

Photo courtesy of Cleveland Clinic

An example of a critical care patient on a mechanical ventilator.

Under Pressure

Patients on ventilators may soon breathe easier

By Brent Ardaugh

Researchers from the Harvard-MIT Division of Health Sciences and Technology (HST) may soon have thousands of critical care patients breathing easier. In the September 12, 2007 issue of PLoS ONE, an open-access journal from the Public Library of Science, Dr. Chi-Sang Poon and his

colleagues at HST announced a safer, more cost-effective approach to deliver breaths to patients on ventilators.

Patients with severe head trauma, multiple broken ribs, or even a prolonged surgical recovery time are not always capable of breathing on their own. Therefore, clinicians often apply machines called ventilators to help patients move air in and out of their lungs more effectively in a process called mechanical

ventilation.

By supplementing mechanical ventilation with nonassociative learning, HST researchers can better synchronize the natural breathing rhythm of a patient with the rhythm of a ventilator, a phenomenon called respiratory entrainment.

Nonassociative learning is the natural ability of the human body to adapt to a single, recurring stimulus. For example, when you unexpectedly become startled by loud

fireworks on July 4th, your body has natural ways of learning more about the characteristics of the fireworks. The loud booms recurring throughout the day serve as a type of stimulus that prompts your body to respond. The same idea applies to mechanical ventilation, where nonassociative learning enables critical care patients to breathe in a more natural, efficient way.

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"It is a new way of delivering artificial ventilation that exploits the patient's innate ability to adapt one's spontaneous respiratory rhythm to the ventilator rhythm," said Dr. Poon, a Principal Research Scientist at HST. "This allows safer and more cost-effective mechanical ventilation and could obviate the need for sedation and paralysis."

Currently, the well-being of a patient almost entirely depends on the ventilator's settings and the patient's moment-to-moment response to the machine. If the breathing rhythm of the patient is not synchronized with the ventilator rhythm, clinicians may induce sedation or paralysis. Otherwise, a patient's body can fight the ventilator-delivered breaths and cause severe lung injuries. Although certain patient-triggered ventilators are common in most hospitals, they are not always beneficial for newborn babies or long-term patients because of their ability to trigger at unwanted times.

In the study, Poon and his colleagues use two types of nonassociative learning called habituation and desensitization to promote a better patient-ventilator interaction. Habituation refers to a person's decrease in responsiveness to a repeated stimulus. In terms of the fireworks example, you may learn to successfully "block out" or become more accustomed to the loud, recurring noises over time. On the other hand, desensitization is a person's diminished response to a second stimulus as a result of the first stimulus. For instance, if you became more accustomed to the loud fireworks through repeated sounds, your ability to hear other noises might have decreased, too.

Your vagus nerves, string-like bundles of sensory fibers, help let you know when your lungs are full by responding to stretch receptors inside your lungs. When you inhale, the expansion of your lungs activates these stretch receptors, which send electrical signals via the vagus nerves to your brain. This phenomenon,

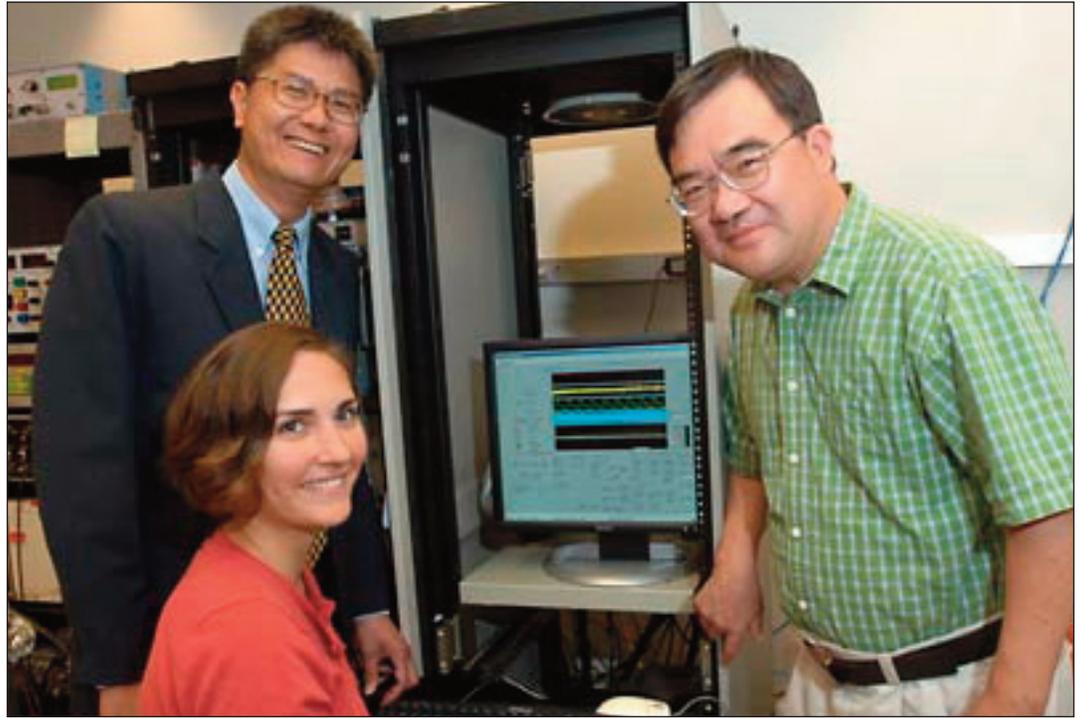


Photo courtesy of MIT News Office

Chi-Sang Poon, from left, Shawna MacDonald and Gang Song have discovered that nonassociative learning, a natural capability of the human body, promotes a better patient-ventilator interaction.

called the Hering-Breuer reflex, is important because it prevents over-inflation of your lungs by letting you know when to stop inhaling and start exhaling.

Most current mechanical ventilators can induce extra pressure (Positive End Expiratory Pressure or PEEP) in the lungs of certain patients to promote better conditions for gas exchange. For example, PEEP commonly assists patients who suffer from Acute Respiratory Distress Syndrome by preventing their lungs from collapsing. This extra pressure applied in other cases, however, can activate the Hering-Breuer reflex by sustaining elevated lung volumes.

Poon explained how PEEP compromises respiratory entrainment when stating, "The respiratory rhythm is entrained to the ventilator rhythm through feedback via the vagus nerves that detect the phasic expansion and recoil of the lungs. This phasic feedback signal may be masked by constant feedback signals elicited by sustained elevation of lung volume due to continuous positive airway pressure that often comes with mechanical ventilation."

If the electrical signals of the vagus nerve become hindered by opposing or conflict-

ing signals, the lungs of a patient can remain inflated. A related event takes place when you are listening to your favorite song on the radio and static interference suddenly interrupts. Continuous lung inflation is responsible for producing the bad static signal that distorts the vagal signal. When the vagal signal becomes compromised, a lower quality patient-ventilator interaction occurs because the breathing rhythm of the patient is no longer synchronized with the rhythm of the ventilator.

Habituation and desensitization both aid mechanical ventilation by operating as a filter: they can block or mask the static signal caused by sustained lung inflation while allowing the vagal signal to pass. Just as when you adjust the treble and bass setting on your stereo, if you pretend the vagal signal is the treble (higher frequency) and the static signal is the bass (lower frequency), you can block certain frequencies while permitting others.

"Habituation and desensitization are two different forms of nonassociative learning," said Poon. "They confer the 'differentiator' or 'high-pass filter' function to the respiratory system that is important for buffering the adverse effects of

sustained lung inflation."

Habituation enables the natural breathing rhythm of the patient to adapt to the rhythm of the ventilator. Similar to the fireworks example, the patient becomes more accustomed to a single type of stimulus: the breaths delivered by the ventilator. Desensitization works by combating the static signal produced by PEEP and continuous lung inflation. The patient, therefore, becomes less affected by changing pressures (second stimulus) as a result of their ability to naturally adapt to the ventilator-delivered breaths. Most ventilators currently used in hospitals do not incorporate such a learning capability.

"Previous mechanical ventilator designs do not consider the possibility of respiratory-ventilator entrainment and that the patient could 'learn' to adapt to changing ventilator pressures," said Poon. "The new design will make use of respiratory-ventilator entrainment and let the patient's nonassociative learning to do the fine-tuning on the fly."

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