

Enhancing the Safety of Medical Suction Through Innovative Technology

Patricia Carroll, RN,BC, CEN, RRT, MS

Abstract: Medical suctioning is essential for patient care. However, few clinicians receive training on the principles of physics that govern the safe use of medical suction. While all eight manufacturers of vacuum regulators sold in North America require occlusion of the tube before setting or changing vacuum levels, anecdotal evidence reveals that clinicians are not aware of this requirement or skip this step when pressed for time. This white paper summarizes the physics relating to medical suction, the consequences of damaged mucosa, the risks to patient safety when suction levels are not properly set and regulated, and technology advances that enhance patient safety.

Medical suction is an essential part of clinical practice. Since the 1920s, it has been used to empty the stomach, and in the 1950s, airway suction levels were first regulated for safety. Today, medical suction is used for newly born babies and seniors, and in patients weighing between 500 grams and 500 pounds. Medical suction clears the airway, empties the stomach, decompresses the chest, and keeps the operative field clear. It is essential that clinicians have reliable equipment that is accurate and easy to use.

Why a Safety Mindset is Important

The current focus on patient safety extends to suction procedures and routines. When suction pressures are too high, mucosal damage occurs, both in the airway¹ and in the stomach. If too much negative pressure is applied through a chest tube, lung tissue can be drawn into the eyelets of the thoracic catheter². Researchers are examining the connection between airway mucosal damage and ventilator-associated pneumonia. In pediatrics, airway suction catheters are inserted to a pre-measured length that avoids letting the suction catheter come in contact with the tracheal mucosa distal to the endotracheal tube³. Mucosal damage can also be mitigated with appropriate suction techniques, and every effort should be made to reduce this insult to the immune system of patients who are already compromised. Damaged airway mucosa releases nutrients that support bacterial growth⁴, and *P. aeruginosa* and other organisms are drawn to damaged epithelium^{5, 6}. Mucosal damage in the stomach can result in bleeding and anemia as well as formation of scar tissue.

Physics of Suction

Flow rate is the term used to describe how fast air, fluid, or

secretions are removed from the patient. Ideally, clinicians need the best flow rate out of a vacuum system at the lowest negative pressure. Three main factors affect the flow rate of a suction system:

- The amount of negative pressure (vacuum)
- The resistance of the suction system
- The viscosity of the matter being removed

The negative pressure used establishes the pressure gradient that will move air, fluid, or secretions. Material will move from an area of higher pressure in the patient to an area of lower pressure in the suction apparatus. The resistance of the system is determined primarily by the most narrow part of the system — typically, a tubing connector — but the length of tubing in the system can increase resistance as well. Watery fluids such as blood will move through the suction system much more quickly than thick substances such as sputum. At one time, it was thought that instilling normal saline into an artificial airway would thin secretions, enhancing the flow of secretions out of the airway. However, research shows no thinning occurs and that patients' oxygenation drops with saline installation. Thus, the practice should be abandoned^{7, 8}.

Increasing the internal diameter of suction tubing or catheters will increase flow better than increasing the negative pressure or shortening the length of the tube. However, in most clinical applications the size of the patient will be the key factor determining the size of the catheter that can be safely used. Researchers at the Madigan Army Medical Center explored factors affecting evacuation of the oropharynx for emergency airway management. They tested three substances — 90 mL of water, activated charcoal, and Progresso vegetable soup — with three different suction systems, progressing from a standard 0.25-inch internal diameter to a 0.625-inch internal diameter at its most restrictive point. All systems evacuated water in three seconds. The larger diameter tubing removed the soup 10 seconds faster and the charcoal mixture 40 seconds faster than the traditional systems. The researchers note that this advantage in removing particulate material can speed airway management and reduce the risk or minimize the complications from aspiration^{9, 10, 11}.

Occlude to Set for Safety

Vacuum regulators are ever-present in the hospital setting. Clinicians use them daily and may not be as attentive to this

equipment with the demands of monitors and devices alarming and competing for the clinician's attention and time. Few clinicians learn the finer points of setting up suction systems. A nursing fundamentals text published in 2007¹² does not specify critical elements except to tell the nurse to follow manufacturers' instructions. The text leaves out the critical, universal "occlude to set" step that is recommended by all eight manufacturers of vacuum regulators used in North America.

While a number of organizations have published guidelines, ultimately the clinician must determine the maximum allowable level of negative pressure that can be applied to the patient. This is determined by a number of factors: where the suction pressure is applied (airway, stomach, oropharynx, pleural space, operative field), the age and size of the patient, the susceptibility for mucosal or other tissue damage, and the risks associated with removing air during the suction procedure.

Once the maximum level has been determined, the vacuum regulator must be adjusted so that the maximum pressure is locked in; that is, the regulator must be set correctly so it will

not permit a higher pressure to be transmitted to the patient. With traditional technology, the clinician must actively occlude the system by either pinching the suction tubing closed, or occluding the nipple adaptor (where the tubing is attached) with a finger. Once the system is occluded, the regulator is set to the maximum desired pressure; then the occlusion is released. If the system is not occluded during set-up, the maximum pressure is then unregulated and can spike to harmful levels (See Figure 1 and Box 2).

Suctioning is a dynamic process. As catheters are used to remove substances from the body, the degree of open flow continually changes based on the fill of the catheter and the viscosity of the substance being removed. Under these dynamic conditions, the regulator continually compensates by adjusting flow rate within the device and the tubing to maintain the desired negative pressure. Periodically, mucus plugs or particulate matter will occlude the patient tube. If the system was not occluded to establish the maximum safe pressure at set-up, pressure will spike to clear the occlusion, and once the occlusion passes, the patient will be subjected to potentially dangerous, unregulated vacuum pressures (see Figure 1).

Figure 1. Occlude to Set for Safety

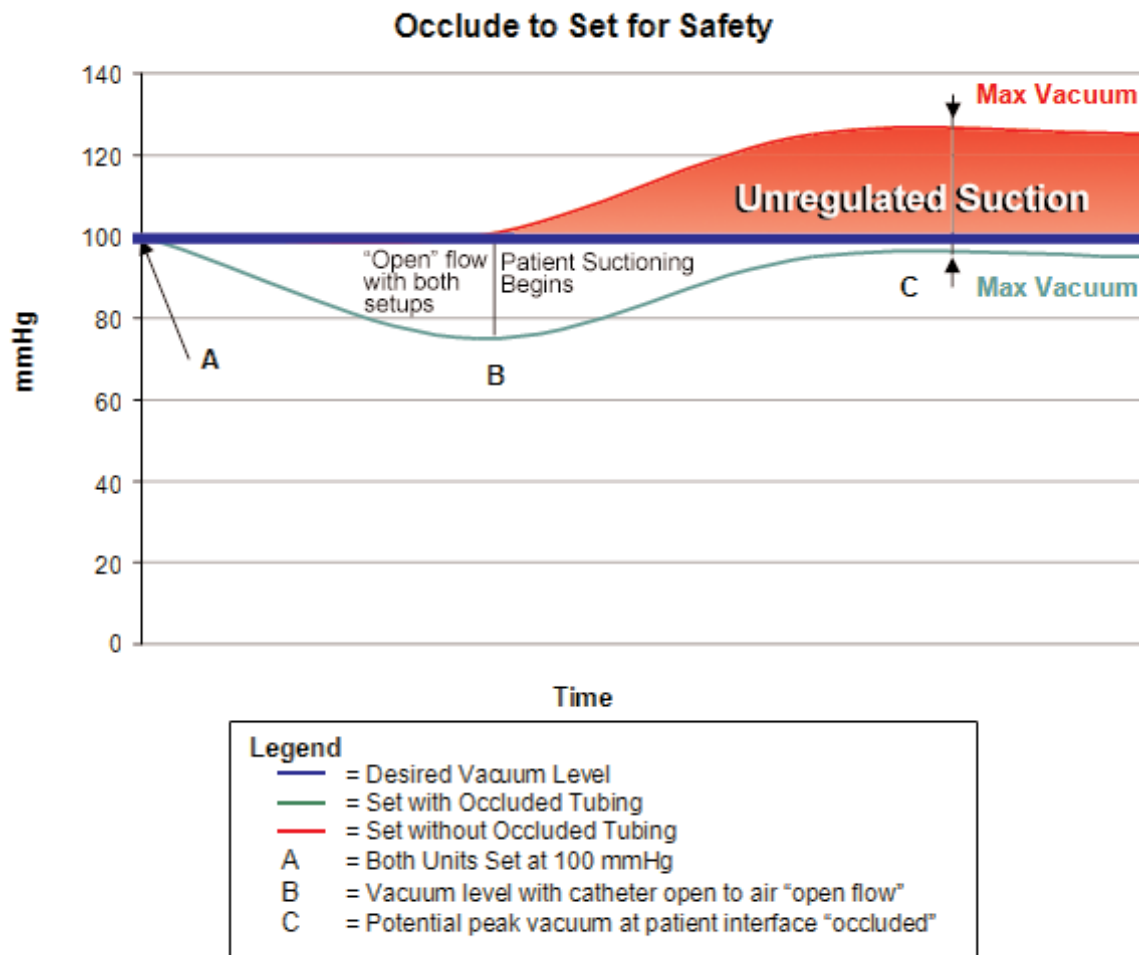


Figure 1 illustrates results of a bench test of two suction systems. The systems were set up identically as noted in Box 1. The desired maximum level of suction is 100 mmHg (A). One system was set at 100 mmHg with the system open to flow (red line); the other was set by occluding the system to set 100 mmHg (green line). During open flow, the “occlude to set” system will have a lower pressure than the desired maximum pressure because there are no occlusions in the system (B). Once suctioning begins, a dynamic flow condition occurs with varying levels of obstruction, and pressure rises in both systems. The point of maximum suction is key. In the “occlude to set” system, the pressure never rises above the desired maximum pressure of 100 mmHg. In the other system, pressure in this bench test spiked to 125 mmHg of unregulated suction. Without “occlude to set,” the pressure can rise to 25% higher than the desired maximum level or more, exposing the patient to a safety hazard when regulated suction is needed.

Box 2. Case study.

A nurse passing the bedside of an infant in the ICU saw blood inside the tube used for airway suction. After checking the child's condition, it was evident that bleeding was not expected.

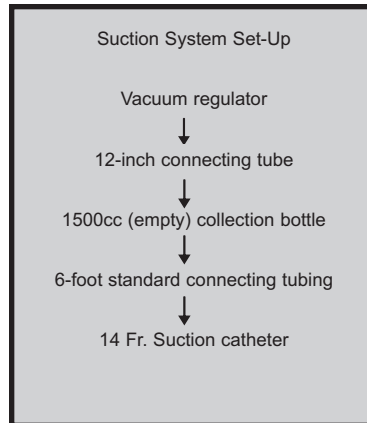
Further investigation determined the maximum level of negative pressure set on the wall regulator was -200mmHg; far more than recommended suction levels for infants. The nurse performing the suctioning did not occlude the tubing to set a safe maximum level of negative pressure. (personal communication to Ohio Medical Corporation)

Higher negative pressure is a particular hazard for patients with friable mucosa in the airway or stomach, making it more susceptible to traumatic tears. It is also a hazard for infants who have small lung volumes. When all other variables are stable, a 25% increase in negative pressure will increase the amount of air pulled through the system by 25%. That increase could result in a significant loss of lung volume in intubated neonates and infants¹³.

Breakthrough Technologies Enhances Safety

An ideal patient safety device removes clinician variables as much as possible by providing the added safety passively while the clinician carries out the procedure. Traditionally, the optimal safety of regulated vacuum pressure has depended on the clinician's action to occlude the system to set maximum pressure. Now a breakthrough technology from Ohio Medical Corporation in its new Intermittent Suction Unit (ISU), occludes the system automatically when the clinician adjusts the pressure level. This creates a highly effective, passive

Box 1. Suction System Set-up.



safety system that removes the clinician variable and protects the patient from unintended, unregulated pressure spikes during suction procedures. The “push to set” innovation assures the clinician that the patient will not be subjected to pressure higher than that set on the regulator.

Another key safety aspect of any vacuum regulator is the ability to quickly adjust to full vacuum mode when emergency strikes and rapid evacuation is essential. An additional unique concept introduced by Ohio Medical is the dual-spring design of the regulating module contained within the vacuum

regulator. This feature provides the clinician with the ability to control vacuum levels more precisely in the clinical range of 0-200 mmHg as well as the ability to achieve full vacuum when needed with only 2 turns of the knob on the regulator. In other regulators, six or more knob turns are needed to achieve “full vacuum,” and “full-vacuum” capability may be limited to the clinical range, not the full system vacuum provided by the Ohio Medical ISU. Since full vacuum is needed in emergency conditions, this enhanced responsiveness saves time when seconds are critical.

While vacuum regulators are often considered basic equipment in the hospital, research and innovation from Ohio Medical Corporation has shown vacuum regulators do have a role in enhancing patient safety in clinical settings. Clinicians should advocate for technology that provides passive safety protection, enhanced control of vacuum pressures, rapid response, and ease of use — all of which contribute to a culture of safety around the patient.

References

1. Czarnik RE, Stone KS, Everhart CC, Preusser BA: Differential effects of continuous versus intermittent suction on tracheal tissue. *Heart & Lung* 1991;20(2):144-151.
2. Duncan C, Erickson R: Pressures associated with chest tube stripping. *Heart & Lung* 1992;11(2):166-171.
3. Altimier L: Editorial [Evidence-based neonatal respiratory management policy]. *Newborn and Infant Nursing Reviews* 2006;6(2):43-51.
4. Wilson R: Bacteria and airway inflammation in chronic obstructive pulmonary disease: more evidence. *American Journal of Respiratory and Critical Care Medicine* 2005;172(2):147-148.
5. Dowling RB, Johnson M, Cole PJ, Wilson R: Effect of fluticasone propionate and salmeterol on *Pseudomonas aeruginosa* infection of the respiratory mucosa in vitro. *European Respiratory Journal* 1999;14:363-369.

-
6. Rutman A, Dowling R, Wills P, Feldman C, Cole PJ, Wilson R: Effect of dirithromycin on *Haemophilus influenzae* infection on the respiratory mucosa. *Antimicrobial Agents and Chemotherapy* 1998;42(4):772-778.
 7. Ackerman MH, Ecklund MM, Abu-Jumah: A review of normal saline installation: implications for practice. *Dimensions of Critical Care Nursing* 1996;15(1):31-38.
 8. Raymond SJ: Normal saline instillation before suctioning: helpful or harmful? A review of the literature. *American Journal of Critical Care* 1995;4(4):267-271.
 9. Vandenberg JT, Rudman NT, Burke TF, Ramos DE: Large-diameter suction tubing significantly improves evacuation time of simulated vomitus. *American Journal of Emergency Medicine* 1998;16(3):242-244.
 10. Vandenberg JT, Lutz RH, Vinson DR: Large-diameter suction system reduces oropharyngeal evacuation time. *Journal of Emergency Medicine* 1999;17(6):941-944.
 11. Vandenberg JT, Vinson DR: The inadequacies of contemporary oropharyngeal suction. *American Journal of Emergency Medicine* 1999;17(6):611-613.
 12. Wilkinson JM, VanLeuven K: *Fundamentals of nursing: thinking and doing* vol. 2. 2007. FA Davis Company, Philadelphia.
 13. Morrow BR, Futter MJ, Argent AC: Endotracheal suctioning: from principles to practice. *Neonatal and Pediatric Intensive Care* 2004;30(6):1167-1174.