

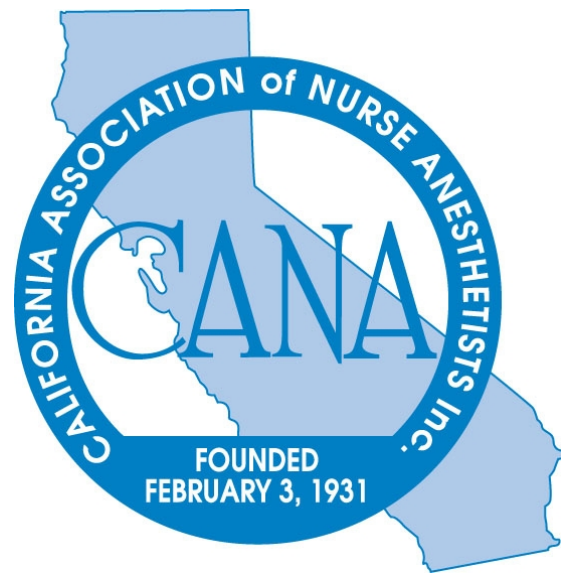
## Editors:

Sarah E. Giron,  
CRNA, MS  
USC Department of  
Anesthesiology  
sarah.giron@usc.edu

Dr. Charles Griffis,  
CRNA, Ph.D  
UCLA Department of  
Anesthesiology  
cgriffis@mednet.  
ucla.edu

## Mission Statement

The California Association of Nurse Anesthetists (CANA) promotes leadership in critical thinking, strategic planning, practice issues, membership education, fiscal accountability, and public relations.



## A Fresh Look at Research and Reviews

By Sarah E. Giron, CRNA, MS

To uphold our mission statement of promoting leadership in critical thinking, practice issues and membership education, the California Association of Nurse Anesthetists is proud to present a biannual E-Journal. Inside every issue you will find updates, case reports and other academically-based articles pertinent to the practice of Nurse Anesthesia. It is our hope to provide new and old members, future members and members-in-training an eco-friendly forum to publish and distribute academic and scientifically-based pieces. Any interested parties are welcome to submit pieces for publication and should see our *Guide to Publishing* inside this issue. We welcome

pieces from everyone including RNs, CRNAs, SRNAs and GRNAs in an environment conducive to learning and in an approachable manner. Our journal will publish pieces from the veteran to the novice writer, with the only stipulation that the content be academic in nature.

Inside this issue we started where most of our careers started; the ICU. From livers to hearts, these ICU RNs provided amazing material for our first issue. We think you will agree, these enthusiastic RNs demonstrate not only a flare for evidence-based practice, but a sound future for our profession.

If we've provoked you to read up on a topic you had questions on,

challenged your intellect just a little or inspired you to write something, we're thrilled. We hope to see your piece in the next issue. We think readers will benefit from the information in our E-Journal and writers will enjoy a less intimidating publishing forum to showcase their talents.

We invite you to share this journal with your colleagues. Most importantly we hope you will enjoy this periodical as just another resource available to you from your state association at [www.canainc.org](http://www.canainc.org).

## In This Issue:

Editors Note: A Fresh Look at Research and Reviews

The Current State of Immunosuppression in Liver Transplant By Teckla Chude, RN, BSN

The Importance of Effective Analgesia in the Post-Operative Adult Cardiac Surgery Patient By Paige Redfield, RN, BSN

Magnesium, Neurological Injury, and Pain By Lisa Chaps, RN, BSN

Sepsis: Improving Patient Outcomes with Early Interventional Therapy By John Scott, RN, BSN

Circulatory Assist Devices: Device Management in the Post-Surgical Cardiac ICU By Heather Colflesh, RN, BSN

Lactate Levels: Indicator of Mortality in Trauma Patients By Gregory Zweigle, RN, BSN, CCRN

# The Current State of Immunosuppression in Liver Transplant

By Teckla Chude, RN, BSN

End stage liver disease (ESLD) is an increasingly significant cause of death in America and liver transplantation is the only cure. Some of the most common causes of ESLD include hepatitis B and C, hepatocellular carcinoma, primary biliary cirrhosis, alcoholic cirrhosis and cryptogenic cirrhosis. Since the first liver transplant in 1963, its popularity has increased "reaching 6641 procedures done in 2005."<sup>1</sup> Today, the 10 year survival rate of these individuals has increased dramatically, but like all transplant patients, they may experience complications or non-transplant related illnesses that require surgical intervention. The medications used to maintain graft function, may or may not pose a change in the method of anesthesia, however, it is important to be familiar with the medications and possible interactions with the anesthetics. As there has not been much research on the issue of the delivery of anesthesia to patients with a non-native organ, this article will serve to review the usual medication regimen in liver transplant patients to provide the reader with some general knowledge.

The drugs used to induce immunosuppression in liver transplant patients depend on the transplant surgeon's choice, patient's medical condition, and cause of liver disease. However, there are four classes of immunosuppressants currently used, and a patient may be on three (triple therapy) or all of these medications at some point in their perioperative course.

**Calcineurin Inhibitors (CNI's):** Tacrolimus and cyclosporine are the two forms currently available. Cyclosporine comes in the form of Sandimmune®, Neoral® and Gengraf®. "They cause selective suppression of cell-mediated immunity via inhibition of T-cell activation."<sup>2</sup> In

theory, cyclosporine should potentiate the effects of barbiturates and fentanyl and lengthen the effect of neuromuscular blocking agents.<sup>3</sup> Tacrolimus, also known as Prograf®, is a very strong compound that binds to FK binding protein. It works by inhibiting the action of calcineurin, which in turn causes the inhibition of IL-2, IL-3, IL-4, and IL-8 transcription.<sup>2</sup> Side effects include post transplant diabetes mellitus, gastrointestinal disturbances, hyperkalemia, hypertension, hypomagnesimias, renal dysfunction and tremors. Dosage of this agent, like cyclosporine, is based on blood levels. The effects of tacrolimus on anesthetics have not been extensively researched but are probably similar to cyclosporine due to their similar function and action.<sup>3</sup>

**Antimetabolites:** They include azathioprine, mycophenolate mofetil (MMF) and mycophenolic acid (MPA). Azathioprine (Immunan®) has been reported to cause severe myelosuppression and liver dysfunction, hence it is rarely used today. Its action inhibits the production of DNA and other purine derivatives.<sup>2</sup> Azathioprine may prolong the effects of succinylcholine and may also inhibit the action of nondepolarizing blocking drugs.<sup>3</sup> The latter antimetabolites' actions on the cell cause the "blockage of DNA replication in T and B lymphocytes."<sup>2</sup> Side effects include gastrointestinal disturbances, anemia, leukopenia, thrombocytopenia and weight loss.<sup>4</sup>

**Corticosteroids:** These agents work on "blocking T-cell derived and antigen-presenting cell-derived cytokine expression, which include IL-1, IL-2, IL-3, and IL-6."<sup>2</sup> Corticosteroids are usually used for maintenance therapy and to treat rejection. Side effects are insidious and include hypertension, hyperglycemia, mental status changes, hypervolemia, and delayed wound healing.<sup>4</sup>

**Immunosuppressive antibodies:** Used to initiate induction and treat rejection, they include antithymocyte globulin, IL-2 receptor antibodies and monoclonal anti-T-cell antibodies. The latter is rarely used because of the life-threatening side effects associated with its administration.<sup>2</sup> Antithymocyte globulin (ATG) is a polyclonal preparation that causes the programmed cell death of T-cells, their receptors and CD-16 on natural killer cells. Side effects may include flu-like symptoms, tachycardia, and gastrointestinal disturbances.<sup>2</sup> IL-Receptor Antibodies have traditionally been used in kidney transplant patients, but recently have been used in increasing number in liver transplant. Daclizumab and basiliximab inhibit T-cell proliferation by

## About The Author

**Teckla Chude, RN, BSN, CCRN is a critical care nurse at UCLA Westwood in the transplant-surgical ICU. This unit cares for liver/kidney/small bowel and pancreas transplant patients along with general surgery patients. She is currently working with her unit CNS at educating staff members about infection control guidelines related to CVC and A-line dressing changes and IV fluid tube changes. Teckla is interested in a future as a nurse anesthetist.**

cont..IL-2, causing marked immunosuppression.<sup>2</sup>

Although this paper has exclusively discussed immunosuppressants in liver transplant patients, it is vital to note that the pharmacological agents highlighted above are not exclusive to this population and are usually used for immunosuppression in most transplant patients. These drugs may interact with anesthetic agents and therefore may influence the method of induction and the dosage or choice of agents used. They may also cause side effects that may influence the hemodynamics of a patient and for this reason, mandates the anesthesia provider to be aware of the possible interactions, side effects, and to adjust their doses accordingly.

## Guide to Publishing in The CANA E-Journal

### References

1. Pomfret EA, Fryer JP, Sima CS, Lake JR, Merion RM. Liver and intestine transplantation in the United States, 1996–2005. *American Journal of Transplantation*. 2007;7(2): 1376–1389.
2. Post DJ, Douglas DD, Mulligan DC. Immunosuppression in liver transplantation. *Liver Transplantation*. 2005;11(11): 1307-1314.
3. Toivonen HJ. Anesthesia for patients with a transplanted organ. *Acta Anaesthesiologica Scandinavica*. 2000; 44: 812-833.
4. Cameron A, Zimmerman M, Hiatt J. The Dumont-UCLA Transplant Guide. Regents of the University of California. 2006.

- The article subjects must be pertinent to Nursing and Nurse Anesthesia and academic in nature.
- If accepted for publication, the manuscript will be edited using the *AMA Manual of Style* to improve presentation without altering the meaning of the text.
- In most cases, edited copy will be submitted to authors for final approval.
- Authors are responsible for all statements made in their work including changes made by the copy editor.
- Authors must disclose commercial associations that might pose a conflict of interest in connection with submitted work. Such disclosure will be noted on the published article.
- Manuscripts should not exceed 10 double-spaced pages, including references, figures, and tables.
- A maximum of 20 references are allowed.
- Cite references in the numerical order that they appear in the text.
- References cited in the article should be of previously published articles or texts.
- Cite written or oral personal communications in parentheses in the text.
- Carefully validate all references to ensure that they are cited accurately, completely, and in the style indicated above. Cite up to 6 authors. If there are more than 6, cite the first 3 only and add “et al.” Consult *AMA Manual of Style*, 10th edition, for complete rules on references.
- Text should be double-spaced throughout.
- Only high quality, reproducible figures will be considered for publication and only when accompanied with permission to reproduce from original author(s)/illustrator(s).
- Tables, figures, and legends must all be properly labeled.
- All articles should be submitted to editors Sarah Giron at [sarah.giron@usc.edu](mailto:sarah.giron@usc.edu) or Dr. Charles Griffis at [cgriffis@mednet.ucla.edu](mailto:cgriffis@mednet.ucla.edu).
- The CANA E-Journal editors and CANA organization are not responsible or liable for any inaccuracies, inconsistencies or fraudulent material put forth by the authors.
- All suggestions for publishing are subject to change without notice and will be disclosed to any authors interested in publishing.
- Most of these guidelines are taken from The American Association of Nurse Anesthesia Journal’s suggestions and can be found at: <http://www.aana.com/authors.aspx>

## The Importance of Effective Analgesia in the Post-Operative Adult Cardiac Surgery Patient

By Paige Redfield, RN, BSN

Pain assessment and management are well-explored concepts in nursing research. However, within the demanding context of the Cardiac Intensive Care Unit (CICU), many nurses may perceive pain to be a less important aspect of their patient care when compared with more objectively measurable parameters, such as blood pressure or heart rate. As a result, ineffective pain management remains one of the major clinical challenges for CICU nurses in the early postoperative period.<sup>1</sup> This paper will discuss the importance of effective analgesia, as it relates to the post-operative cardiac surgery patient, through pain assessment tools and commonly used analgesic medications.

One possible barrier to the effective assessment and management of pain by healthcare professionals is the belief that pain, while it may be uncomfortable for a patient, is not dangerous.<sup>2</sup> Unfortunately this is a false statement. The adequacy of myocardial tissue oxygenation is determined by the balance between the oxygen delivered to the tissues and oxygen required to sustain aerobic metabolism.<sup>3</sup> The perception of pain by a patient initiates the stress response.<sup>4</sup> The cardiovascular system in particular responds to painful stress by activating the sympathetic nervous system, producing a number of effects including increases in heart rate, blood pressure and cardiac output with the end result being an increase in cardiac work and myocardial tissue oxygen consumption.<sup>5</sup> Because heart rate is increased, diastolic filling time is decreased resulting in reduced delivery of oxygen to the myocardium.<sup>4</sup> This combination of increased myocardial oxygen demand (related to increases in heart rate, blood pressure and cardiac

output) and decreased myocardial oxygen supply (related to decreased diastolic filling time) puts the patient at risk for myocardial ischemia and infarction. This is an especially relevant concern for CICU nurses considering that the pathophysiology of cardiac disease already puts this patient population at risk for inadequate myocardial perfusion.<sup>6</sup>

In addition to increasing myocardial oxygen demand, pain-related hypertension increases the risk of bleeding in the post-operative patient. Cardiac surgery patients are routinely anticoagulated causing a significant disruption of the clotting system and predisposing them to hemorrhage. The bleeding patient often requires use of multiple blood products to maintain normovolemia, and to correct anemia and coagulopathy. Transfusions increase the risk of infection and also increase operative and long-term mortality.<sup>6</sup>

Post-operative cardiac surgery patients should be mobilized and encouraged to cough and take deep breaths as soon as possible after surgery to prevent complications that can arise from loss of functional residual capacity, such as atelectasis and pneumonia.<sup>6</sup> Severe pain can result in decreased compliance with these pulmonary toileting activities. Patients with pain also voluntarily limit their thoracic and abdominal muscle movement, becoming as immobile as possible in an effort to reduce the pain they are experiencing. This results in decreased range of motion and an inability to participate in physical therapy exercises.<sup>5</sup> All of these side effects of uncontrolled pain have the potential to result an increased length of hospitalization and higher health-care costs.

For these reasons, pain is clearly an important consideration in the care of the post-operative cardiac surgery patient. Unfortunately, while the side effects of pain are objectively easy to measure, pain itself is not. This stems

**“...Ineffective pain management remains one of the major clinical challenges for CICU nurses in the early postoperative period.”**

from the fact that pain is such a highly personal and subjective phenomenon, unique to each individual patient. The most widely accepted definition of pain is “an unpleasant sensory and emotional experience associated with actual or potential tissue damage.”<sup>5</sup> This definition reflects the complexity of the pain experience. Many factors are known to affect the experience of pain including gender, age, culture and previous pain experiences but no predictable relationship exists between identifiable tissue injury and the sensation of pain. As a result, every experience of pain for each patient can only be assessed and managed effectively at an individual level.<sup>2</sup>

Effective post-operative pain management starts with effective pain assessment. Without assessment it is impossible to identify the nature of pain, the individual characteristics of pain or to gauge the effectiveness of pain management interventions. A multitude of pain assessment tools are available to be used as a framework for pain assessment. The most commonly used tools for assessing pain in the CICU are categorized as uni-dimensional since they typically focus on one or two specific aspects of pain, most frequently the intensity of pain and the location of pain. Examples of uni-dimensional tools include the visual analogue scale and numeric rating scale. Multi-dimensional tools, such as the McGill Pain Questionnaire and the Wisconsin Brief Pain Questionnaire, measure not only pain intensity but also the sensory, affective and behavioral components of that pain. These more complex pain assessment tools are rarely found in

**“Effective post-operative pain management starts with effective pain assessment. Without assessment it is impossible to identify the nature of pain...”**

cont.. clinical practice, as they tend to be too time consuming to be used properly.<sup>7</sup>

The patient’s self-report of pain remains the single most reliable indicator of pain.<sup>5</sup> Unfortunately, critically ill patients are often unable to communicate their level of pain due to sedation or intubation. Patients who cannot verbally communicate should be assessed by CICU nurses through subjective and objective observation of pain-related behaviors (movement, facial expression and posturing) and physiological indicators (heart rate, blood pressure and respiratory rate) and the change in these parameters following analgesic therapy.<sup>7</sup>

Regardless of which pain assessment tool is chosen, it should be used with caution since all are subject to misinterpretation. As long as the nurses using these tools are aware of their limitations and make efforts to supplement pain assessment with additional individualized inquiry and observations, then these tools can serve as an effective starting point for pain assessment and management. It is also important to note that however limited the commonly used pain assessment tools appear to be, some form of pain assessment is certainly better than no assessment at all.<sup>2</sup>

The principles of pharmacological management of post-operative pain focus on the use of the World Health Organization analgesic ladder, originally designed for use in managing pain in palliative care. When used for managing acute post-operative pain, rather than starting at the bottom of the analgesic ladder (as in palliative care) it can be used from the top down, starting with strong opioid-based analgesic drugs.<sup>2</sup> The parenteral analgesic agents most commonly used in CICU patients are fentanyl, morphine and hydromorphone.<sup>7</sup> The characteristics of these commonly used opioids are reviewed in Table 1 (see Table 1).

The selection of an anesthetic agent depends on its pharmacology and potential for adverse effects. In the CICU, anesthetic techniques are designed to achieve early extubation and expedite the recovery of patients. With this goal of early extubation in mind, short-acting medications are used to provide relief from pain and anxiety while minimizing respiratory depression.<sup>6</sup> Other desirable qualities of an opioid include rapid onset, ease of titration and lack of accumulation.<sup>7</sup>

Patients receiving pain medicine require frequent and routine assessment to ensure that pain relief is effective. If patients are unable to effectively communicate, CICU nurses can assess for successful pain relief by observing for the prevention or reversal of pain related behaviors and physiological indicators. These include a decrease in movement, facial expression, posturing, heart rate, blood pressure and respiratory rate. Successful pain relief will not only prevent unnecessary levels of distress and suffering for the patient, but will decrease stimulation of the stress response thereby both decreasing myocardial oxygen demand and increasing myocardial oxygen supply.<sup>4</sup>

Adverse effects of opioid analgesics are common and must be closely observed for by CICU nurses during frequent assessment of patients receiving opioid analgesia. While adequate pain relief can allow patients to take deep breaths and prevent atelectasis, respiratory depression is a concern in spontaneously breathing patients and may delay extubation of ventilated patients. CICU nurses should observe for significant decreases in respiratory rate and increase ventilatory support as necessary. Inhibition of the sympathetic nervous system by opioids can prevent hypertension related hemorrhage but can also result in hypotension in hemodynamically unstable patients. CICU nurses should frequently monitor blood pressure and initiate inotropic support as necessary. Intestinal hypomotility is another side effect of opioids and as a result, gastric retention and ileus are common in critically ill patients. Routine prophylactic use of a stimulant laxative can minimize constipation and assist patients in resuming or maintaining optimal bowel function.<sup>7</sup>

Optimal pain management is clearly an essential component of successful surgical outcomes for the post-operative adult cardiac surgery patient. Unrelieved pain prolongs the stress response and can adversely affect a patient’s recovery from surgery. Pain assessment and response to therapy should be performed regularly by using a scale appropriate to the patient population and systematically documented. The most appropriate pain assessment tool for each situation will depend on the patient involved, his/her ability to communicate and the caregiver’s skill in interpreting pain behaviors and physiological indicators. The CICU nurse must be alert to pain in their post-operative patients in order to promote effective and humane care and to prevent complications that may arise during the use of opioid

**Table 1**  
Commonly Used Opioids (Jacobi et al. 2002)

Agent	Dose	Onset Time	Half Life
Fentanyl	1-2mcg/kg/dose q30 min	Almost immediate	2-4 hr
Hydromorphone	1-4 mg q4-6 hr	2-3 minutes	2-3 hr
Morphine	1-10mg q2-6 hr	5-10 minutes	2-4 hr

cont. analgesics. Nurses who underestimate the importance of pain will never make pain relief one of their top priorities, so the first step towards effective analgesia is the education of health-care professionals. health-care professionals.

#### About the Author

Paige Redfield RN, BSN is a critical care nurse in the UCLA Cardiothoracic ICU. She is involved in a unit based research committee, precepting new graduate RNs and studying for the CCRN. Paige is interested in a future career as a Nurse Anesthetist.

#### References

1. Bell L & Duffy A. Pain assessment and management in surgical nursing: a literature review. *British Journal of Nursing*. 2009; 18(4).
2. Mackintosh C. Assessment and management of patients with post-operative pain. *Nursing Standard*. 2007; 22(6).
3. Marino P. *The ICU Book*. Philadelphia, PA: Lippincott Williams & Wilkins; 2007.
4. Wall PD & Melzack R. *Textbook of Pain*. New York, NY: Churchill Livingstone Inc.; 1994.
5. McCaffery M & Pasero C. *Pain Clinical Manual*. St. Louis, Missouri: Mosby, Inc.; 1999.
6. Bojar RM. *Manual of Perioperative Care in Adult Cardiac Surgery*. Malden, Massachusetts: Blackwell Publishing Inc.; 2008.
7. Jacobi J, Frasier G & Coursin D. Clinical practice guidelines for the sustained use of sedatives and analgesics in the critically ill adult. *Critical Care Medicine*. 2002; 30(22).

## Magnesium, Neurological Injury, and Pain

By Lisa Chaps, RN, BSN

As a critical care nurse in the Neuroscience/Trauma ICU at Ronald Reagan UCLA Medical Center, pain and the effects it has on the brain and body of my patients has been of particular interest to me. The majority of my patients have endured intense, noxious stimuli during the course of their treatment. I receive patients immediately after craniotomies, tumor resections, and other surgical procedures that suffer severe pain postoperatively. As a clinical nurse, I have begun to explore the potential link between magnesium abnormalities and painful stress, since my patients often have low plasma levels of this cation. After learning that there is involvement in the pathways of the body related to pain and the connection between magnesium ions, I decided to do some research to see if there is any information available that shows a correlation between low serum magnesium levels and people who have received some form of pain and noxious stimuli. What I found was a dearth of research regarding any relationship between serum magnesium levels in patients and postoperative or traumatic pain.

A pilot study completed by Collins S. et al. from the Department of Anesthesiology VU Medical Center in Amsterdam explored the administration of intravenous magnesium to patients with Complex Regional Pain Syndrome Type 1 (CRPS 1). One group of study participants received 70mg/kg of magnesium sulfate infusions while the other group received NaCl 0.9% solutions. The interventions were accompanied with standardized physical therapy to both groups. Pain was assessed using an 11-point Box scale and the McGill Pain Questionnaire. The study concluded, "Intravenous magnesium significantly improved pain, impairment, and quality of life and was well tolerated."<sup>1</sup> The study suggests that IV magnesium as a treatment for CRPS 1 should be further explored.

**"After learning that there is involvement in the pathways of the body related to pain and the connection between magnesium ions, I decided to do some research to see if there is any information available that shows a correlation between low serum magnesium levels and people who have received some form of pain and noxious stimuli."**

Another study performed by Ghrab et al. explored the combination of intrathecal magnesium sulfate and morphine to patients undergoing caesarean section. One hundred and five adult patients undergoing caesarean section were enlisted and allocated to one of three groups. One group received intrathecal morphine, bupivacaine, and fentanyl. The second group received magnesium, bupivacaine, and fentanyl. Finally, the third group received morphine plus magnesium and bupivacaine and fentanyl. In this randomized, double blind, controlled study, "the addition of intrathecal magnesium to morphine and spinal bupivacaine-fentanyl improved the quality and the duration of postoperative analgesia without increasing the incidence of adverse effects."<sup>2</sup>

Another study I reviewed looked at the effects of adding magnesium to bupivacaine and fentanyl for spinal anesthesia in knee arthroscopy patients. The study was conducted by the Department of Anesthesiology at the University of Kocaeli in Turkey by Dayioglu and colleagues. Specific aims were to explore the effects of the addition of 50mg of intrathecal magnesium to low dose bupivacaine-fentanyl on the duration, regression of spinal block, and postoperative pain relief in patients undergoing knee arthroscopies. The study was randomized and it recorded the highest level of dermatomal sensory blockade, the time to reach that level from the time of injection, Bromage scale of

cont.. not decreased significantly either. However, the time to first analgesic requirement was prolonged significantly.

3

I found the research regarding magnesium and pain to be very compelling, but feel further studies are necessary. I was unable to find any studies exploring the connection, if any, on the effect of administration of IV magnesium on pain levels in surgical patients. It has been intriguing for me to individually assess my patients' level of pain before and after giving magnesium infusions. I have seen firsthand that post-magnesium administration patients require less medication for breakthrough pain. I have also observed that postoperative patients have lower serum magnesium levels than patients who are preoperative. Perhaps this may suggest that after experiencing pain and noxious stimuli, serum magnesium levels decrease and future studies must address this correlation with pain. I anticipate much more research to be completed regarding magnesium as a treatment for pain intraoperatively and postoperatively, using both the IV and intrathecal routes, and I look forward to more conclusive information.

## References

1. Collins S, Zuurmond WW, de Lange JJ, van Hilten BJ, Perez RS. Intravenous magnesium for complex regional pain syndrome type 1 (CRPS 1) patients: A pilot study. 2009. PubMed, 19496957. Retrieved from <http://www.ncbi.nlm.nih.gov/sites/entrez/>
  2. Ghrab BE, Maatoug M, Kallel N, Khemakhem K, Chaari M, Kolsi K, Karoui A. Does combination of intrathecal magnesium sulfate and morphine improve postcaesarean section analgesia? 2009. PubMed, 19427159. Retrieved from <http://www.ncbi.nlm.nih.gov/sites/entrez/>
  3. Dayioglu H, Baykara ZN, Salbes A, Solak M, Toker K. Effects of adding magnesium to bupivacaine and fentanyl for spinal anesthesia in knee arthroscopy. 2009. PubMed, 19234817. Retrieved from <http://www.ncib.nlm.nih.gov/sites/entrez/>
- Tauzin-Fin P, Sesay M, Svartz L, Krol-Houdek MC, Maurette P. Wound infiltration with magnesium sulfate and ropivacaine mixture reduces postoperative tramadol requirements after radial prostatectomy. 2009. PubMed, 19226292. Retrieved from <http://www.ncib.nlm.nih.gov/sites/entrez/>

### About the Author

Lisa Chaps, RN, BSN, is a critical care nurse at the UCLA Neuroscience/Trauma Unit. She volunteers on the hospital-wide Falls Committee and is chairperson for the Adopt-A-Family project for her unit. She also volunteers for School on Wheels, a non-profit organization that offers tutoring services to homeless children. Lisa is interested in a future career as a nurse anesthetist.

**Interested in supporting the work you see?  
Donate to your state association that provides for this and other E-Resources on [www.canainc.org](http://www.canainc.org).  
Donations can be made at  
<http://www.canainc.org/ecommerce/donations.htm>**



# Sepsis: Improving Patient Outcomes with Early Interventional Therapy

By John Scott, RN, BSN

Severe sepsis, a systemic manifestation of infection combined with severely impaired tissue perfusion and organ dysfunction, has become one of the most expensive and deadliest healthcare obstacles in the modern world of medicine. Today, severe sepsis affects approximately 750,000 people annually on a national scale, with a resulting number of 215,000 deaths per year. This equals the mortality rate of acute myocardial infarction and continues to grow with an estimated 934,000 new sepsis cases in the United States by the year 2010.<sup>1</sup> The total annual costs attributed to sepsis and disease morbidity is estimated to be approximately 17 billion dollars. With the staggering mortality rate and heavy financial burden that severe sepsis imposes on the healthcare system, it is important to examine the benefits of early interventional therapies. Several therapeutic interventions have shown significant improvement in patient outcomes by virtue of improved mortality rates when employed by the healthcare teams within 6 hours of initial recognition of sepsis.

Sepsis is characterized by a series of inflammatory and coagulation processes in response to infection which progress to circulatory abnormalities. When the human body is invaded by infectious microbial agents, the body responds with an inflammatory process to protect from further invasion of the infectious disease. In the early development of sepsis, structural components of bacteria such as peptidoglycan, endotoxin and lipopolysaccharide (LPS) activate a cascade of coagulation and inflammatory events causing deleterious effects to vascular endothelium.<sup>2</sup> When these outer membrane components bind with

CD14 receptors on the surface of circulating monocytes, a production of pro-inflammatory cytokines, tumor necrosis factor-alpha (TNF-alpha) and interleukin-1 (IL-1) begins.<sup>3</sup> The production of these cytokines trigger the activation of the coagulation pathway, which ultimately leads to a production of thrombin at the endothelial level. The resulting production of thrombin combined with impaired fibrinolysis causes fibrin clotting in microvasculature.<sup>4</sup> These manifestations of disseminated intravascular coagulation (DIC) become a hallmark trait in septic patients as thrombus formation becomes excessive and traps platelets causing further blood vessel occlusion that results in impaired perfusion and oxygenation to tissues and organs.<sup>5</sup>

Recent investigations have shown marked improvement in patient outcomes when goal-directed treatment begins within the first six hours of being diagnosed with septic shock.<sup>6</sup> The presence of infection, or suspected infection combined with two or more of the following indicators of systemic inflammatory response syndrome (SIRS) indicate the need to initiate immediate therapy to prevent potential cardiovascular collapse and tissue hypoxia resulting from septic shock. The SIRS indicators include: 1) Heart rate >90 beats per minute, 2) Hyperthermia, 3) Tachypnea or PaCO<sub>2</sub> below 32mmHg, 4) WBC >12,000 cells/mm<sup>3</sup>, or more than 10% bands, 5) Evidence of one organ dysfunction such as hypotension, tachycardia, elevated central venous pressures, anuria, elevated serum lactate levels, and elevated glucose levels indicate the need to initiate immediate therapy to prevent potential cardiovascular collapse and tissue hypoxia resulting from septic shock. Once these factors have been identified upon patient assessment, vital importance is placed on initiating broad-spectrum antibiotic administration immediately. Appropriate cultures (blood, sputum, wound, etc.) should be obtained prior to initiating intravenous antibiotics, but should not significantly

## About the author:

**John S. Scott, RN, BSN, is a 2005 graduate of the Medical University of South Carolina, College of Nursing. He is currently a staff critical care nurse at UCLA Neuroscience/Trauma ICU and is involved in several unit committees. Mr. Scott is interested in nurse anesthesia training.**

delay the administration of antimicrobial therapy. Once causative organisms have been identified, anti-infective therapy can be modified to provide source control and reduce the development of drug resistance. Placement of a central venous catheter for central venous oxygen saturation (ScvO<sub>2</sub>) and central venous pressure (CVP) monitoring, in addition to arterial line placement for continuous mean arterial blood pressure monitoring is necessary. Maintaining CVP between 8-12 mmHg via colloid/crystalloid administration to provide preload correction, combined with the use of intravenous vasopressors (such as norepinephrine or dopamine) to maintain mean arterial pressure (MAP) greater than 65mmHg will give hemodynamic support and prevent autoregulation loss within vascular beds in the septic patient with ongoing capillary leak. Maintaining ScvO<sub>2</sub> greater than 70mmHg (or mixed venous oxygen saturation greater or equal to 65mmHg when a pulmonary artery catheter has been placed) and hematocrit (Hct) value of 30% via red cell transfusion, in combination with the administration of intravenous inotropic medications to maintain adequate cardiac output and optimize systemic oxygen delivery, have

been shown to improve survival rates in the patient at high-risk for further tissue hypoxia, cell death, and imminent cardiovascular collapse.<sup>7</sup>

The use of steroid therapy has shown to be beneficial to patients with sepsis in the presence of hypotensive shock who experience poor response to fluid resuscitation and vasopressor therapy. Deep vein thrombosis prophylaxis, stress ulcer prevention, and glucose control also play important roles in overall patient care and promoting improved patient outcome.

In conclusion, recognizing and treating sepsis before patients experience deterioration and poor clinical outcomes is of major concern for the healthcare system. As one tool of measuring the effectiveness of disease treatment in sepsis, clinicians can ascertain that decreasing the extent of morbidity, mortality rates, and length of hospital stay time are of utmost importance. With the percentage of dollars provided by

Medicare decreasing for sepsis-related healthcare costs coupled with a national economy in decline, it is of critical importance that healthcare workers are able to recognize and provide early treatments for patients known to be at risk for developing severe sepsis. The greatest outcome improvement can be made through education and process change for those caring for severe sepsis patients in the non-ICU setting and across the spectrum of acute care.<sup>7</sup> Increased education in the effective care of septic patients will decrease the development of severe sepsis, multi-organ failure, and improve the high mortality rate associated with this national healthcare problem. Therefore, emphasis should also be applied to increasing national awareness and promoting continuing education in the assessment, diagnosis, and effective care of sepsis for medical care providers.

contribute to a failing component of the cardiac cycle causing an insult profound enough to necessitate artificial assistance.<sup>1</sup>

#### A. Ventricular Assist Device Augmentation

When the heart “pump” is failing, a ventricular assist device or VAD is often needed to augment the normal flow of blood to the tissues, as well as to temporarily rest the heart from a significant insult. Depending upon which ventricle needs assistance the surgeon will typically cannulate the ventricular apex with the inflow graft, decompressing the chamber and functioning to shunt blood either to the lungs, the ascending aorta, or both in order to provide satisfactory systemic circulation.<sup>2</sup>

#### B. Target Population & Indications for Use

There are several clinical scenarios resulting in the need for a circulatory assist

## Circulatory Assist Devices: Device Management in the Post-Surgical Cardiac ICU

By Heather Colflesh, RN, BSN

### Introduction

In a healthy heart, the electrical and mechanical elements of the cardiac cycle function to maintain adequate perfusion to the body’s organs and tissues, sustaining a delicate balance of rest and muscular contraction. The sinoatrial node is responsible for commanding the electrical portion of the cardiac cycle, while the muscle tissue itself responds to both blood volume and wall stretch in order for adequate stroke volume and subsequently, sufficient cardiac output. When any element of this complex system becomes compromised, whether it is slow to develop or acute in onset, the need for a ventricular assist device may be indicated. Malignant arrhythmias, sudden or chronic lack of blood flow, structural damage, and viral/bacterial pathologies all may

### References

1. Angus DC, Linde-Zwirble WT, Lidicker J, et al.. Epidemiology of severe sepsis in the United States: Analysis of incidence, outcome, and associated costs of care. *Crit Care Med.* 2001; 29:1303-10.
2. La Rosa SP: Sepsis. *The Cleveland Clinic Journal of Medicine.* 2002;69:65-73.
3. Glauser MP, Heumann D, Baumgartner JD, et al.. Pathogenesis and potential strategies for prevention and treatment of septic shock. *Clinical Infectious Diseases.* 18 Suppl2:S205-16,1994 Feb
4. Vervloet MG, Thijs LG, Hack CE. Derangements of coagulation and fibrinolysis in critically ill patients with sepsis and septic shock. *Semin Thromb Haemost.* 1998;24:33-44.
5. Remick DG. Pathophysiology of sepsis. *The American Journal of Pathology.* 2007;170:1435-1443.
6. Rivers E, Nguyen B, Havstad S, et al.. Early goal-directed therapy in the treatment of severe sepsis and septic shock. *The New England Journal of Medicine.* 2001;345:1368-1377.
7. Dellinger RP, Levy MM, Carlet JM, et al.. Surviving sepsis campaign: International guidelines for management severe sepsis and septic shock. *Crit Care Med.* 2008;36:296-317.

*cont.* device, including both patients with long term, chronic needs and those suffering from acute episodes or events. Patients receiving short term or acute recovery assistance include those with acute perioperative cardiogenic shock, severe postcardiotomy ventricular dysfunction including arrhythmias and other tissue insulting events, multiple blood transfusions, and inability to wean from cardiopulmonary bypass (CPB).<sup>3</sup> Typically, patients must be deemed eligible to survive an invasive cardiac procedure and have undergone correction of any metabolic issues such as acidosis and electrolyte dysfunction before the device can be considered appropriate. Additionally, a cardiac index  $< 1.8\text{-}2\text{L}/\text{min}$  must be noted, as well as a systolic BP  $< 80\text{ mm Hg}$ , left atrial pressure (LAP)  $> 20\text{ mm Hg}$ , systemic vascular resistance (SVR)  $> 2100\text{ dynes}$ , mean right atrial pressure (RAP)  $> 20\text{ mm Hg}$  (with no tricuspid regurgitation) on maximal medical support (MMS), and specifically for biventricular devices, inability to maintain LVAD flow over  $2\text{ L}/\text{min}$  with a RAP  $> 20\text{ mm Hg}$ .<sup>1</sup>

Conversely, patients with chronic heart failure conditions meeting the inclusion criteria for heart transplantation, as well as those who do not meet the requirements but wish to have a higher quality of life in their remaining years, are candidates for long term assist device use. Exclusion criteria for assist device implantation have been identified in a risk factor model designed by the Columbia-Presbyterian group and have been highlighted as predictive of poor outcomes/survival after VAD placement. This includes, oliguria, CVP  $> 20\text{ cm}$  of water, mechanical ventilation dependency, elevated INR, re-operative status, WBC  $> 15,000$ , and a fever  $> 101.5$  degrees centigrade.<sup>1</sup> Additionally, RV function, pre-existing comorbidities such as kidney/liver failure and neurological status, as well as other medical issues (diabetes, infections, vascular diseases, etc.) must be intensely pondered before a patient can become a candidate for bridge therapy, especially after taking into consideration the vast economic impact of these devices.<sup>2</sup>

### C. Categories and Types of Circulatory Support Devices

Ventricular assist devices can be separated into categories based on several defining factors, all of which affect a practitioner's decision when choosing an assist device for a specific patient. The following items should be considered: single or dual ventricular support, pulsatility, anticoagulation requirements, patient size and mobility needs, and most importantly, the goal of use i.e. long term support (bridge to transplant or destination therapy) or short term support for recovery of acute cardiac insults.<sup>4</sup>

#### 1. Ventricular Support

Ventricular support is most commonly achieved using a left ventricular assist device, but has since developed to include dual or biventricular support, as well as isolating the right ventricle (RV) in situations where RV

failure has occurred. Although RV failure is uncommon and is usually related to left ventricular failure, issues such as intraoperative RV infarction and progression of pre-existing failure related to worsening pulmonary hypertension are often causes leading to the need of RV augmentation with an assist device. Biventricular assist devices are indicated in about 10 % of patients who require augmentation and they provide support of both the pulmonary and systemic circulation.<sup>1</sup> As stated above, the need for biventricular support is not always identified upon initial examination. In fact, it is often not until left ventricular decompression is established with a LV assist device, that RV failure can be discovered and therefore treated with a biventricular support device.<sup>2</sup>

#### 2. Pulsatility

Pulsatility can be divided into two main branches in relation to assist devices and mechanism of pumping blood, pulsatile pumps and non-pulsatile pumps. Pulsatile pumps are often indicated in patients who need full circulatory support to allow complete rest of the supported ventricle(s) while often improving end organ perfusion leading to multiorgan preservation. These pumps are usually operated using a diaphragm, creating a compressible chamber driven by a pneumatic (air) pump or electric motor and pusher plate device. Unidirectional valves placed in both the inflow and outflow grafts, promote the forward flow of blood as the chamber is compressed and emptied. These pumps are considered pulsatile since the mechanism of action is much like that of the heart itself, and it is the efficacy of the resulting cardiac output that increases blood flow to vital organs like the kidney and liver; improving the prior clinical status of many patients suffering from chronic heart failure and low cardiac output states. On the other hand, non-pulsatile pumps allow the native ventricle to retain a small portion of the pumping work, providing slightly less support and making less of an impact on end organ perfusion. These particular pumps use either axial or centrifugal flow mechanisms to propel the blood from the ventricle to its destination. Axial pumps propel blood forward using a corkscrew-like method, while centrifugal pumps spin the blood from the center of the pump outward, pushing the blood to the periphery and eventually into the outflow

*cont.* graft. Non-pulsatile pumps are indicated in both short and long-term support, but although controversial, the ability of pulsatile pump to improve end organ perfusion over non-pulsatile pumps should be considered when deciding which pump is most suitable for a particular patient.<sup>1</sup>

### 3. Anticoagulation

Anticoagulation is an important consideration for clinicians when deciding which device to implant. Of the pumps that will be discussed within this paper, only one device, the Heartmate I XVE, requires minimal anticoagulation with a daily dose of aspirin. In contrast, the other devices being discussed all require full anticoagulation with intravenous heparin sulfate or more commonly, with an oral dose of Warfarin (Coumadin). As a result, bleeding issues and coagulopathies should be considered on an individual basis.<sup>1</sup>

### 4. Patient Size and Mobility

Patient size and mobility are additional factors to consider. Many of the new devices come equipped with travel kits, which allow previously tethered devices to become mobile. Special straps and transportable battery packs allow patients to increase ambulatory function, which acts to further improve their clinical status. In addition, many devices have been altered to become smaller and as a result more functional for patients who are receiving an assist device for both bridge to transplant and destination therapy. Devices such as the Jarvik 2000 are both smaller in size and more lightweight, improving mobility while also catering to smaller patients, such as women and small-framed males, who might have otherwise not been candidates for an assist device.<sup>4</sup>

### 5. Support Goal

Two main support goals have been identified for the patient populations receiving assist devices, long term support, which can be further divided into bridge to transplantation (BTT) and destination therapy (DT), and short term support otherwise known as acute recovery assistance.<sup>5</sup> Often, patients do not meet the strict inclusion criteria for transplantation and other options to improve current quality of life must be discussed.<sup>4</sup>

main types are as follows: 1) left ventricular assist devices or LVAD, 2) right ventricular assist devices or RVAD, and 3) biventricular assist devices or BiVAD.<sup>6</sup>

#### 1. LVAD

LVADs are indicated in patients with a CI <1.8 L/Min, systolic blood pressure <80 mm Hg, and a LAP > 20 mm Hg on MMS. In addition, in order to achieve sufficient flows, RV function must be intact and adequate circulatory volume present. Statistically LVADs often reduce LV wall stress by 80% and subsequently reduce myocardial tissue demand by 40%, greatly reducing the stress and workload of the LV.<sup>1</sup> The following devices are those that have the capability to support the LV only.

- Heartmate I vented electric (XVE): Pulsatile, electrically driven, titanium, intracorporeal (internal) pump. No anticoagulation needed (daily aspirin only), best suited for large patients and patients with known coagulopathies. Encourages mobility with the use of specialized travel devices and is most commonly used for DT and BTT.<sup>7</sup>
- Heartmate II: Non-pulsatile, intracorporeal axial flow rotary pump capable of 3-10 L/min of cardiac output. Fits a range of patient sizes, requires full anticoagulation, and is typically indicated for BTT and acute LV recovery.<sup>8</sup>
- Jarvik 2000: Non-pulsatile, intracorporeal axial flow pump (smaller and lighter than the HM II), requiring full anticoagulation and used mostly for BTT and acute recovery. The compact size of this particular device allows practitioners to use a left thoracotomy incision versus the traditional sternotomy, resulting in lower infection and post-operative pain rates. In addition, the percutaneous lead can be tunneled to the retro-auricular region, also resulting in lower infection rates.<sup>2</sup>
- Novacor: Pulsatile, intracorporeal, electrically driven device implanted into the abdominal cavity or with a pouch created by the rectus abdominis muscle with a percutaneous driveline. This device requires anticoagulation, is only suitable for large patients, and is used for DT, with a documented success rate of over two years post implantation.<sup>1</sup>

#### 2. RVAD

Specific inclusion criteria for an RVAD includes a Mean RAP > 20 mm Hg, LAP < 15 mm Hg with no TR. As noted earlier, isolated RV support is not

Types of circulatory support devices are often categorized based on the ventricle(s) it supports. The three

2. *cont.*  
common and just as with the LVAD, is dependant upon adequate circulatory volume and LV function. Since RV support is rare, support is achieved from devices that will be discussed in the BiVAD section, since they can be used as LVADs, RVADs, and BiVADS.<sup>8</sup>
3. BiVAD  
Inclusion criteria described in both the LVAD and RVAD sections, as well as the inability to maintain LVAD flow over 2 L/min with a RAP > 20 mm Hg indicate the need for a BiVAD.<sup>1</sup> The two main devices used for Biventricular support include:
  - Thoratec Pneumatic (PVAD): Pulsatile, paracorporeal (pump located outside, but in close proximity to the body cavity, i.e. lies on the abdomen), pneumatically driven dual or single ventricular device which requires full anticoagulation.<sup>6</sup> Commonly used for BTT and recovery, this device is sufficient for all patients sizes and is one of the most successful BTT devices, with a post-transplant survival rate of 86%.<sup>2</sup>
  - Abiomed BVS 5000: Pulsatile, extracorporeal (pump located at the patients bedside), pneumatically driven pump, requiring anticoagulation, most prominently used for periods of two weeks or less for patients experiencing acute cardiac insults necessitating short term recovery periods.<sup>9</sup>

#### D. Cardiovascular ICU Nursing Care of Patient with a VAD

Although each device may have some individual management variations, in general, patient management goals include three main concepts, 1) Restore hemodynamic stability as well as augmenting perfusion to vital organs and tissues, 2) Normalize vital organ (kidney, liver) function estimated using laboratory values such as liver function tests (AST, ALT, Bilirubin, etc.) and BUN/ Creatinine, and lastly, 3) Prevention, early detection, and treatment of post-operative complications such as hypotension or low circulating blood volume, cardiac tamponade, bleeding, arrhythmias, and infection and/or sepsis.<sup>8</sup>

In addition to the prevention of complications, the nursing staff must advocate for several key post-operative tasks to get completed. These key tasks include, 1) Early patient mobilization in collaboration with both physical and occupation therapy departments, 2) Early and sufficient nutritional support, often achieved using small frequent meals which are high in both calories and protein, and 3) Proper care of and prompt removal of invasive lines to decrease systemic infection rates. Nutritional support should be established within 24 hours, most favorably with oral diets, but if complications ensue and postpone oral dietary supplementation, total parenteral

nutrition (TPN) should be initiated.<sup>10</sup> As well, if titration of inotropic medications using a swan ganz catheter and/or close blood pressure monitoring with an arterial line is indicated, strict central line care should be enforced, including proper rotation of puncture sites. Similarly, dressings and exit site wounds should be cared for with strict aseptic technique, using dry sterile dressings that are usually changed daily. Although each hospital will establish a unique protocol for the care of these devices, most VAD companies support the use of a chlorhexadine based solution to clean the exit site, followed by a sterile saline rinse and finally a dry, occlusive sterile dressing. Furthermore, the stabilization of exit site apparatuses such as the polyester woven velour lead of the Heartmate II, is extremely important in the prevention of infection as well as the promotion of tissue in-growth of the device.<sup>8</sup> Adequate flows and stroke volume values should be maintained per each devices specific requirements, and support devices such as chest tubes, inotropes, and pacing wires should be well maintained per each hospitals specific policies and procedures.<sup>1</sup>

#### Conclusion

Technology has certainly changed the course of how we care for patients. With the development of circulatory assist devices such as those discussed above, we have increased the years of life and more importantly the quality of life in patients who might have otherwise suffered premature death. We can only hope to anticipate further advances in healthcare, finding increasingly more innovative methods to provide cardiac surgical care using circulatory assist devices.

#### About the Author:

Heather Colflesh, RN, BSN is a critical care nurse at UCLA Ronald Reagan Medical Center in the Cardiothoracic Intensive Care Unit. Her love of pathophysiology, pharmacology, research, and bedside nursing care brought her to this exceptional institution. At UCLA, Heather has had the opportunity to care for a diverse population of post-cardiac surgical patients, including patients with ventricular assist devices. The innovative environment at UCLA has opened the door to research opportunities, committee work, teaching, and mentorship and Heather hopes to continue her journey towards further leadership goals, such as charge nurse on her particular nursing unit. Her love of critical care nursing has motivated her to pursue a career in nurse anesthesia.

## References

1. Bojar RM. Manual of perioperative care in adult cardiac surgery, 4<sup>th</sup> ed. Oxford: Blackwell Publishing, Inc.; 2005.
  2. Boehmer JP & Popjes E. Cardiac failure: Mechanical support strategies. *Critical Care Medicine*. 2006;34(9) 34-39.
  3. Karfer R. Mechanical circulatory support with the thoratec assist device in patients with postcardiotomy cardiogenic shock. *The Annals of Thoracic Surgery*. 1996; 61(1): 314-316.
  4. Moriguchi J. Mechanical circulatory support in advanced heart failure [Power point slides]. Retrieved from the University of California Los Angeles Ronald Reagan Medical Center; 2009.
  5. Pitsis AA, Dardas P & Mezilis N. Temporary assist device for postcardiotomy cardiac failure. *The Journal of Thoracic and Cardiovascular Surgery*. 2004;(77)31-33.
  6. Copeland JG, Smith RG & Arabia FA. Cardiac replacement with a total artificial heart as a bridge to transplantation. *New England Journal of Medicine*. 2004; 59 -67.
  7. Frazier OH, Rose EA, Oz MC. Multicenter clinical evaluation of the HeartMate vented electric left ventricular assist system in patients awaiting heart transplantation. *JAMA*. 2001; 36 -41.
  8. Thoratec Corporation. Retrieved November 20, 2009 from <http://www.thoratec.com>.
  9. Thomas NJ & Harvey AT. Bridge to recovery with the Abiomed BVS-5000 device in a patient with intractable ventricular tachycardia. *The Journal of Thoracic and Cardiovascular Surgery*. 1999; 53-58.
  10. Kaplow R & Hardin SR. Critical care nursing: Synergy for optimal outcomes. Sudbury, MA: Jones and Bartlett Publishers; 2007.
- Jurmann MJ & Siniawski H. Initial experience with miniature axial flow ven- tricular assist devices for postcardiotomy heart failure. *The European Journal of Cardiovascular Surgery*. 2005; 42-47.

## Lactate Levels: Indicator of Mortality in Trauma Patients

By Gregory Zweigle, RN, BSN, CCRN

Patients involved in traumatic accidents have shown an increase in serum lactate levels upon presentation in the Intensive Care Unit. Marked increase in Lactate levels may warn the physician that an increase in morbidity is imminent due to decreasing oxygenation to vital organs and the surrounding tissues. In direct correlation to an injury or traumatic insult, an aggressive plan of action is warranted to correct metabolic insufficiencies.

Throughout present modern-day serum analysis, many tests have been implemented to assist care givers in their decisions to treat critically-ill patients. Serum lactate analysis was modernized by Broder and Weil<sup>1</sup> with their use of photospectrometric methodology of whole blood. Today, measurement of lactate through this method can be done in less than 2 minutes with a plethora of hand-held devices.<sup>2</sup>

The correlation between lactate levels and morbidity in the intensive care patient stems from a relationship debate between increasing blood lactate levels and the presence of oxygen debt called tissue hypoxia.<sup>3</sup> The pathophysiology of

anaerobic metabolism is concentrated around the glycolytic pathway of

muscle cells. The anaerobic energy pathway, or glycolysis, creates ATP exclusively from carbohydrates, with lactic acid being a by-product. Anaerobic glycolysis provides energy by the partial breakdown of glucose without the need for oxygen. Anaerobic metabolism produces energy for short, high-intensity bursts of activity lasting no more than several minutes before the lactic acid build-up reaches a threshold known as the lactate threshold which creates cellular fatigue. The acidosis that is associated with increases in lactate concentration during trauma arises from a separate reaction. When ATP is hydrolysed, a hydrogen ion is released. ATP-derived hydrogen ions are primarily responsible for a decrease in pH. Trauma, shock, reduced cardiac output and lack of oxygen, create aerobic metabolism which cannot produce ATP quickly enough to supply the demands of the muscle. As a result, anaerobic metabolism becomes the dominant energy

**“The correlation between lactate levels and morbidity in the intensive care patient stems from a relationship debate between increasing blood lactate levels and the presence of oxygen debt called tissue hypoxia.”**

cont. producing pathway, as it can form ATP at high rates. Due to the large amounts of ATP being produced and hydrolysed in a short period of time, the buffering systems of the tissues are overcome, causing a state of acidosis; a natural process which facilitates the easier dissociation of Oxyhaemoglobin and easier transfer of oxygen from the blood<sup>4</sup>

In trauma patients, two forms of shock present on a regular basis. The first form of shock is called circulatory and the second is classified as clinical, or distributive shock.<sup>5</sup> In circulatory shock, signs and symptoms of the patient include hypotension, tachycardia, cold and clammy skin and decreased urine output. In the beginning of this symptomatic shock state, poor perfusion begins to mount and cellular oxygen is decreased due to a reduced cardiac output.<sup>6</sup> Serum lactate levels drawn on this patient are consistent with a marked spike in the concentration of lactate in the blood and an ensuing significant morbidity potential. Experts believe that prompt treatment in the first hour of care in circulatory shock will bring lactate levels down and will increase the patients chance for survival by 75%.<sup>7</sup>

In addition to circulatory shock, distributive shock can develop as a consequence of an injury related to the traumatic event. A classic distributive

shock that presents is Neurogenic shock, usually seen in trauma patients with spinal cord injuries which results in further physiological decompensation. Adequate circulating blood supply is critical for the trauma patient, as survival depends upon oxygenation at the tissue and cellular level. Adequate circulation is a demand-driven system, in that oxygen demand for the tissues is met by increases in oxygen delivery through increases in blood flow. An adequate blood supply through the tissues is maintained through mean arterial pressure, which can be compromised by circulatory and distributive shock states.

Blood pressure in the trauma patient is maintained by compensatory mechanisms in the body, provided that there is an adequate cardiac output. Cardiac output is maintained by having a sufficient intravascular volume fluid for the body to enable tissue perfusion and cellular oxygenation. When cardiac output fails, tissue and cellular hypoxia may not be seen clinically until it is irreversible.<sup>8</sup> Falling or normal lactate levels in hemodynamically stable patients within the first twelve hours of traumatic injury are predictive of increased survival.<sup>9</sup>

Other investigators have found that normalization of serum lactate levels

**About the Author**  
**Gregory Zweigle is an experienced critical care nurse with a wide range of experience in medical, surgical and cardiothoracic critical care. Mr. Zweigle was accepted this year into the Kaiser School of Nurse Anesthesia.**

within 24 hours of traumatic injury increases the patients percentage of survival by 25%.<sup>10</sup> One of the main therapeutic goals towards increasing patient survival and decreasing serum lactate levels would be to optimize oxygenation of the tissues by increasing cardiac output through the use of inotropes and fluid resuscitation.<sup>11</sup> This increases aerobic metabolism, halting lactate production.

Although it cannot be said that all patients that suffer traumatic injury will survive when serum lactate levels are stabilized, it is strongly urged that all clinicians monitor lactate levels and focus on decreasing hypoperfusion of tissue whenever possible. With the combination of lactate monitoring and hemodynamic circulatory resuscitation, the trauma patient has a greater opportunity of survival.

## References

1. Broder G, Weil MH. Excess lactate: an index of reversibility of shock in human patients. *Science*. 1964; 143:1457-1459. PubMed Abstract
2. Brinkert W, Rommes JH, Bakker J. Lactate measurements in critically ill patients with a hand-held analyzer. *Intensive Care Med*. 1999; 25:966-969. PubMed Abstract
3. Meakins J, Long CNH. Oxygen consumption, oxygen debt and lactic acid in circulatory failure. *J Clin Invest*. 1927; 4: 273.
4. Sussman I, Erecinska M and Wilson DF. Regulation of cellular energy metabolism: the Crabtree effect. *Biochim. Biophys. Acta*. 1980; 591: 209-223. PubMed Abstract.
5. Aric RN. Shock!. <http://www.alpharubicon.com/med/shockaricrn.htm>. Obtained 09/10/2008.
6. Rackow EC, Weil MH. Physiology of blood flow and oxygen utilization by peripheral tissue in circulatory shock. *Clin Chem*. 1999; 36:1544-1546. PubMed Abstract.
7. Blow O, Magliore L, Claridge JA, Butler K, Young JS. The golden hour and the silver day: detection and correction of occult hypoperfusion within 24 hours improves outcome from major trauma. *J Trauma*. 1999; 47:964-969. PubMed Abstract.
8. Bakker J, de Lima A. Increased blood lactate levels : an important warning signal in surgical practice. *Crit Care Med*. 2004; 8:96-98. PubMed Abstract.
9. Meregalli A, Oliveria RP, Friedman G. Occult hypoperfusion is associated with increased mortality in hemodynamically stable, high-risk, surgical patients. *Crit Care*. 2004; 8:R60-R65. PubMed Abstract.
10. Smith I, Kumar P, Molloy S, Rhodes, A, Newman PJ, Grounds RM, Bennett ED. Base excess and lactate as prognostic indicators for patients admitted to intensive care. *Intensive Care Med*. 2001; 27: 74-83. PubMed Abstract.
11. Polonen P, Ruokonen E, Hippelainen M, Poyhonen M, Takala J. A prospective, randomized study of goal-oriented hemodynamic therapy in cardiac surgical patients. *Anesth Analg*. 2000; 90:1052-1059. PubMed Abstract.