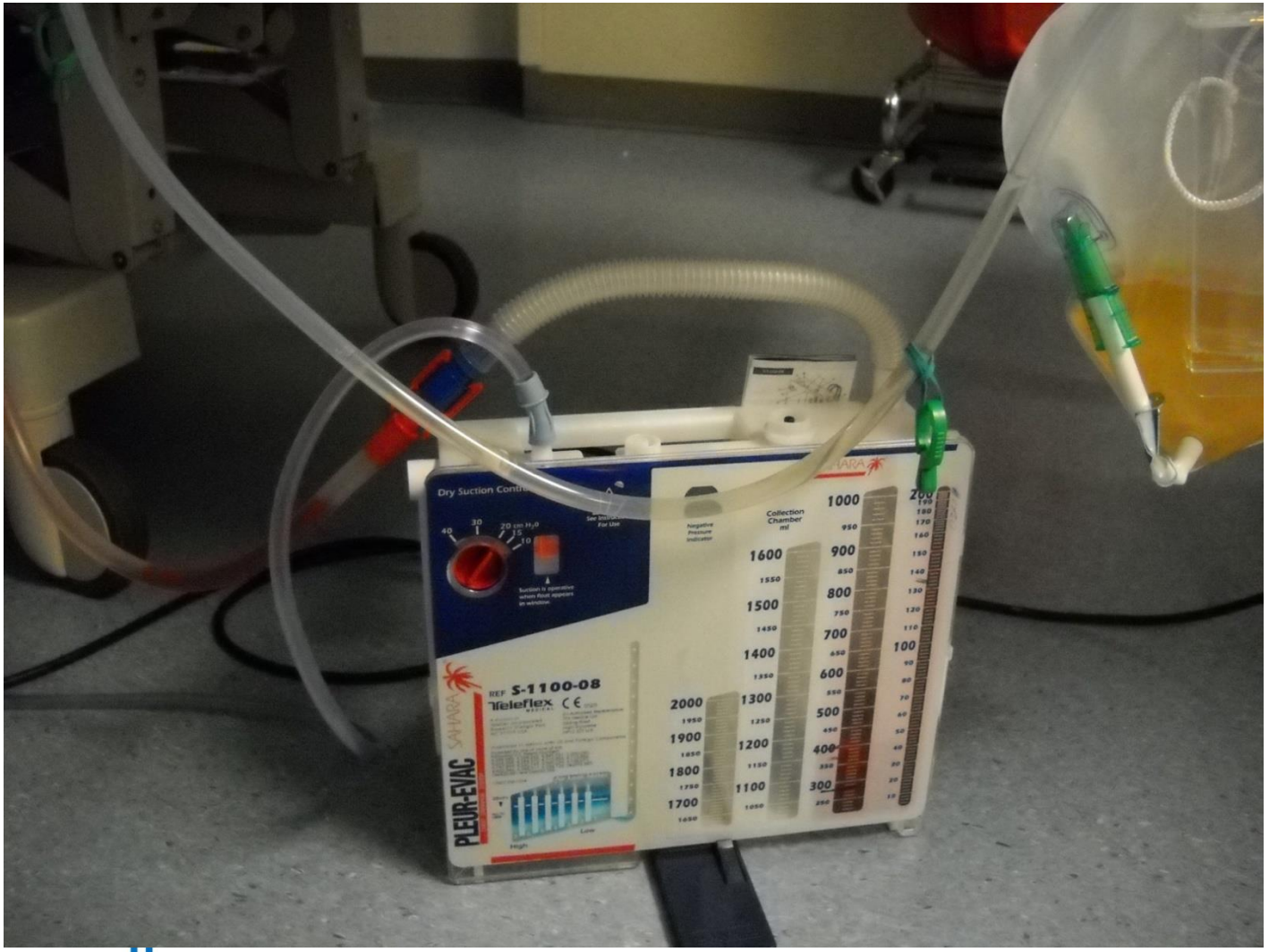
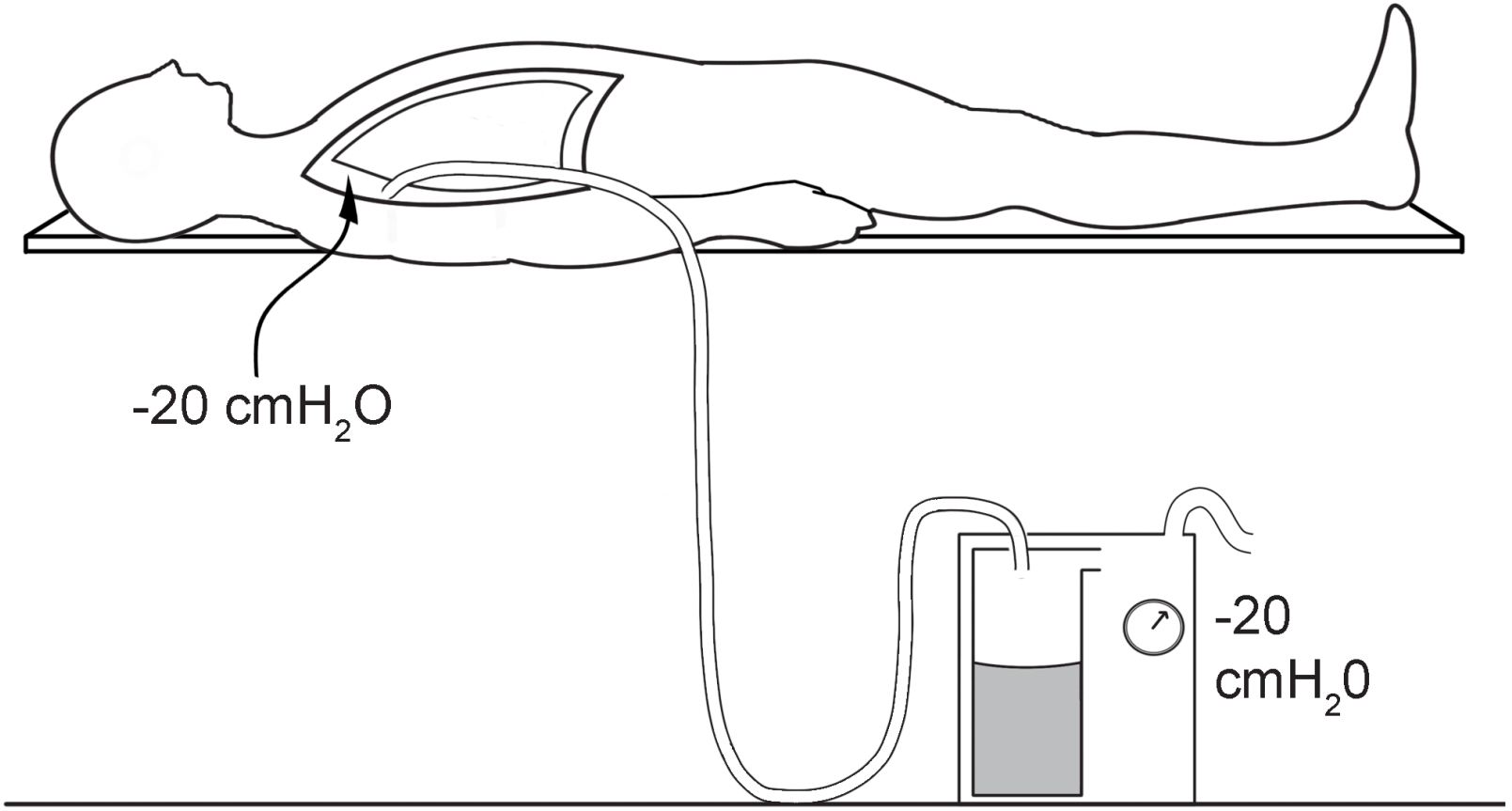


Photo by Nikolaus Gravenstein, MD, 2010

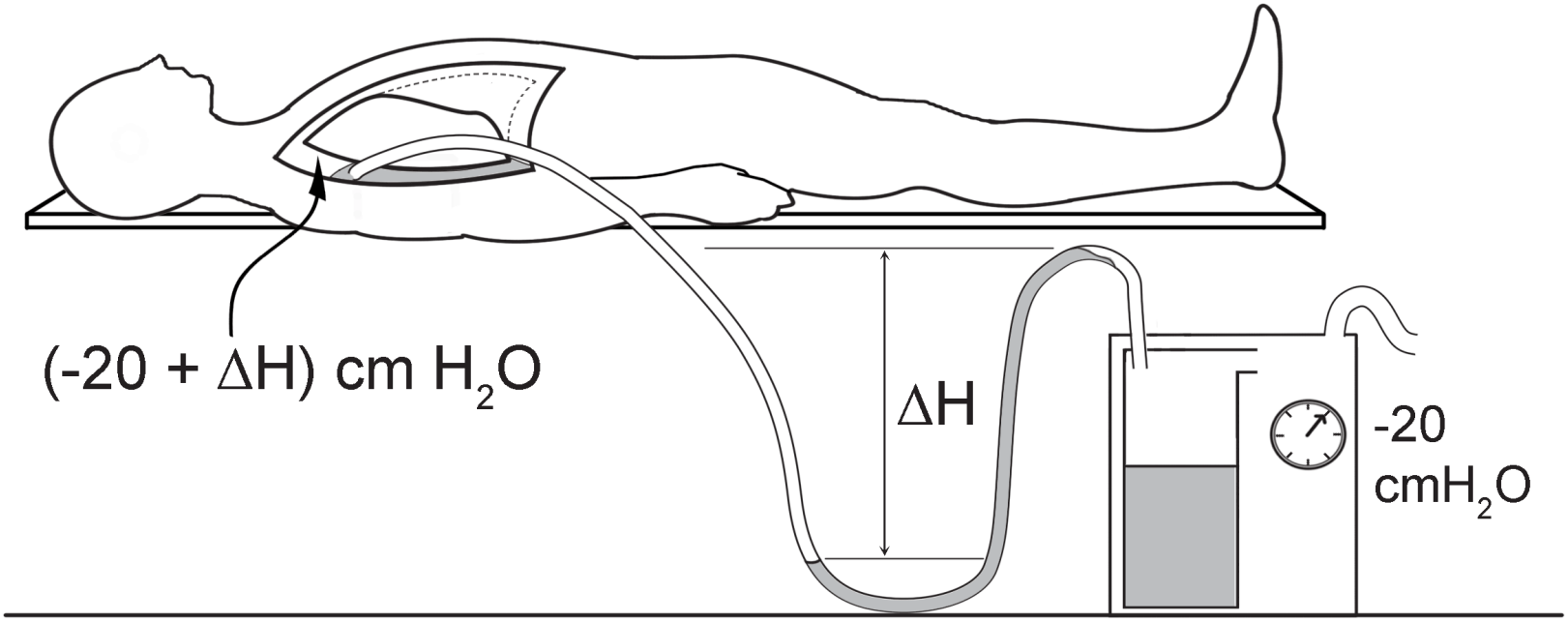
Chest drainage system

(as intended to be used; drained tubing, expanded lung)



Chest drainage system

(as used; undrained tubing, collapsed lung)



Hypothesis

- Dependent loops in chest drainage systems behave as U-tube manometers
- Difference in meniscus heights Δh (in cm) is equal to the difference in pressures (in cm H_2O) across the dependent loop, according to the hydrostatic equation:

$$p = \rho.g.h$$

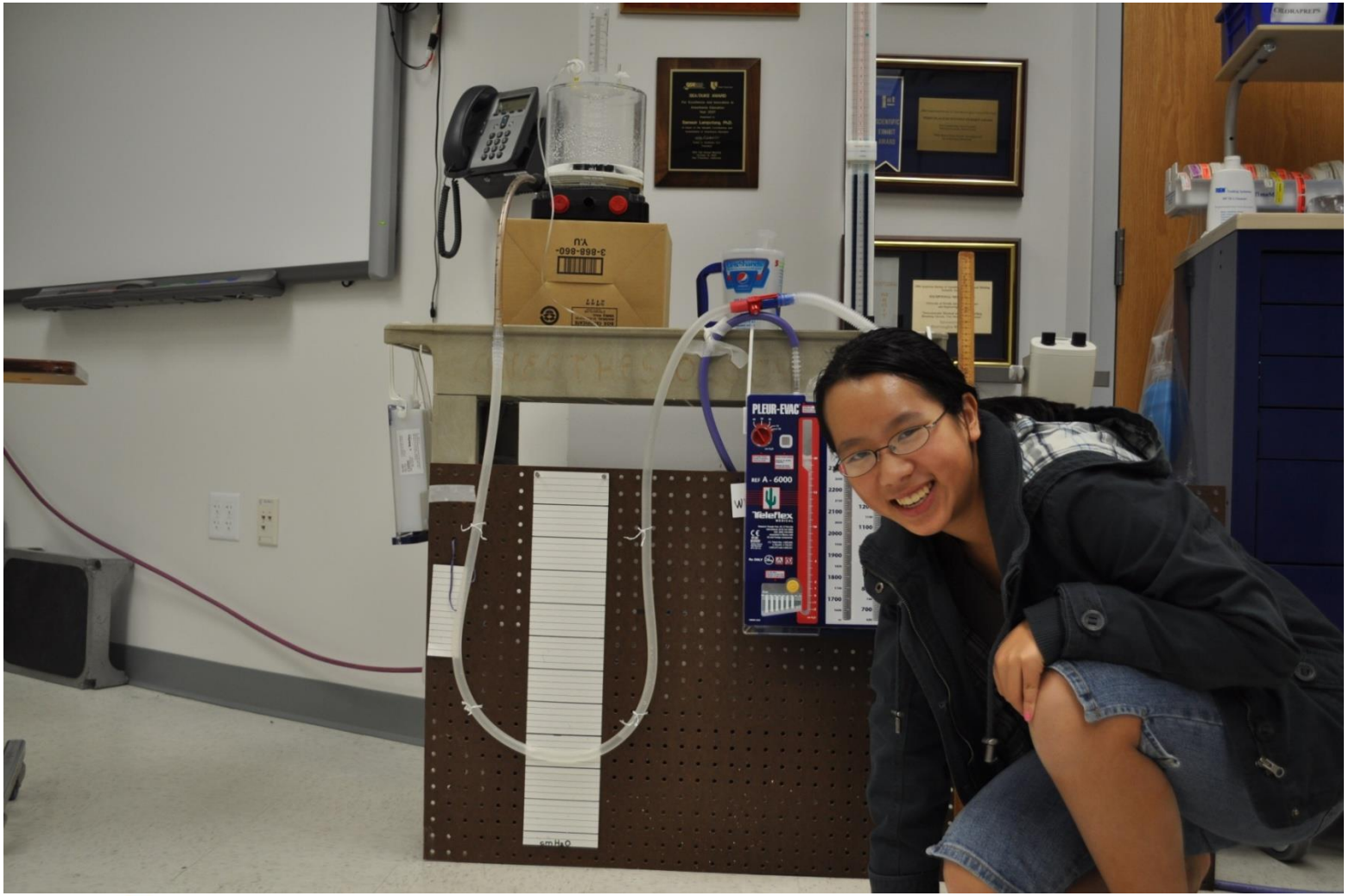
$$\Delta p = \rho.g.\Delta h$$ where

p = pressure, ρ = density of fluid

g = acceleration due to gravity

h = height of a column of fluid

Bench Model Experimental Set-Up
Not rocket science; Middle school science



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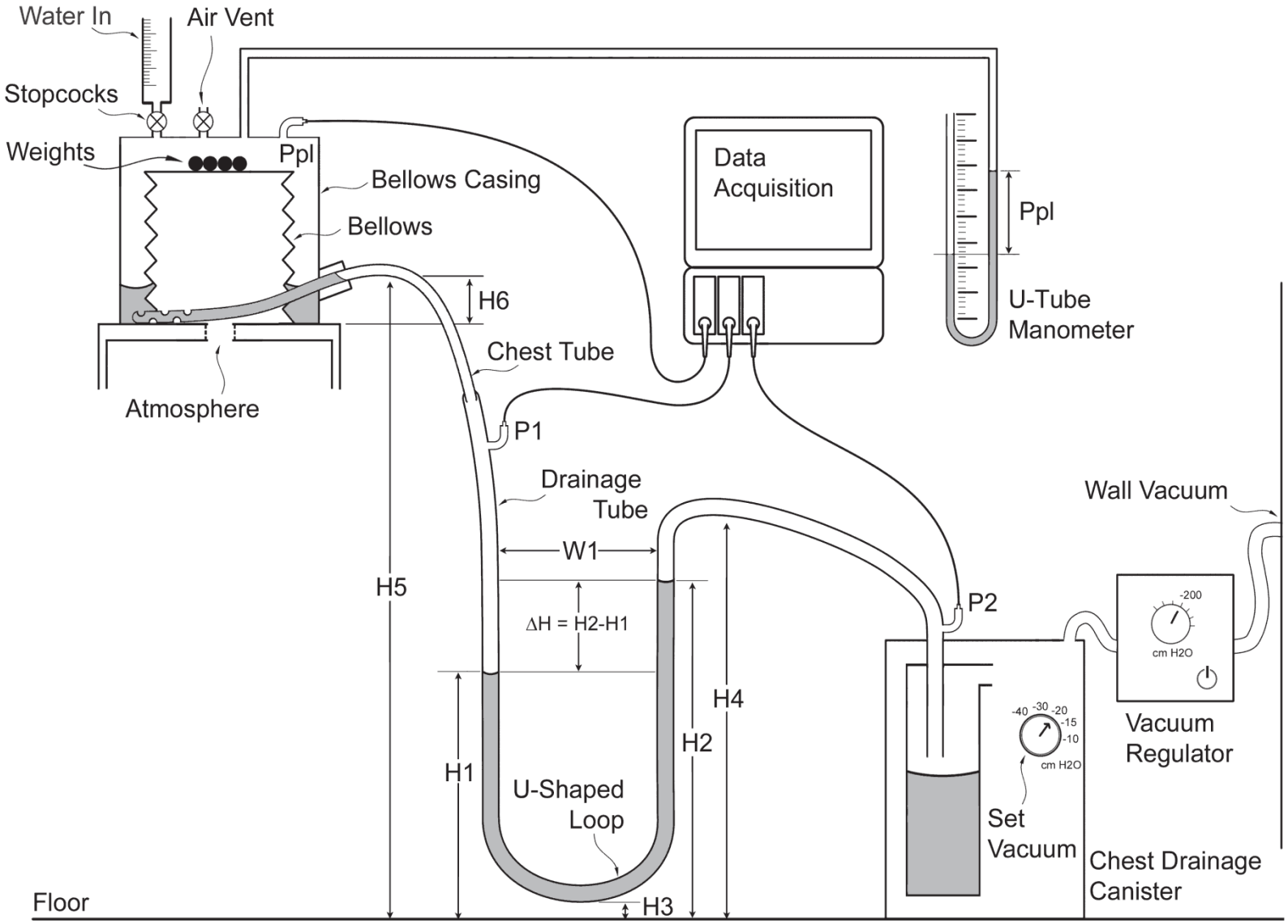
Experimental Set-Up - Schematic



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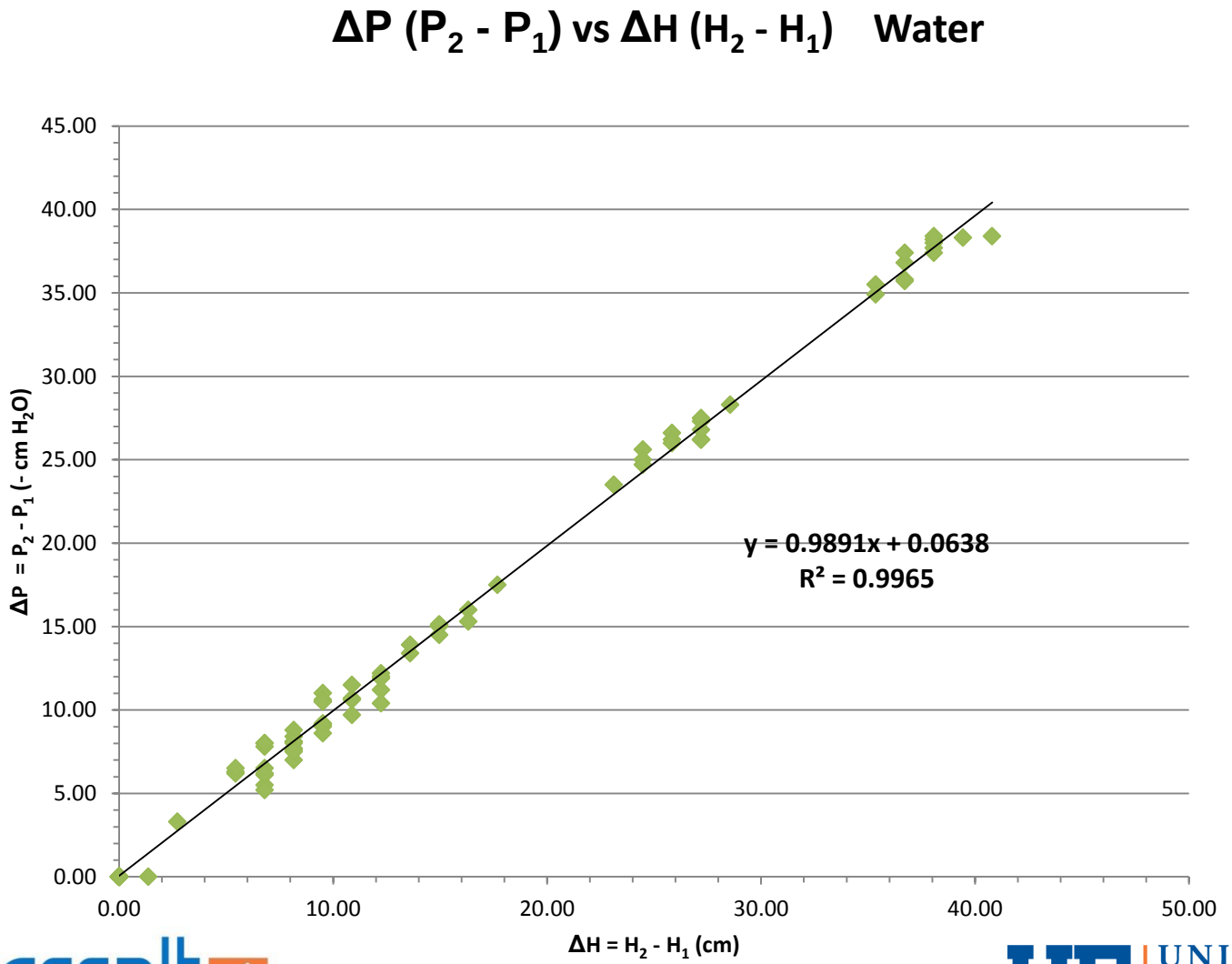
Dependent Loop Acts Like a U-Tube Manometer



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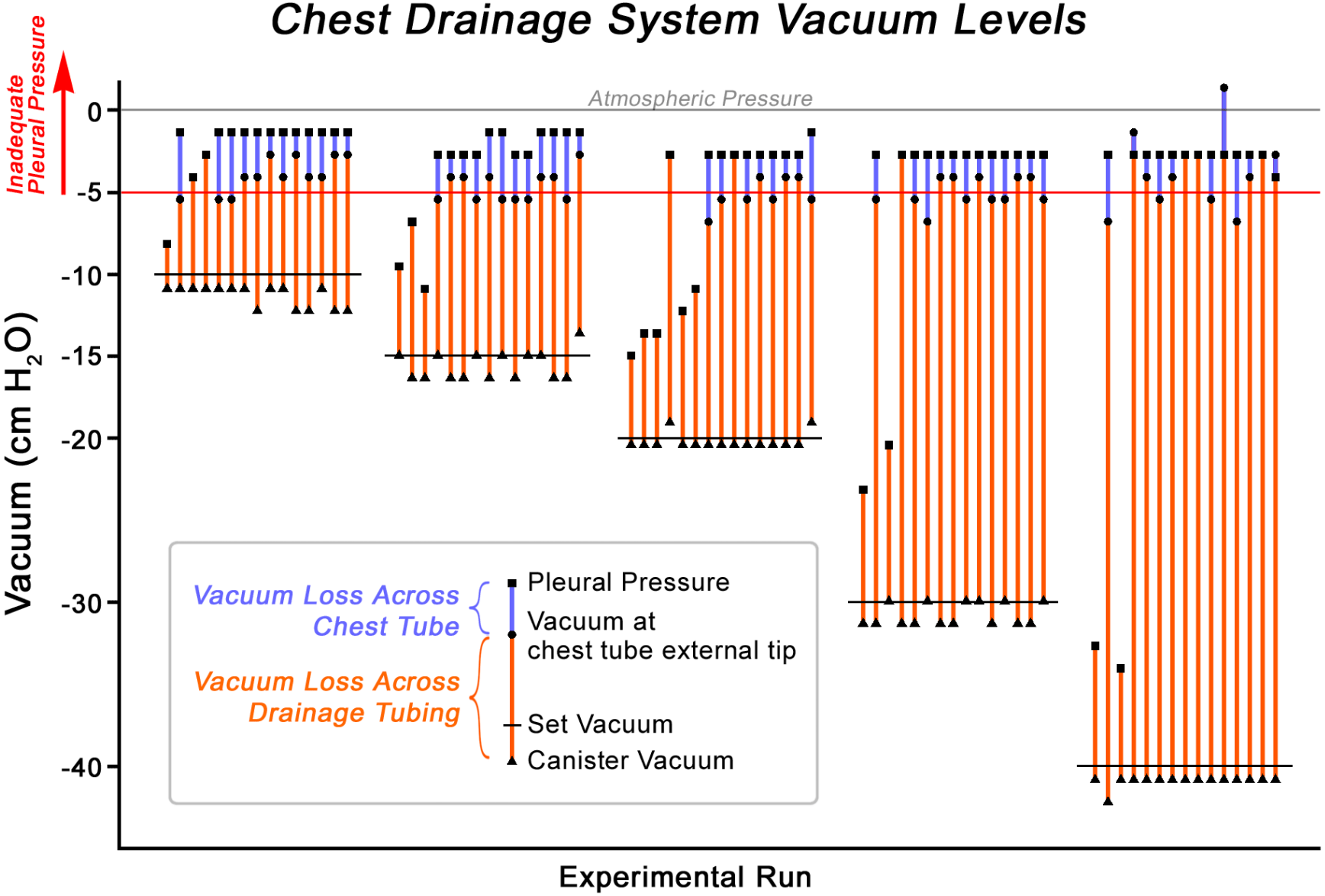
Chest Drainage System Vacuum Levels



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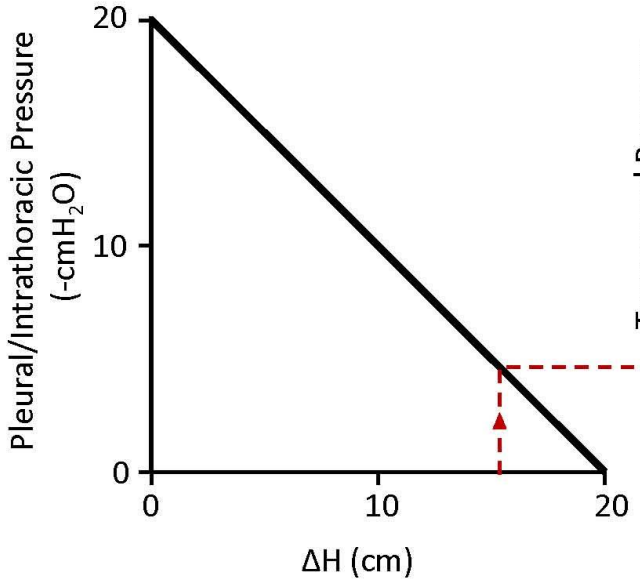
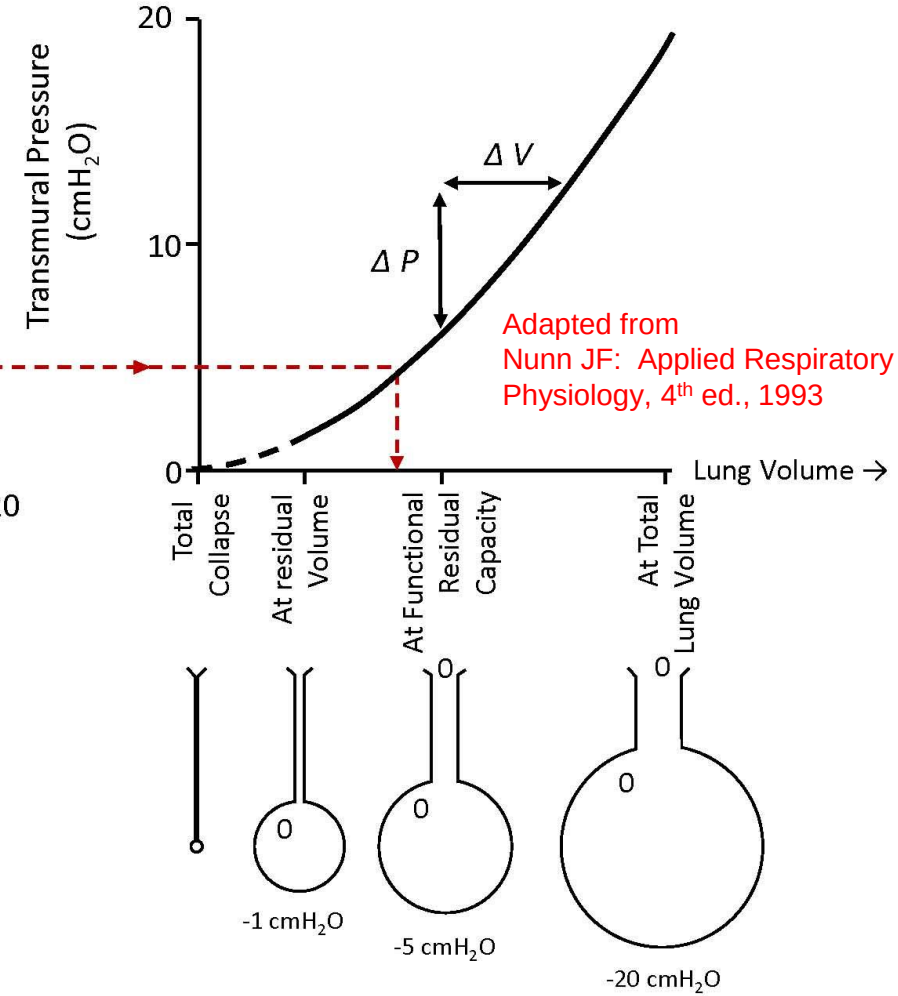
Physiological Effect

Slope = $\frac{\Delta V}{\Delta P}$ = Lung Compliance



University of Florida In-vitro data



Adapted from
Nunn JF: Applied Respiratory Physiology, 4th ed., 1993

All pressures are indicated relative to atmospheric pressure

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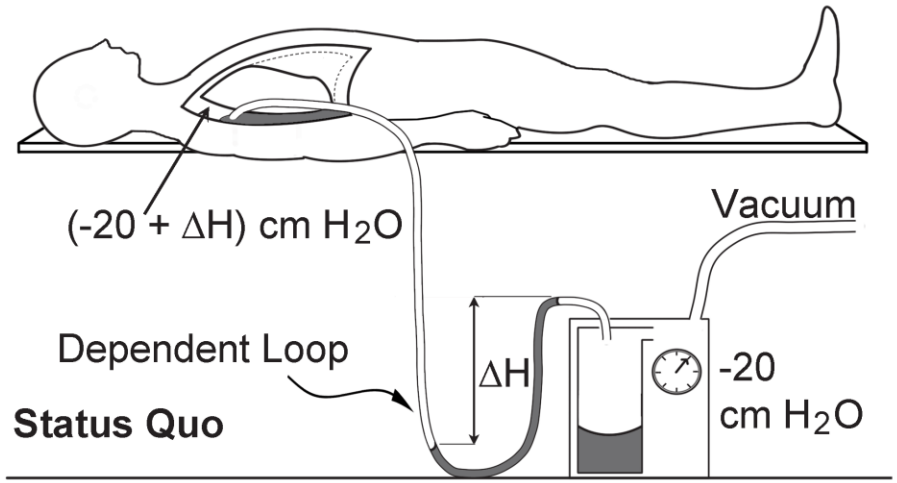
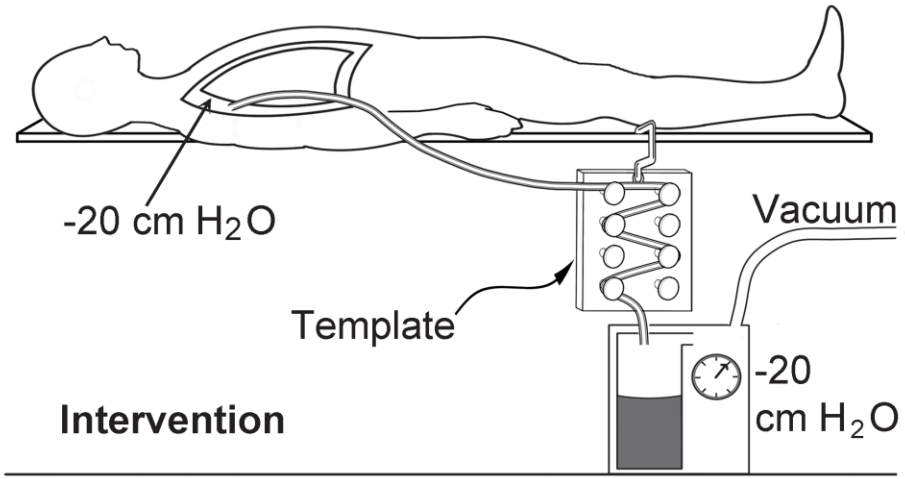
Solution 1: Template Remove Dependent Loop





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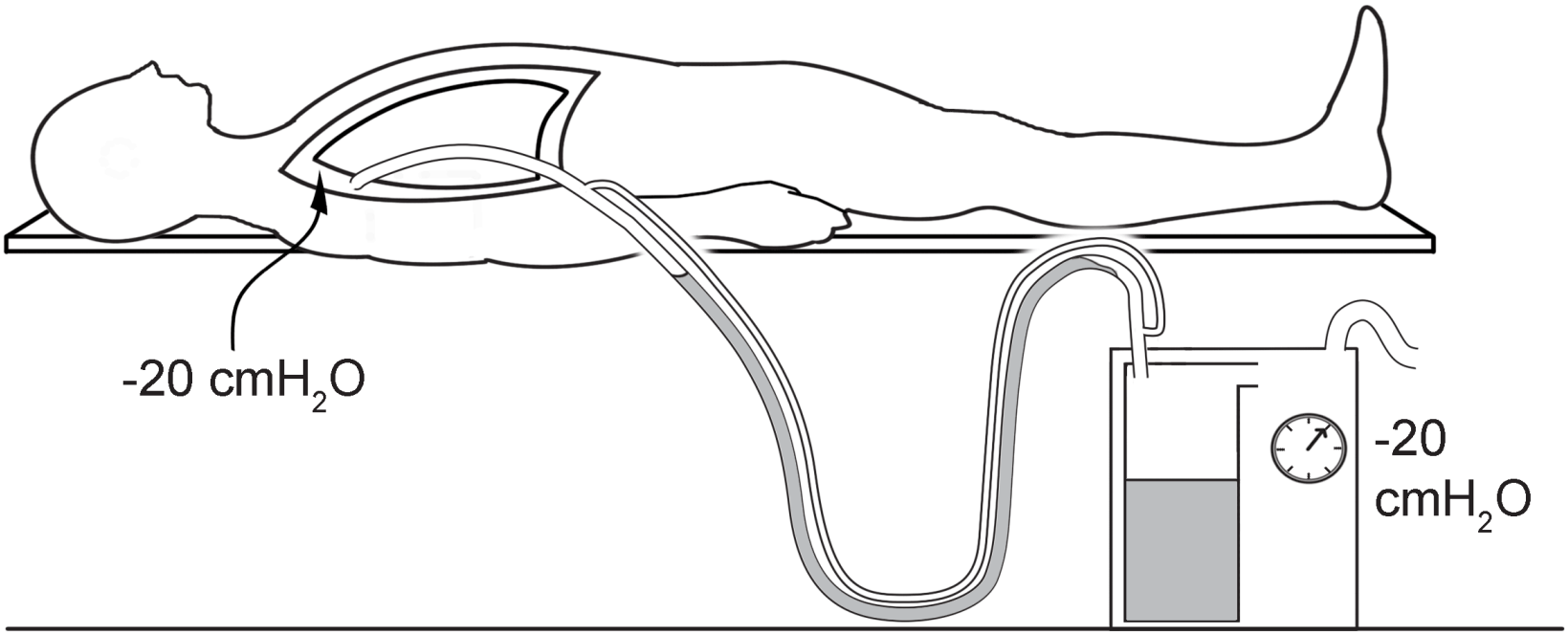
Solution 2: Bypass
Remove Effect of Dependent Loop



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Hypothesis/Clinical Implications

- Undrained fluid-filled dependent loops decrease the set vacuum by ΔH cm H_2O, potentially resulting in failure to re-expand a pneumothorax or clear an effusion
- Consequently, hospital length of stay ($3,000 per non-admission day in US) may be lengthened
- Our research may impact the standard of care for 1.4 M US patients per year (3M/yr worldwide) who need a chest tube

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Clinical implications for Mauritius

- Actionable items:
  - Prevent/remove dependent loops (it's hard)
  - Always empty dependent loops of blood; blood may clot and completely block tubing; nursing manpower intensive
  - Daily (in US) supine AP chest X-ray is insensitive to detect PTX
  - Explore using ultrasound (less ionizing radiation to patients) imaging to detect PTX

Questions on chest drainage systems?

Questions?

- slampotang@anest.ufl.edu
- http://vam.anest.ufl.edu/simulations/simulationportfolio.php
- http://simulation.health.ufl.edu/

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