Life Is a Gas
by Jaclyn Jones, RRT, clinical research associate, pulmonary care services, University of Texas Medical Branch, Galveston, TX

It’s been one of those nights that just seem to go on forever. The respiratory therapist, doctor, and nurse have been at bedside in a level two NICU for hours. Looking down at the 3-week LGA (large for gestational age) baby girl, the RT is silently praying for a miracle — any one will do. Things have gone from bad to worse.

When the baby was born she was sort of a slow starter. Just didn’t pink up as well as expected. The story is one we all know too well. Being conservative by nature, the doctor first had the RT try a 40% hood. When the color did not improve, intubation and ventilation were necessary. Now, on high pressure and peep with FIO2 of 95%, the pulse-ox still will not stray higher than 85%. ABGs only confirm the bad news, and the transport team from a university hospital is called. PPHN has reared its head once more. The RT can’t imagine how the parents will feel if they have to see their new daughter on ECMO.

At last, the team from 150 miles away rolls through the nursery door. Smiling and very cheerful despite the fact that it’s 3 a.m., they assess the infant and ask to see the parents. When they return to the NICU with a consent in hand, the baby is changed over to the transport ventilator. The transport therapist explains to the NICU staff that they have a new system that will allow them to deliver NO (nitric oxide). The NO is titrated by the RT until it reads 5 ppm (parts per million). Almost immediately, the pulse-ox rises to SaO2 of 99%, and the baby girl turns a very nice shade of pink. At the university hospital just three days later, the NO is off, and the next day the baby is in a hood, but only for a short while. The parents have been spared the sight and hazards of ECMO, and about a week later, are able to take their new baby girl home. Miracle or magic?

Now, NO is not a new concept. It was even featured on a segment of the TV show “ER.” Dr. Benton’s son was saved by NO right there in the television NICU. But while the producers of “ER” found NO useful to the story line, many health care professionals are still a bit vague about the proper use of inhaled NO. So here we go. In a few moments you will be ready with an answer when asked, “how does it work?”

Let’s start with a little history. All of us produce NO naturally in our body. It occurs in the brain and all the way down to our toes. It’s also a hot topic. There are currently more research projects dealing with NO and its role in human physiology than there are IPPB machines in storage. But while a lot of mystery surrounds some of its functions, one thing is clear: nitric oxide is a potent vasodilator.

The thing that sets NO apart from other drugs that cause vasodilatation is quite simple. It has a regional effect on the vasculature of the lung when inhaled, without affecting the systemic vascular function. (Here’s a little tidbit of information: the exhaust from a bus contains around 1000 ppm of NO. But I don’t suggest that you spend much time inhaling bus exhaust.)

In the human body NO acts as an EDRF (endothelium-derived relaxing factor). NO is a naturally occurring substance that is produced in the cells by the enzyme nitric oxide synthase (NOS). NOS combines with Nicotinamide adenine dinucleotide phosphate + oxygen and then converts L-arginine to NO and Citrulline. Researchers have found that current vasodilators work via a nitric oxide-
transported in the plasma. Most drugs used to transport calcium are cytoplasmic calcium inhibitors.

Now, take a deep breath because here comes the rest. Increased levels of cGMP (Cyclic Guanosine 3',5' Monophosphate) inhibit intracellular Ca++ levels by preventing the release of bound Ca++ from the sarcoplasmic reticulum. NO activates the enzyme guanylate cyclase, which produces cGMP. Because NO is inhaled and becomes inactive when combined with hemoglobin, it is very regional in action. It is the only option at present that allows us to achieve pulmonary vasodilatation without systemic effect.

Whether the patient is an adult or a neonate, NO has only one benefit. If pulmonary hypertension is due to a breakdown in the production of NOS, NO has the potential to cause pulmonary vasodilatation and increase blood flow through the lungs. That is the whole story. Not magic, but at times it sure looks like a miracle. When it works, the results can be astounding. Most patients who respond do so almost in the blink of an eye. But it does not always work.

According to a study done in 1997, NO improved oxygenation in about 53% of the neonates who received it. Only 7% of infants in the same study who did not receive NO and were supported with conventional ventilation had an improvement in oxygenation. Most studies have not shown an improvement in survival as compared to conventional therapies or ECMO. There has not been much time to evaluate the long-term effects of NO as compared to other methods of support, so little data exist in this area.

In adults, the results of the majority of research have not been as promising. My own experience with adult respiratory distress patients has been mixed. In the adult patient, the best benefit seems to be a decrease in the intensity of mechanical ventilation. Overall mortality seems unchanged.

Reduction in the number of infants on ECMO is without a doubt a prime objective of this treatment, and NO does accomplish that goal. However, NO is still considered experimental and requires an IND (investigational new drug) number from the Food and Drug Administration (FDA) for use or purchase of gas or equipment. Approval for neonatal use is just around the corner, but for now the use of NO, although widespread, is restricted.

Now then, let’s suppose you have met all the FDA requirements. This means that you submitted a protocol to your IRB and now have the required IND. How do you safely administer NO to your patients? Remember, NO is considered a toxic gas and must be treated with respect. It really doesn’t matter if the gas is used in-house or in transport — certain safety issues apply to both. You must be able to titrate the gas delivery accurately down to 1 ppm. The most common concentration available is 800 ppm mixed in nitrogen. You must also be able to continuously analyze the ppm the patient is receiving, as well as the ppm of nitric dioxide. Nitric dioxide forms when nitric oxide is mixed with oxygen. NO is a strong acid and can cause injury to mucosal surfaces — as well as to many of the components in your ventilator. We have not had any problems with our ventilators yet, but the exhalation valve would be an issue.

There are three possible ways to get the NO from the tanks to the patient. You can run the gas through a blender and then into the air inlet on your ventilator. But while this method produces a stable concentration, it is full of hazards. If the ventilator is placed on 100% oxygen, NO will abruptly cut off to your patient. Plus, you are then running NO through the entire internal workings of the ventilator.

Second, you can bleed NO continuously into the inspiratory side of the circuit. You will need low range flow meters (1 l/m and 200 cc/m), because in the neonatal population it takes very careful knob twisting to get close to a stable concentration. Even at that, NO will fluctuate in ppm by quite a bit at the beginning of inspiration.

You also need to remember that the patient will need to be bagged when on nitric oxide. Both of the above methods can make that difficult.

The best solution is an injector module that delivers gas during the inspiratory phase based on the flow. So far there is only one manufacturer with a product capable of doing this. No matter what system you use, make sure that you have alarms that alert you to low FIO2, as well as NO and NO2 concentrations. And remember that any problems that could possibly arise in the ICU will be magnified when you attempt to transport a patient on NO in-house or by air or ground. Make sure you choose a system that suits your needs.

Finally, we come to the patient. Until NO is approved for use by the FDA, you will need to have an informed signed consent from the patient or someone with the authority
to make decisions for the patient. Most importantly, you need to ask yourself this question: will the patient benefit from NO? No matter how you look at it, NO is only effective in the treatment of pulmonary hypertension. Conditions that appear to respond to inhaled nitric oxide are:

- Persistent pulmonary hypertension of the newborn
- Adult respiratory distress syndrome
- Pulmonary hypertension (primary)
- Pulmonary hypertension caused by pharmacological response (some drugs act as NO scavengers)
- Reversal of refractory bronchospasm
- Surgical procedures requiring lowering pulmonary vascular resistance (heart and lung transplants)

At present, the FDA is only considering the use of NO in the neonatal setting.

Short term side effects of NO include increased levels of met hemoglobin (>1.7-2.0%). If met hemoglobin rises higher than 3-4% above the patient’s baseline, NO should be discontinued. But note that the sudden discontinuance of NO could cause a sudden increase in pulmonary resistance and could be fatal in some compromised patients.

Patients with the following conditions should either not be given NO or at least be very carefully monitored:

- Bleeding disorders (DIC, thrombocytopenia)
- Multi-system organ failure
- Refractory systemic hypotension despite vasopressor and volume support

Weaning the gas should begin as soon as clinically appropriate. This would be when the FIO₂ is less than 40%, the peep is +5 or less, and the patient is otherwise stable. If the patient does not respond to NO it should be stopped. When weaning, it is important to use caution when you get to only 2 or 3 ppm. Some patients will desaturate and may require restarting the NO or increasing the FIO₂.

As research in this area continues, hopefully more uses for this molecule will be found. Our experience with NO has been positive, and I can’t think of any other modality that has had such an immediate effect on neonatal outcome.

Hyperbaric Oxygen Therapy: Transport Considerations
by Tammy Babcock, RRT, DMT, assistant instructor, Diver Medic Technician and Certified Hyperbaric Technician Courses, UTMB, Galveston, TX

Hyperbaric oxygen (HBO) therapy is a procedure we have all heard of, but many medical personnel know very little about how or why it works. HBO is a medical treatment that saturates the body with 100% pure oxygen under pressure. In this way the cells of the body become saturated with oxygen to a far greater degree than they ever could under ambient atmospheric pressure. The concentration of oxygen normally dissolved in the bloodstream can be increased up to 2000%. Thus an arterial PO2 of 1500-2000 mm Hg can be achieved. In addition to the blood, all body fluids are saturated with oxygen, so much so that hemoglobin is no longer needed.

Oxygen is essential to any healing process. HBO is used to accelerate the healing process for wound care, burn victims, and many neuralgic, orthopedic, and emergency conditions. HBO therapy is traditionally used in the treatment of decompression illness (DCI) in divers and in anyone suffering from smoke inhalation.

HBO treatments typically last from one to two hours and frequently continue daily or BID for 10-20 days for up to 40 treatments. The patient is placed in a cylindrically-shaped chamber, either a “monoplace” (single person) or a “multiplace” (up to 10 people). Patients are exposed to 100% oxygen intermittently throughout the one to two hour treatment, at which times their oxygen levels are up to 2000% greater than at normal atmospheric levels.

HBO therapy is administered under the supervision of a trained physician in a controlled environment commonly run by certified hyperbaric technicians or respiratory therapists. HBO is approved by the American Medical Association, Food and Drug Administration, and by Medicare. Medicare and many insurance companies now recognize at least 17 different diseases for which HBO is recommended as either primary or secondary treatment. Reimbursement is approved for the following conditions: acute carbon monoxide intoxication, decompression illness, gas embolism, necrotizing fasciitis, diabetic ulcers, gas gangrene, cyanide poisoning, and radiation necrosis. HBO is also a valuable adjunct therapy to acute traumatic peripheral ischemia, crush injuries and suturing of severed limbs, osteoradionecrosis, chronic refractory osteomyelitis, soft tissue radionecrosis, and actinomycosis.

In addition to the many approved diseases for HBO there are a multitude of other diseases for which there are supporting research and published papers regarding the use of hyperbaric oxygen as a primary therapy or an adjunctive therapy. Some incredible results have been seen with the use of HBO in anoxic head injuries, closed head injuries, and cerebral palsy.

HBO works by a combination of processes. We have already discussed the massive increase in the amount of oxygen to the tissues. This, in turn, enhances the fibroblast division, the neoinformation of collagen, and capillary angiogenesis in areas of neovascularization, or areas of greatly impaired or no tissue perfusion. Hyperoxia also enhances antimicrobial activity, and causes toxin inhibition and toxin inactivation in gas gangrene. Hyperoxia also stimulates phagocytosis and white cell oxidative killing.

The application of direct pressure...
HBO Therapy” continued from page 3

utilizes the well-known concept of Boyle’s Law to reduce the volume of intravascular or other free gas. For a long time this formed the basis of HBO therapy as a standard of care for CAGE. Bubbles form in blood or tissues from the inert gas (nitrogen) as the diver returns to sea level too rapidly, causing severe pain and/or serious symptoms and signs, which may be referable to the central nervous, peripheral nervous, and cardiopulmonary systems. Reduction of these bubbles in the bloodstream and tissues is achieved by pressurizing a chamber, which also allows for reduction of edema caused by the bubble at the site of injury.

Transporting a patient who is a potential for HBO therapy is much like transporting any acutely injured person. The ABC’s of patient assessment are always foremost in our minds. First, the *airway*: make sure you have a patent airway, and if the patient is intubated and you are traveling via an unpressurized cabin, the cuff from the endotracheal tube should be filled with saline or water. This will prevent the air in the cuff from expanding or collapsing on ascent or descent. Second, *breathing*: make sure the patient is adequately ventilated. Third, *circulation*: the volume expander of choice is lactated ringers. If you are transporting a diving accident to a hyperbaric facility, the cabin of the aircraft must be pressurized or an altitude of less than 500 ft. must be maintained. This, again, will prevent current free air in the body from expanding on ascent.

Other than these few considerations, transporting a possible hyperbaric patient is the same as transporting any other acutely injured patient. Stabilize and transport as quickly as possible.

Although HBO therapy is not a common therapy, it is becoming much better understood through education and research. As our knowledge of its benefits increases, HBO will become a more commonplace treatment for many diseases. The list is growing all the time.

Preparing for the Worst: What the Emergency Medical Community Needs to Do

Saying that it’s not a matter of “if” but “when,” experts from America’s emergency medical community are billing on their colleagues to prepare for potential acts of terrorism in the United States. Several articles in the August issue of *Annals of Emergency Medicine* discuss the history and threat of attack, the status of emergency medicine training, and the skis for the emergency medical community. They include:

**Emergency Physicians and Biological Terrorism** — This article presents the history and threat of biological weapons, and discusses planning and response issues central to a potential bioterrorism event. It describes how recent developments, such as the bombings of the World Trade Center in 1993 and the federal building in Oklahoma City in 1995; the sarin attacks in Tokyo and Matsumoto, Japan; and the U.S. Embassy bombings in Kenya and Tanzania in 1998, have heightened fears of terrorist attacks.

**Emergency Department Impact of the Oklahoma City Terrorist Bombing** — A new study of medical records from 388 victims of the 1995 bombing in Oklahoma City provides information that may aid emergency planning and help reduce injury in a terrorist attack. The study found that more than half of the patients arrived in emergency departments by privately owned vehicles, converging on the geographically closest hospitals. Victims in this “first wave” arrived within 5 to 30 minutes after the bombing, with more seriously injured patients taking longer to arrive than those who were treated and released, supporting previous studies that found that more seriously injured patients arrive in a “second wave.”

- **Chemical Warfare Agents**
  - *Emergency Medical and Emergency Public Health Issues* — This article presents a comprehensive discussion of chemical warfare agents and discusses how communities must address both emergency medical and emergency public health issues in their preparedness and response activities. It outlines the risks of chemical warfare agents to civilian populations, presents an overview of agent classification and characteristics, and discusses issues in disaster preparedness, including education and training, disaster plans and exercises, public education, specialized response teams, and stockpiling antidotes. It also covers the principles of emergency response and medical treatment.

- **Principles for Emergency Response to Bioterrorism** — This article discusses a series of anthrax-related hoaxes that occurred during 1998 and early 1999 and affected nearly 6,000 persons across the US. The article focuses on the need to educate emergency personnel about how to best ensure patient and worker safety in cases of suspected exposure to biological threat agents. It also describes how emergency physicians, first responders, and hazardous materials response teams need a standardized approach to manage patients who may have been exposed. Their need for a working knowledge of recommended isolation and infection control measures, as outlined in the Centers for Disease Control’s *Guidelines for Isolation Precautions in Hospitals*, is covered as well.

- **Editorial: Education is the Key to Defense Against Bioterrorism** — The greatest threat to the US and its citizens in the first decade of the 21st century will not come from a military confrontation, but from an attack within the borders, says Edward Eitzen, Jr., MD, MPH, colonel, US Army Medical Corps. The editorial describes how biological weapons pose perhaps the greatest threat and says that the main defense against the massive
“Preparing” continued from page 4

casualties, panic, and disruption they could cause will be the astute emergency clinician with a high index of suspicion who spots a suggestive clinical or epidemiologic pattern in victims early on and sounds the alarm.

• Do US Emergency Medicine Residency Programs Provide Adequate Training for Bioterrorism? — A survey of emergency medicine residency programs found that there is no standardized curriculum for training emergency physicians about health hazards related to weapons of mass destruction. Opportunities for widespread teaching of this material have remained limited, and the range of knowledge regarding even general disaster medical care is variable among most residency training programs in the US.

• Telecommunications Systems in Support of Disaster Medicine: Applications of Basic Information Pathways — This article explores various telecommunications tools for enhancing medical response in a disaster, including telemedicine. It describes how a lack of communication is one of the most serious problems experienced during a disaster; specifically, the lack of appropriate means to efficiently collect, process, and transmit information.

• Editorial: Chemical Incidents in the Emergency Department: If and When — Dr. Peter Pons of the Denver Health and Hospital Authority, says that the effort to educate the medical community about managing a victim of hazardous material contamination has received a lukewarm reception. The editorial discusses the need for emergency personnel to be trained in “syndrome recognition,” the problems associated with identifying hazardous materials, and the reality of emergency care stresses the need for readiness in emergency departments, not dependence on outside assistance.

• Editorial: The Medical Response to Modern Terrorism: Why the “Rules of Engagement” Have Changed — Dr. Marc Eckstein, of the Los Angeles City Fire Department, says that the bombings of American embassies in Africa, New York’s World Trade Center, and the federal building in Oklahoma City have profound consequences for health care providers. The editorial discusses the need for a uniform approach to these incidents and notes that emergency responders, including law enforcement and EMS providers, are not only potential victims but potential targets.

CAMTS Representative Needed

Jerry Focht, our long-time representative to the CAMTS Board of Directors, will soon be vacating that position. We are currently looking for a replacement. If anyone is interested in representing the AARC three times a year at the CAMTS board meetings, please contact Jerry at (800) 572-3210 ext. 2, or e-mail focht@arias.net. The AARC and CAMTS provide funding for this position.

CAMTS Accredited Transport Services

The following list contains all of the programs that were CAMTS accredited as of 4/1/98.

* = Reaccredited/RW= Rotorwing/FW= Fixed Wing/G= Ground Critical Care

AeroCare — Lubbock, TX RW/FW

*Air 1 — Tyler, TX RW

*Air Evac Services, Inc. — Phoenix, AZ RW/FW

Air Med Team — Modesto, CA RW

AirMed — Salt Lake City, UT RW

AIR TREK — Punta Gorda, FL FW

*AirEvac for Tulsa — Tulsa, OK RW/G

AirLife of Greeley — Greeley, CO RW

Airlift Northwest — Seattle, WA RW/FW

Allegheny Life Flight — Pittsburgh, PA RW/FW

Angel Flight — Little Rock, AR RW

* + Butterworth AeroMed — Grand Rapids, MI RW

* CareFlight — Dayton, OH RW

*CareFlite Dallas — Dallas, TX RW/FW

Conemaugh Med Star — Johnstown, PA RW

CAREFLIGHT — Lexington, KY RW

CAREFLIGHT — Lexington, KY RW

Flight Care — Saginaw, MI

Flight For Life — Denver, CO RW/FW

Flight For Life — Milwaukee, WI RW

Gallup Med Flight — Gallup, NM FW

Guardian Air Transport — Flagstaff, AZ FW
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**Request for Assistance: New Technology**

Susan Blonshine is writing a “clinical perspectives” article for *AARC Times* on new technologies in 1999 and would like to know what new technology this year has had the greatest impact on your specialty area and why. Please respond by October 10 to Susan by email (sblonshine@aol.com) or fax (517-676-7018).

**Transport Section Classifieds**

The following position is now available —

**Internet Coordinator**: Responsible for monitoring section and AARC web site and bulletin boards, alerting section chair of postings that require an answer, and posting answers as appropriate. Would monitor other web sites that may be of interest to the section membership or benefit from an AARC link. Develop new ideas for the section web site. For information or to apply contact Kathleen Adams, chair, Transport Section, AARC at (909) 824-0800 ext. 43809 or e-mail: kadams@ccmail.llumc.edu