Fluid-Filled Dependent Loops in Chest Drainage Systems Attenuate Set Vacuum Levels and Impede Lung Re-Inflation in an In-Vitro Model

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BACKGROUND

Fluid-filled dependent loops are often observed in the drainage tubing of chest drainage systems, with the elevation (H_2) of the canister-side meniscus higher than the height (H_1) of the patient-side meniscus. **Our hypothesis is that fluid-filled dependent loops attenuate the vacuum level set by the user (P_{set}) by an amount equal to the difference in elevation (ΔH) between the two menisci ($\Delta H = H_2 - H_1$).**

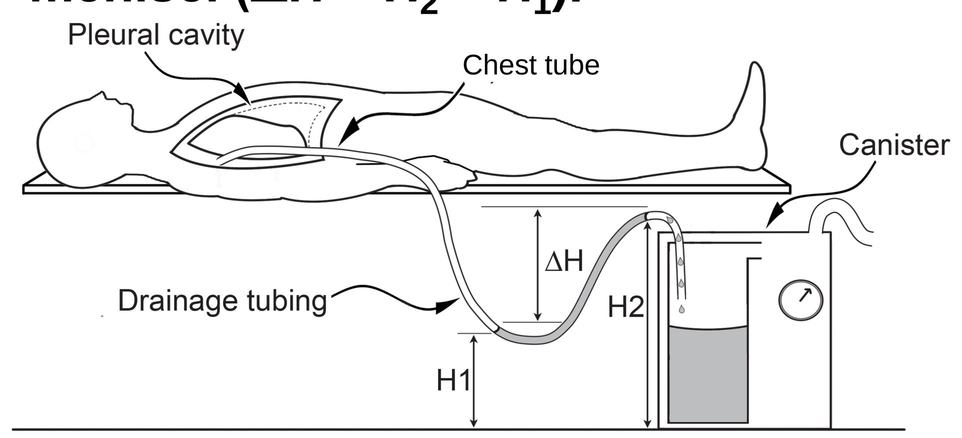

Figure 1. A typical chest drainage system set-up with fluid accumulation in a dependent loop

SIGNIFICANCE

Chest tube usage is high (~1.4 M/yr in the US, ~3M/yr worldwide). The average length of stay (LOS) for patients with a chest tube is **22.8 days v 5.4 days** for patients without chest tubes at Shands Hospital in CY2010. For cardiac surgery patients, the similar LOS comparison is **23.7 v 10.4 days**.

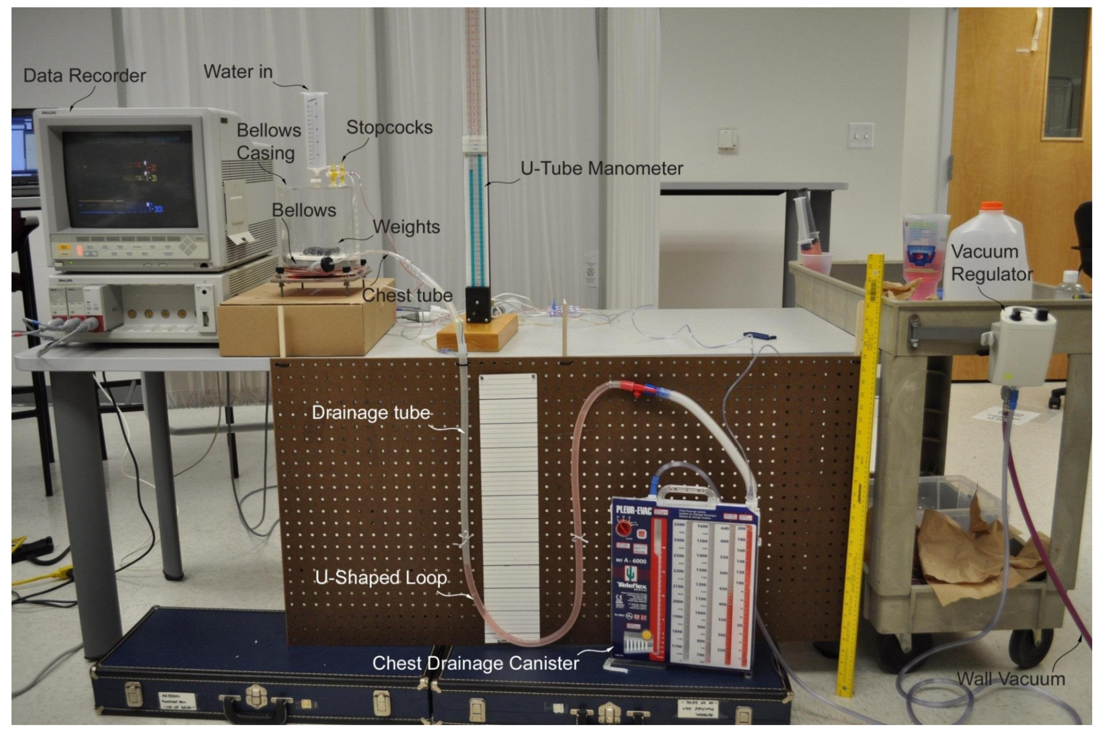

Figure 3. A labeled photograph of the experimental set-up

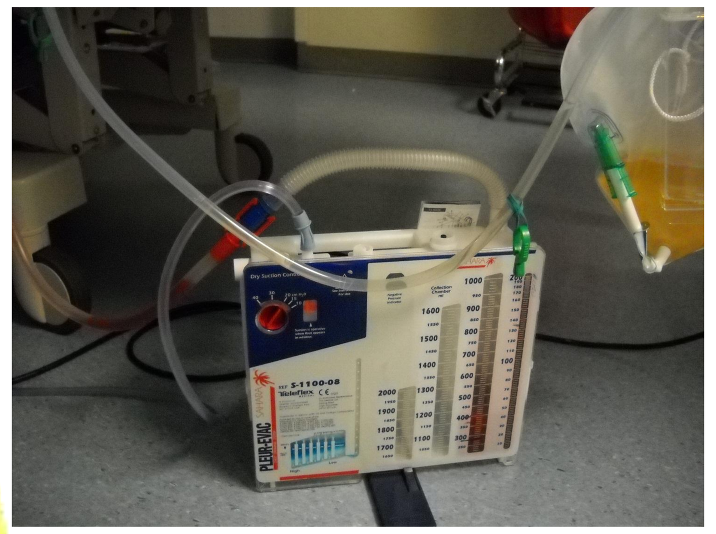

Figure 2. Dependent loops in an actual clinical setting in chest and urine drainage systems

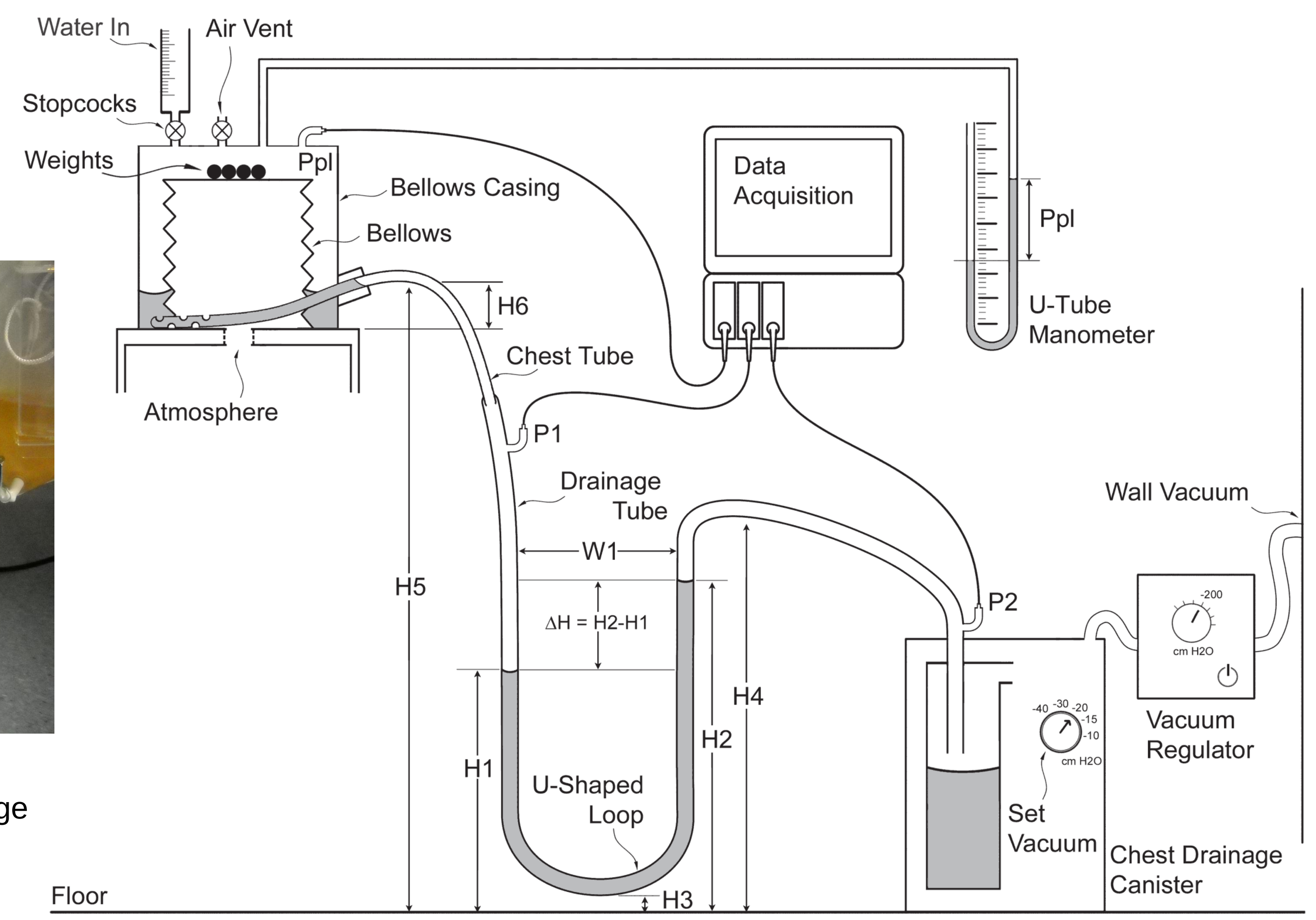

Figure 4. A line drawing of the experimental set-up

Our in-vitro data show that chest drainage systems will not re-inflate the lungs when fluid-filled dependent loops are present, potentially leading to extended LOS, at an cost of about $3,000/non-admission day.

METHODS

We built an in-vitro model of the lung, rib cage, and pleural space by modifying an ascending bellows assembly of an anesthesia ventilator. Six different volumes of fluid (water) were introduced in the model's pleural cavity and subsequently removed via a chest drainage system with a fixed dependent loop, with the vacuum set (P_{set}) at -10, -15, -20, -30, and -40 cm H_2O. Each combination of initial water volume and P_{set} was repeated three times. The elevation of the two menisci and pleural pressure (P_{pl}), vacuum at the drainage canister inlet (P_2), and vacuum above the patient-side meniscus (P_1) were measured.

RESULTS

When a fluid-filled dependent loop was present in the drainage tubing, P_{pl} was always lower than P_{set}. The vacuum at the canister inlet (P_2) was not always the same as the set vacuum P_{set}, indicating that the canister we tested did not deliver the dialed vacuum level setting on a consistent basis. The vacuum loss ($\Delta P = P_2 - P_1$) across the water-filled dependent loop was identical to ΔH (R^2 0.997). The vacuum above the patient-side meniscus (P_1) was sometimes different from pleural pressure, P_{pl}, indicating a potential vacuum loss across the chest tube as well.

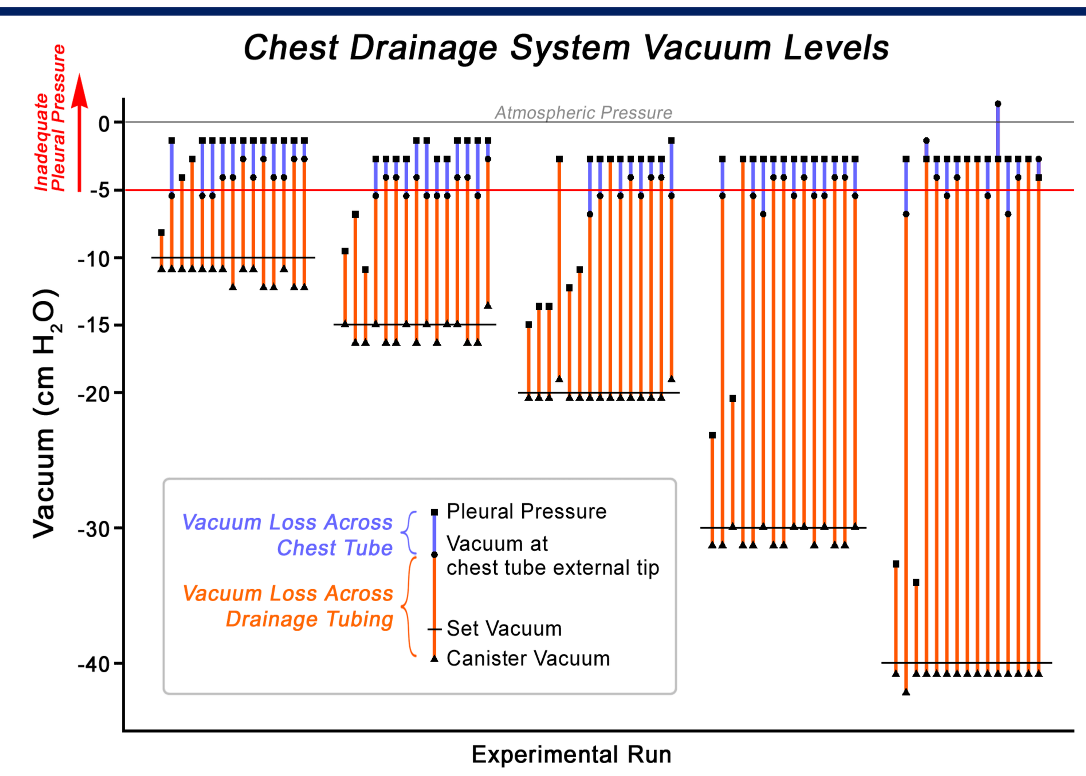

Figure 5. Vacuum losses during the individual experimental runs. Note the vacuum loss across the chest tube, a previously unappreciated loss.

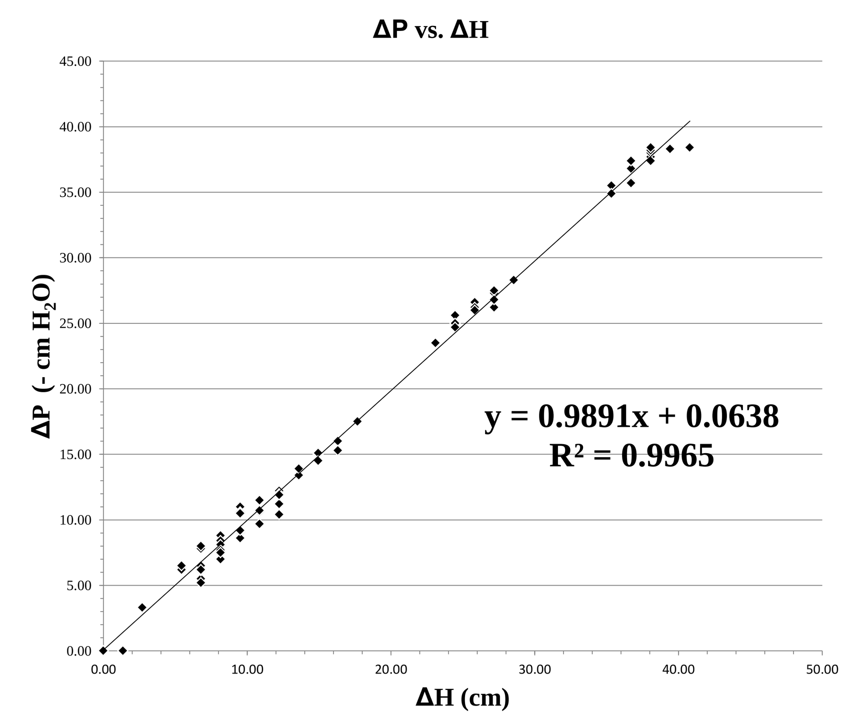

Figure 6. Plot of the vacuum loss across the dependent loop v ΔH

CONCLUSION

Fluid-filled dependent loops attenuate vacuum transmission to the pleural space in an in-vitro model. Given the observed high clinical incidence of fluid-filled dependent loops in chest drainage tubing, our in-vitro data suggest that many patients may not have optimal management of intrapleural pressure, even when the vacuum level is properly set at the canister. Within the limitations that they were collected in an in-vitro model, our data indicate that clinical practice should be re-evaluated to more consistently prevent or mitigate fluid-filled dependent loops in chest drainage systems so that the set vacuum level can be transmitted unimpeded to the pleural cavity. **In addition to proving our hypothesis, our data also indicate that there are vacuum losses across the chest tube, a previously unappreciated finding** (Figure 5)**.**

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