# Pulmonary Thromboendarterectomy:

## *A Nursing Challenge*

By Tove King, RN, BSN, CCRN

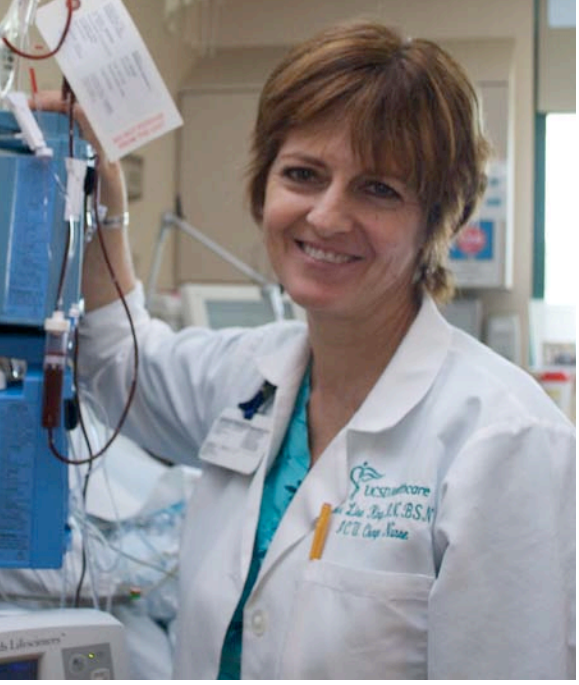
The ICU doors swing open to the rhythmic beeping of an ECG monitor and the postop PTE patient rolls in with an entourage of surgeons, anesthesiologists, OR nurses, techs and a respiratory therapist. Within minutes of arrival the jumble of wires, tubes, and IV lines has been transferred to the ICU room hookups and the entire OR team gathers its equipment and exits, leaving the patient in the capable hands of a PTE nurse. The Thornton ICU nurse assuming that responsibility is thoroughly knowledgeable, highly skilled, and proficient in postoperative care of the PTE patient. PTE is Thornton Hospital's specialty, and the cardiothoracic surgery nurses in Thornton's ICU are trained to manage the specific acute care needs of this unique patient population.

PTE stands for pulmonary thromboendarterectomy, the precise surgical dissection of chronic thromboembolic material that has become integrated into the pulmonary artery walls, obstructing blood flow and causing pulmonary hypertension which results in right heart failure. Surgical removal of the thromboembolic material accomplishes three major goals: first, it restores blood flow to ventilated but previously non-perfused areas of the lung, converting that physiologic dead space back to normal pulmonary function. Second, it alleviates the excessive pulmonary pressures that cause right heart enlargement and failure. Third, it prevents disease progression, including extension of the clot material as well as secondary changes in unobstructed vessels. Early symptoms of chronic thromboembolic pulmonary hypertension (CTEPH) are so nonspecific that misdiagnoses such as asthma or lack of fitness are common, so CTEPH may not be accurately diagnosed until individuals decline in functional status to New York Heart Association Class III or IV; they experience dyspnea, palpitations and fatigue with activity, and as the disease progresses they develop complete exercise intolerance and become symptomatic at rest. Once CTEPH is confirmed through clinical assessment and diagnostic testing, most notably pulmonary angiography and a lung ventilation/perfusion (V/Q) scan, PTE surgery is the treatment of choice. It can reverse or significantly ameliorate this debilitating condition that severely limits quality and length of life.

UCSD is unquestionably the world leader in PTE surgery and UCSD Medical Center La Jolla attracts patients from across the country and around the world. Dr. Nina Braunwald performed UCSD's first endarterectomy nearly forty years ago in 1970 with a successful outcome for the patient, who returned home and resumed normal activity. Since 1989, major revisions to the surgical procedure coupled with subsequent refinements in perioperative management have achieved a surgical mortality rate of approximately 5%, with over 2300 surgeries completed to date. The program's success is attributable to the multidisciplinary PTE team of expert surgical and medical practitioners that care for the patient from preoperative evaluation through postoperative management and discharge.

PTE surgery requires a completely bloodless field that allows the surgeon to visualize the artery wall and create a plane of dissection between the intima and the media to separate and remove the fibrotic thromboembolic material. This is achieved through deep hypothermic circulatory arrest. The patient is gradually cooled to a core temperature of 20˚C with cardiopulmonary bypass and cooling blankets, including a special cooling jacket around the head. Deep hypothermia and barbiturate administration suppress the EEG to an isoelectric line. A 20-minute period of circulatory arrest allows the expert surgeon to perform a right-sided endarterectomy, followed by restoration of circulation and then a second 20-minute circulatory arrest period for the left-sided endarterectomy. Once cardiopulmonary bypass is re-established the patient is warmed to normothermia over a period of several hours, hemodynamically stabilized, and transported to the ICU. Thornton ICU nurse Maureen Parsons, who has nearly completed her PTE orientation, marvels at the OR to ICU turnover. "An entire OR team cares for this patient, who is basically brought back to life after being blue and cold with no brainwaves, and then we get to take over their baby," she observes. It is a responsibility the PTE nurse is well prepared to handle.

The special circumstances of this surgery - hypothermia, EEG suppression, full circulatory arrest, and removal of pulmonary blood flow obstruction - dictate PTE-specific postoperative considerations above and beyond the nursing care



**Tove King** received her BSN from San Diego State University in 2001. She began working at Thornton ICU as a new grad and has never left, in her words, "because I love it so much!" Tove was Thornton ICU Nurse of the Year in 2008.

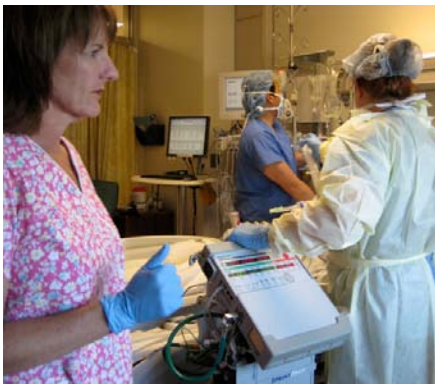
for more common cardiothoracic procedures such as bypass surgery or valve replacement, so Thornton critical care nurses orient to these patients at the bedside under the tutelage of experienced nurses who are experts in PTE patient assessment and care. "PTE nurses are thoroughly knowledgeable about the disease pathology and the surgery, so they know exactly what complications to expect and how to handle them," says RN Laura Lubomirsky. "It is the PTE nurse whose eyes are on the patient 24/7, and it is the quality and expertise of the PTE nurses that allows them to predict instability." Mary Hellyar agrees: "The PTE nurse has to be knowledgeable to be able to recognize changes in the patient's condition early and intervene right away."

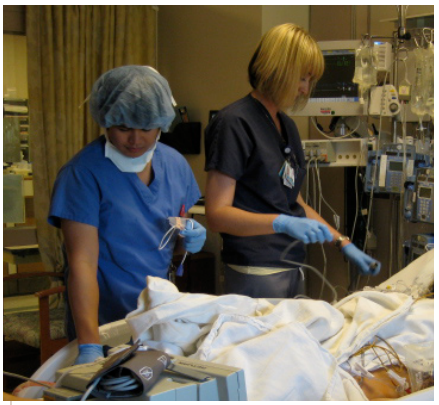
Long before the patient arrives in the ICU, the nurse reads through the history and physical, reviews all diagnostic test results, formulates a patient-specific plan of care, and prepares the room. The patient arrives from the OR on a portable ventilator with a pulmonary artery catheter, femoral and radial arterial catheters, atrial and ventricular pacing wires, and multiple chest tubes in place. Nurses place ECG leads and a pulse oximetry sensor, connect and calibrate the systemic, central venous and pulmonary artery pressure lines, verify all continuous medication infusions, initiate chest tube suction, check the pacemaker settings, draw a full set of labs, and perform a 12-lead ECG. A chest X-ray is done, and physicians verify all tube and line placements. In the ensuing postoperative period the focus is on establishing and maintaining optimal ventilation and perfusion.

## Ventilation

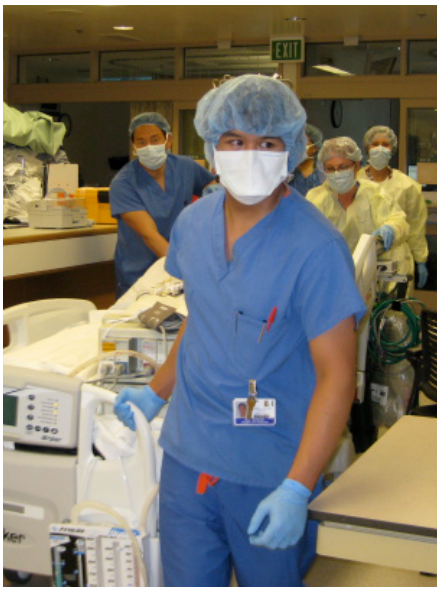
Following endarterectomy, blood flow is redirected through previously obstructed arteries and flow is reduced to lung areas that were well perfused before surgery. This blood redistribution phenomenon, known as pulmonary artery steal, presents some challenges to establishing optimal oxygenation. Blood flow through endarterectomized vessels can cause capillary leak and pulmonary edema, which interferes with gas exchange; additionally, the concomitant reduction in flow through normal vessels can cause hypoxia, with reactive vasoconstriction of the pulmonary vasculature in those areas. PTE patients are therefore ventilated with relatively high tidal volumes of 10 to 12 ml/kg to overcome atelectasis and promote optimum gas exchange, and diuretics are administered to maintain a negative fluid balance and minimize pulmonary edema. Initial ventilator settings maintain a high minute ventilation until the metabolic acidosis resulting from altered tissue perfusion during hypothermia, bypass and circulatory arrest resolves. PTE nurses monitor arterial blood gases and pulse oximetry closely, consulting with the physician and the respiratory therapist to adjust ventilator settings according to changes in the patient's condition. Once the patient is hemodynamically stable, the nurse elevates the head of the bed to at least 30 degrees and begins side-to-side turning to promote further fluid mobilization and gas exchange.

One major complication of PTE is reperfusion lung injury, a localized acute inflammation of the lung tissue that allows leakage of protein and fluid into the alveoli, creating a significant barrier to gas exchange. Severity varies among patients, ranging from pulmonary edema and hypoxemia to (rarely) hemorrhage. Reperfusion injury requires supportive care until the inflammation subsides and gas exchange normalizes. In most cases this means prolonged mechanical ventilation, higher positive end expiratory pressure (PEEP) for alveolar recruitment, and diuresis. Some RPI patients cannot

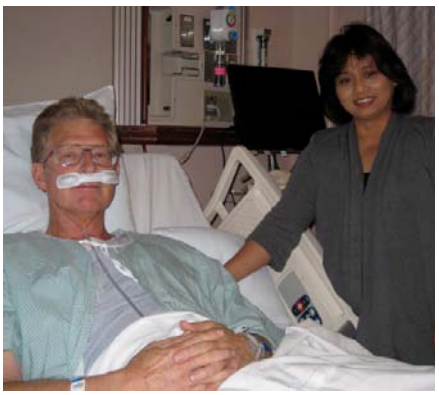




tolerate being turned to a particular side and occasionally an individual may not tolerate being turned at all, which incurs significantly higher risk for pressure-related skin injury. RPI patients may be so severely hypoxemic that nitric oxide (iNO) is added to the ventilator circuit. Nitric oxide is a vasodilator, and since it is inhaled through the ventilator circuit it affects only those vessels in ventilated lung areas, improving ventilation/perfusion matching and gas exchange. The PTE nurse coordinates care with the respiratory therapist to ensure arterial



blood gas sampling immediately prior to initiation of iNO and approximately 10 minutes after it is started; comparison of the two gases allows the team to assess the effectiveness of therapy. The nurse must also be thoroughly familiar with the iNO machine, which has a special circuit for the ambu bag that provides continued delivery of iNO during use. In the most extreme cases of reperfusion



injury refractory to these therapies, the physician may institute extracorporeal support for oxygenation, carbon dioxide removal, or both. A perfusionist runs the ECMO (extracorporeal membrane oxygenation) or ECCO2R (extracorporeal carbon dioxide removal) machine and coordinates all associated care and lab draws with the bedside nurse. In all cases, treatment for reperfusion injury is supportive until the condition abates, characterized by resolving chest radiograph opacities and improvements in arterial oxygen and carbon dioxide tension. The RPI and recovery process may last several weeks. Fortunately only about 10% of PTE patients experience RPI as a significant postoperative complication.

## Perfusion

CTEPH patients present with right heart enlargement and hypertrophy that has developed in response to abnormally high pulmonary pressures, which constitute the workload (afterload) of the right heart. The right heart is ordinarily a low pressure system, but with CTEPH the pulmonary artery pressures, normally about 25/10 mmHg (tip: remember a quarter over a dime!) may equal or even exceed systemic blood pressure, and pulmonary vascular resistance, usually no more than 250 dynes/sec/cm5, can be quadruple normal or worse. True to the Frank-Starling law of the heart, the right heart changes in response to the increased workload by enlarging and stretching to accommodate more volume, which generates more rebound force with each contraction, enabling the right ventricle to overcome the resistance and pump blood into the pulmonary arteries. Tricuspid regurgitation develops. Eventually the ventricle becomes so enlarged that it exceeds the capacity for increased rebound with increased stretch; the heart muscle becomes overstretched, weak, and eventually fails completely.

A successful endarterectomy produces a dramatic decrease in right heart workload, eventually restoring normal or near-normal pulmonary pressures. Tricuspid regurgitation resolves, cardiac output increases, and right heart enlargement begins to reverse. In the immediate postoperative period hemodynamic management specifically targets right ventricular function, which distinguishes PTE from other cardiothoracic surgeries. The right heart remains volume dependent for optimal function, so hemodynamic management becomes a balancing act between ensuring adequate volume (preload) for right ventricular function while keeping the patient "dry" to minimize pulmonary edema and support good gas exchange. The PTE nurse can determine the best central venous pressure (CVP, a correlate of preload) to achieve this balance through careful analysis of the patient's hemodynamic profiles, and can use the data to plot a right ventricular function curve that graphs the optimal CVP range for that patient.

In other respects hemodynamic management is similar to other cardiothoracic surgeries. The nurse titrates dopamine for intropic support to strengthen ventricular contractions and maintain a mean arterial pressure of 65 to 85 mmHg and a cardiac index above 2 L/min/m2. Atrial and ventricular pacing wires enable the nurse to pace the heart to support cardiac output and treat postoperative arrhythmias, most commonly junctional and atrial arrhythmias. Serum electrolytes are drawn every six hours and replaced per protocol when low, to prevent ectopy or poorly perfusing heart rhythms. When necessary, 5% albumin is used to restore adequate preload, although PTE management generally dictates that fluid administration be minimized. The nurse checks hemoglobin and hematocrit levels every six hours, apprises the physician of acute changes and transfuses blood products as necessary. A continuous sodium nitroprusside infusion may be titrated for tight control of systemic hypertension as general anesthesia wears off, or as the patient is awakened in preparation for the ventilator weaning process.

PTEs are the only CT surgery patients to have two arterial pressure catheters, one femoral and one radial, placed in the OR. The femoral arterial line provides an accurate blood pressure once the patient is rewarmed and the core temperature restored to near normal after hours of deep hypothermia at 20˚C. The radial arterial line is inaccurate until several hours after ICU admission when the patient is sufficiently recovered to regain normal perfusion and body temperature in the

extremities. Once the femoral and radial arterial pressure readings correlate, the nurse removes the femoral line.

Anticoagulation management is diligent and individualized. CTEPH is a disease of abnormal, chronic clot formation, so anticoagulation is vital to prevent re-thrombosis after endarterectomy. All patients have an inferior vena cava filter placed preoperatively as prophylaxis against migration of emboli into the pulmonary bed from deep venous thromboses, and sequential compression stockings are applied after surgery. The PTE nurse begins administration of subcutaneous heparin as soon as the chest tube output has slowed to a physician-specified hourly level, usually within 12 hours of the patient's arrival in ICU. Individuals with prothrombotic factors such as antiphospholipid antibody, factor V Leiden, or protein C or S deficiency may be on a heparin drip postoperatively, entailing regular PTT monitoring and careful heparin titration to achieve the therapeutic goal without incurring acute postoperative bleeding.

## Neurological Assessment

Despite every effort to ensure cerebral protection during circulatory arrest, neurological insult is a possible sequela of surgery, so once the patient is hemodynamically stabilized the PTE nurse weans the sedative infusion until the patient rouses enough to nod yes or no to simple questions and move all four extremities to command - usually just a weak squeeze of the hands and a wiggle of the toes. The nurse assesses for pain, briefly reviews the plan of care with the patient, and then reinstates sedation to maintain a Richmond Agitation Sedation Scale (RASS) of -2 to -3 depending upon the individual's tolerance of the endotracheal tube, lines and other devices. The following morning the sedation is weaned completely off if the PTE physician determines the patient is a candidate for extubation. Delirium may become apparent as the patient awakens and may be a contraindication for extubation if the patient is unable to remain calm and cooperative for the ventilator weaning process. The incidence and treatment of delirium in this patient population is similar to that for other cardiothoracic surgeries.

## Psychosocial Issues

Nursing is both a science and an art, and the art of nursing is fully realized in the psychosocial aspects of PTE care. The description of the surgery alone is frightening, and to a layperson the ICU environment seems overwhelming and intimidating. Just walking into a room full of complicated machines can create profound stress, which is intensified by the unending barrage of noise from alarms and equipment. The bedside nurse has the perfect opportunity to create a rapport with the patients and family members that engenders trust and reduces their stress. Much of the PTE nurse's time is spent educating families about the recovery process and plan of care as well as explaining the alarms, monitoring parameters, machines and medications. Kim Kerr notes the vital role PTE nurses play in nurturing both patients and families. "Many of our patients are from out of town; some have never even been on a plane! Families are here alone without their support systems. They really depend on the nurses to help them." PTE patient Robert Ledeboer observes, "We met many hardworking, friendly, professional PTE nurses. Their attitude was always positive, and my wife always received all the help that she needed. All of our nurses were highly skilled and seemed to really love what they do." His wife Mary heartily agrees. "The ICU nurses were so supportive and friendly," says Mary. "They could easily be distant because everything is so critical and they have so much to do, but they were always professional and accommodating, never impatient. I felt free to ask questions and never felt bothersome. I really appreciated that the nurses treated my husband with dignity and respect even when he was sedated and unconscious. They genuinely care." For the patients and families, the PTE nurse is the primary resource for all their immediate postoperative needs, from coordinating conferences with the physicians to finding a good restaurant for dinner after a weary day in the waiting room.

Once the patient is extubated, the nurse weans off the drips, removes the pulmonary artery catheter and gets the patient out of bed to a chair as soon as possible. Priorities of nursing care are patient mobilization, nutrition, and diligent pulmonary toilet with incentive spirometry, with the goal of transferring the patient to a lower level of care a day or two after extubation.

PTE nursing is an opportunity to provide holistic patient and family-centered care for a truly unique patient population that demands the very best critical care nursing has to offer. UCSD's leadership in this field, coupled with the academic medical center culture, ensures that Thornton ICU nurses engage in cutting edge practice as vital and collaborative members of the multidisciplinary PTE team. As any PTE nurse will tell you, the very best reward is seeing former patients walk back through our ICU doors months or even years later for a purely social visit, with a smile and a hug for the nurses who helped make that possible and a story or two about the wonderful lives they've reclaimed.

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