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Clinical Update

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Managing Air Leaks Through Chest Tubes

Large air leaks are uncommon but challenging complications following major lung resections (primarily for cancer), in trauma patients and in those with necrotic lung infections, chemo- or radiotherapy for lung cancer, tuberculosis[1], and pulmonary barotrauma resulting from mechanical ventilation.

If a leak is related to suture failure or another identifiable opening in the tracheobronchial tree or lung, the opening can be sealed through bronchoscopy, thoracoscopic surgery, or open surgery. In other patients, air leaks from pneumothorax related to a parenchymal injury can present clinical management challenges when the patient is receiving positive pressure ventilation with positive end expiratory pressure (PEEP), since positive pressure increases the air flow through the pneumothorax.

Research over the past 20 years has shown that the air leaving the chest through a chest tube has already participated in gas exchange. The carbon dioxide levels measured in gas sampled from thoracostomy tubes are similar to those in exhaled gas. Thus, the air is not "wasted" or physiologically functioning as additional dead space (ventilation without perfusion). There is no need to "make up" for the air leak by adding to the patient's tidal volume, so minute ventilation can be maintained at a lung-protective level without risking hypercapnia and acidosis directly related to hypoventilation from the leak.

Physics of Air Flow

At the bedside, flow physics can be a delicate balance, and complete evacuation of the pleural space may not be required if oxygenation is adequate, particularly if the patient requires positive pressure ventilation. Research on routine postoperative patients has shown that when chest drains are connected to a vacuum source, air leaks can be prolonged because the suction pulls air through the opening and delays healing. Thus, routine suction is no longer recommended after uncomplicated lung resections; gravity drainage is preferred. (See Clinical Update Sept/Dec 2005, Sept 2002.)

For clarity, we'll define the physics terms:

- *Vacuum* is a space in which the pressure is significantly lower than atmosphere or surrounding pressure
- *Suction* is the movement of fluid or air as it rushes from an area of higher pressure to an area of lower pressure (across a pressure gradient)
- *Negative pressure* is a measurement of the amount of vacuum force exerted
- *Flow rate* indicates how fast air or fluid moves

Regardless of whether we are talking about fluid flow through intravenous tubing or air flow through a chest drainage system, three key elements affect flow rate: the amount of negative pressure, the resistance of the system, and the viscosity of the substance moving through the system[2].

Negative Pressure

Negative pressure establishes the pressure gradient that will move air or fluid. When suctioning an airway, that negative pressure is determined by the vacuum regulator. Chest drainage negative pressure is a bit more complex. The negative pressure force that is applied to the chest is limited by the suction control device on the drain. That can be the level of water in the suction control chamber, or the level of suction set on a dry suction drain. Source vacuum, typically from the wall, is attached to the drain, and then increased until bubbling starts in a water-filled suction drain, or until an indicator shows an adequate setting in a dry suction device. Excess negative pressure will then be vented to the atmosphere.

However, the gradient can still be enhanced by increasing the source vacuum pressure. This will increase the rate of flow without imposing additional negative pressure on delicate structures in the chest. This is an added safety feature present in chest drainage systems; if you were to increase source vacuum pressure while suctioning the airway with a catheter, the tissue would be subjected to the higher pressures[2].

System Resistance

Resistance is a force that opposes air or fluid movement. In healthcare applications, the two factors with the greatest effect on resistance are the diameter and the length of the tube through which air or fluid must flow. In trauma resuscitation, for example, short, large diameter peripheral IV catheters are placed in the antecubital space because large volumes of IV fluids will flow through these access devices and enter the intravascular space much more quickly compared with a longer, smaller-diameter central venous line. In pediatrics, patient size limits the size of tubes and catheters that can be used. Increased resistance can be a clinical issue when a tiny chest tube is placed in a 1000-gram neonate, or a ventilator must push air through a small endotracheal tube. A multi-part system, such as a chest drainage device, is limited by the smallest part of the entire system. In pediatrics, the smallest point may be the plastic connector between the chest tube and the drainage tubing since it must be a slightly smaller diameter to fit inside the chest tube. Otherwise, in the most common wet and dry chest drains available today with self-regulating dry suction control, the smallest part of the system is typically the connecting point between the chest drain and the tubing that connects the drain to the source vacuum. If the connector's inner diameter is one-quarter inch, for example, using 3/16-inch inner diameter connecting tubing would increase the resistance of the system and decrease flow.

Clinicians rarely think about the length of the tubing that connects the drain to the vacuum source, but the longer it is, the more resistance to flow it generates. If you are trying to maximize flow rate through the system, shortening this tubing will help reduce resistance.

Another aspect of resistance is the maintenance of the wall vacuum system in the entire hospital. If you are caring for a patient with a large air leak and bubbling does not begin in the wet suction control chamber when wall vacuum is increased, vacuum system maintenance may be needed. In busy intensive care units, there is often little down time for maintenance of wall systems. Flow rate at wall vacuum outlets should be measured at least annually; minimum

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In The Literature

Could You Replicate This Study?

The current issue of the *Journal of Nursing Scholarship* contains an important article analyzing published nursing research. One of the basic tenets of published research is to include significant detail on the intervention so that a reader could replicate the study to prove or disprove the thesis. These researchers examined 141 research articles published in 27 journals in 2005. Of the studies examined, only 27% had enough detail to allow study replication or to translate the research into practice. This is a must-read for all potential authors and those of us trying to implement more research in our practices.

Source: Conn VS, Cooper PS, Ruppar TM, Russell CL: Searching for the intervention in intervention research reports. *Journal of Nursing Scholarship* 2008;40(1):52-59.

Is Synergy Magnetic?

The current issue of *Nursing Economic$* features a detailed article describing how the AACN Synergy Model can be used to fulfill one of the requirements for hospital Magnet status – that of having a professional model of care. It's been more than 10 years since AACN convened a think tank to establish a new model of nursing that could serve as the basis for certified practice. This new approach focused on patient needs and optimizing patient outcomes rather than focusing on nursing skills per se. This piece describes the model in detail, including patient characteristics, nurse characteristics as they relate to patient needs, and how this model can be used as a framework for successful relationships between patients and their nurses throughout a healthcare organization.

Source: Kaplow R, Reed KD: The AACN synergy model for patient care: a nursing model as a force of magnetism. *Nursing Economic$* 2008;26(1):17-25.

Plug and Play in the ICU?

If you have ever repeatedly hit the "alarm delay" button on a monitor while you were performing a procedure because you were concerned that if you turned the alarms off, you might forget to turn them back on before you left the bedside, this article is for you. It's a great description of how plug-and-play technology we take for granted in our everyday lives — such as synching our portable music players with our computers, or plugging in a USB flash drive, or using a Bluetooth headset with our cell phones — should be implemented to optimize safety in healthcare. The authors describe the Medical Device Plug-and-Play Interoperability Program, affiliated with Massachusetts General Hospital, the Center for the Integration of Medicine and Innovative Technology, and Partners HealthCare Information Systems, with additional support from the US Army. The researchers are actively looking for case studies from clinicians to establish needs that new interoperability standards can meet.

Source: Whitehead SF, Goldman JM: Getting connected for patient safety. *Patient Safety and Quality Healthcare* 2008. 5(1):20-26.
Also available online at: http://www.psqh.com/janfeb08/connected.html

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acceptable levels are published by the Compressed Gas Association. Measurements should be done during the day with all operating rooms functioning so there is maximal draw on the entire vacuum system at the time of testing. Outlets and piping should be cleaned as necessary.

Viscosity

Viscosity is the thickness of the material flowing through the tube. Air will flow faster than blood or purulent empyema drainage. As viscosity increases, the pressure gradient needs to be increased in order to maintain an adequate flow rate.

By understanding physics and maximizing air flow through the system, clinicians can facilitate evacuation of air leaks without subjecting patients to potentially dangerous increases in negative pressure.

Sources:

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2. Carroll P: Enhancing the safety of medical suction through innovative technology. *RTMagazine* 2008;21(2):30, 32-34. Available online at: http://www.rtmagazine.com/issues/articles/2008-02_04.asp

Additional Reading Classics

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Powner DJ, Cline CD, Rodman GH: Effect of chest-tube suction on gas flow through a bronchopleural fistula. *Critical Care Medicine* 1985;13(2):99-101. [classic for discussion of physics]

On the World Wide Web

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Learn More About Medical Plug and Play

You can learn more about the Medical Plug and Play program described above at the organization's web site: http://www.mdpnp.org. Not only is there additional information about the program, but also full-text articles, white papers and slide presentations about medical device safety.