Damage Control Anesthesia

Richard P. Dutton, MD, MBA
Associate Professor of Anesthesiology
University of Maryland School of Medicine
Director of Trauma Anesthesiology
R Adams Cowley Shock Trauma Center
University of Maryland Medical System
Baltimore, MD 21201 USA
rdutton@umm.edu

Learning Objectives: 1) To understand the essential components of damage control anesthesia. 2) To learn the resuscitation goals related to damage control surgery.

Abstract
The role of the anesthesiologist in the damage control approach to the patient is of utmost importance and can have a profound impact on the patient's ultimate outcome. The anesthesiologist is vital in overseeing the process of fluid resuscitation to optimize hemostasis and long-term survival. Another critical role of the anesthesiologist is prevention of a second hit caused by recurrent shock. It is essential for any anesthesiologist who cares for unstable trauma patients to know and understand the concepts of damage control anesthesia. This article presents these concepts in detail.

The Evolution of Damage Control

"Damage control" is one of the buzzwords in modern trauma care, a bandwagon that everyone has boarded. Yet what does it really mean? Put most simply, damage control is a plan of care for the badly injured patient. In the 1970s, thinking was focused on "the Golden Hour," a fictional construct intended to emphasize the importance of rapid diagnosis, surgery, and resuscitation.[1] This was a laudable goal, and necessary for the times. This led in the 1980s to a "fix everything now" mentality. Sometimes this had advantages: early fracture fixation improved patient mobilization and reduced the incidence of pulmonary complications[2]; early diagnosis and treatment of aortic injuries doubtless saved lives.[3] In other cases, though, prolonged surgical procedures may have done more harm than good. With the crack cocaine epidemic of the late 1980s came the need for a new paradigm.

Damage control was invoked as a means to avoid "operating the patient to death," a way of limiting prolonged surgical procedures that increased blood loss, and with it the potential for hypothermia, coagulopathy, and acidosis. Instead, only those procedures that were necessary for hemostasis were done, while others, such as anastamosis of discontinuous bowel segments or definitive closure of the abdomen, were delayed until the patient was more stable. Damage control was a technique confined to the abdomen, and known primarily by trauma surgeons.

In the new millennium, the concept of damage control has expanded. There is now a realization that prolonged early surgery may be deleterious to the patient even in the absence of

hypoperfusion or coagulopathy. The "second hit" produced may become the straw that breaks the camel's back, leading to fatal exacerbation of traumatic brain injury (TBI), to the systemic inflammatory response syndrome, to the development of acute lung injury, or to early sepsis. This realization in turn has broadened the thinking about damage control, so that it is now applied to orthopaedic procedures (external fixation vs. intramedullary nailing of femur fractures),[4] intrathoracic surgery (delayed repair of stable aortic injuries), and even neurosurgery (craniotomy without replacement of the bone flap, even in the absence of massive edema). The previous articles in this issue of *TraumaCare* have described damage control in some detail as it is seen today by experienced and innovative trauma surgeons.

To date there has been nothing written about the anesthesia component of damage control, and little public discussion of what the anesthesiologist can do to facilitate the overall goals of the trauma team. To some degree, this reflects the lack of specialized trauma anesthesiologists in the United States; in addition, it stems from a failure to recognize the critical importance of anesthetic management in the early care of the trauma patient. Consider Table 1, a simple list of early management goals for the severely injured patient. When one thinks about how many of these variables are under the control of the anesthesiologist it becomes obvious that anesthetic management may be as critical as surgical management in achieving the best possible patient outcome.

Table 1. Goals for Damage Control in the Severely Injured Patient

- Stable airway and oxygenation
- Hemostasis—control of life-threatening hemorrhage
  - Exploratory laparotomy or thoracotomy
  - Rapid, wide exposure
  - Excision over repair of "expendable" organs
  - Focus on hemostatic procedures only
    - Vessel ligation or repair (avoid grafting if possible)
    - Packing for diffuse bleeding
  - Temporary closure
  - Angiographic embolization in selected cases
- Effective analgesia and sedation
- Appropriate blood composition:
  - Oxygen-carrying capacity (red blood cells)
  - Clotting potential (platelets, clotting factors)
  - Chemistry (especially calcium, glucose, potassium, chloride)
- Stabilization/reversal of tissue acidosis
- Normothermia

Table 2. The Essentials of Damage Control Anesthesia

- Airway and ventilator management
  - Rapid sequence intubation
  - Titration of ventilation
- Control of bleeding
  - Deliberate hypotensive resuscitation
  - Maintenance of blood composition
- Preservation of homeostasis
  - Normothermia
  - Restored and sustained end-organ perfusion
- Analgesia and sedation

The Goals of Damage Control Anesthesia

Table 2 is a modification of Table 1, focused on the components of damage control that are in the hands of the anesthesiologist. Some activities, such as airway control and provision of adequate analgesia, will be obvious to any practitioner. Other activities, such as control of hemostasis and avoidance of the second hit, require a deeper understanding of the trauma patient and the ways in which the anesthesiologist contributes to outcome. The remainder of this article will illustrate these points in detail.

Airway and Ventilator Management

The hemodynamically unstable patient is likely to be in pain, is likely to require one or more surgical procedures, and has a very high probability of clinical deterioration. For all of these reasons, early definitive airway management is strongly recommended.[5] Higher levels of oxygenation can be assured, the airway can be protected against aspiration, and adequate levels of analgesia and sedation can be provided without fear of hypoventilation or apnea. Intubation should occur early in the diagnostic phase, prior to sending the patient for a computerized tomographic (CT) scan, with the equipment and personnel on hand to do the job correctly.

Because the damage control approach emphasizes speed in diagnosis and therapy, the approach to intubation should be as swift and certain as possible. Figure 1 is the emergency airway management algorithm used at the Shock Trauma Center in Baltimore. This approach depends on the presence and participation of a senior anesthesiologist and experienced trauma surgeon, and focuses on achieving the best possible conditions on the first attempt at intubation.[6] Members of the trauma team are delegated to provide manual in-line cervical stabilization and cricoid pressure. Oxygen is provided throughout the procedure by bag-valve-mask assisted ventilation. A small, titrated amount of a sedative agent (thiopental or etomidate) is administered, immediately followed by a generous dose of succinylcholine (1.5 mg/kg). Intubation is attempted two or three times, facilitated by a gum-elastic bougie (intubating stylet) on the second attempt, and personally performed by the most experienced provider present on the last attempt. If successful endotracheal passage of the tube cannot be documented by the presence of exhaled carbon dioxide, the team moves rapidly to placement of a laryngeal mask airway (LMA). Clinical deterioration of the patient or inability to establish ventilation with the LMA is an indication for emergent cricothyroidotomy. Successful LMA placement may be followed by either cricothyroidotomy or formal tracheostomy, depending on the patient's hemodynamic status.

Because the patient was unstable even before the start of airway management, there is little role for awake intubation techniques or fiberoptic bronchoscopy, and no thought given to waking the patient if attempts at intubation are unsuccessful. Despite the simplicity of this approach and the chaotic environment in which it is usually applied, an experienced team can achieve excellent results. Quality management data from the Shock Trauma Center over the past decade has shown a consistently low need for surgical airway access, on the order of 0.1% of all emergency intubations.

In addition to skill at rapid sequence intubation, the anesthesiologist can contribute important insights to the ventilatory management of hemorrhaging patients. Already noted was the need to limit the dose of sedative medication in unstable patients because of the potential for hemodynamic collapse associated with a sudden drop in serum catecholamine levels. Similarly, initial tidal volumes and ventilating pressure should be kept as low as necessary to maintain oxygen saturation because positive intrathoracic pressure
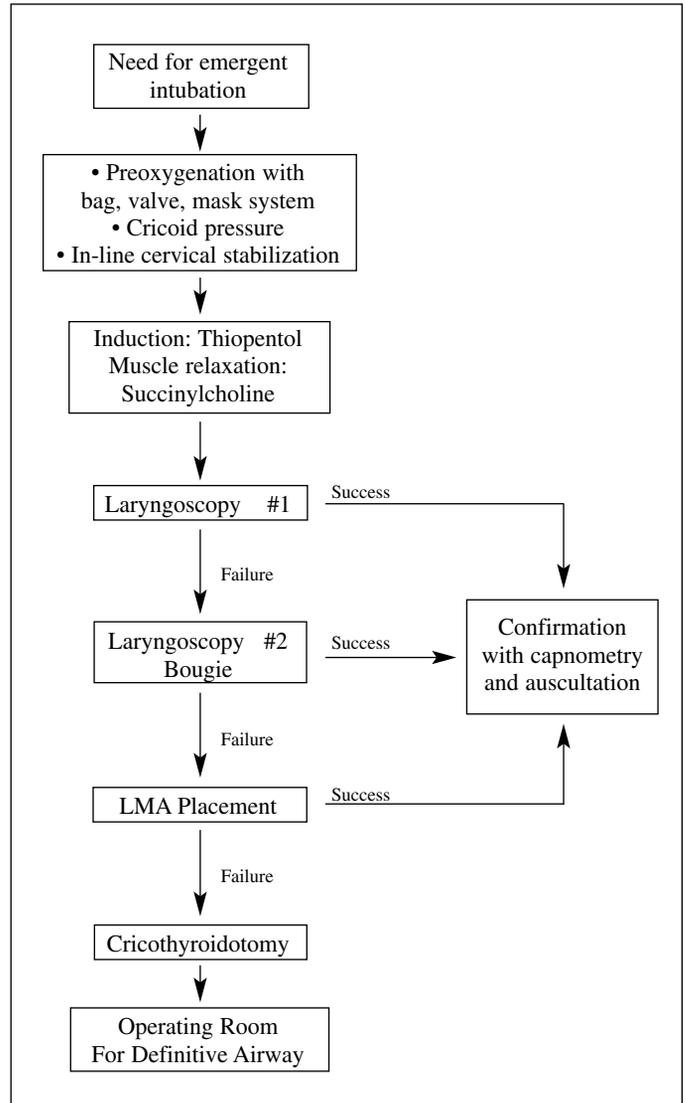

Figure 1. The emergency airway management algorithm currently in use at the Shock Trauma Center (January 2006). This algorithm is reviewed and updated each year to include new drugs (such as etomidate) or techniques (such as the LMA). Adapted from Dutton and McCunn.[6]

will decrease venous return to the chest, decrease right atrial filling, and reduce cardiac output. We commonly employ initial tidal volume settings of 5 to 6 mL/kg, with positive end-expiratory pressure (PEEP) of 5 cm, and a rate of 8 to 10 breaths per minute. Higher levels of PEEP, and even the conversion to pressure-controlled modes of ventilation, may well be necessary later in the patient's course to treat acute lung injury associated with trauma and massive resuscitation.[7] In the early phase, however, the greater risk is ongoing hemorrhage and associated hemodynamic instability.

Control of Bleeding

Most of the techniques for hemostasis described in this issue of *TraumaCare* are the province of the surgeon or angiographer. In clinical practice there is scant attention paid to the influence of fluid resuscitation on the rate of hemorrhage and the incidence of

rebleeding. It is true, however, that the kind and quantity of fluids administered will have an impact on the patient's clinical course. Animal models of uncontrolled hemorrhagic shock using standardized injuries and surgery have shown as much as a 60% difference in outcome based on the fluid resuscitation regimen.[8] In the clinical arena it is likely that the more this process is knowledgeably and consistently managed by a single individual—ideally the anesthesiologist—the better the patient will do.

Skillful resuscitation of the unstable patient requires adequate intravenous (IV) access, frequent diagnostic feedback, and experienced management. Placement of at least two large-bore (16 gauge or greater) IVs is a priority in the early management of the bleeding patient, usually accompanied by sampling of blood for laboratory assays (complete blood count, electrolytes, coagulation studies, lactate, and toxicology) and for blood bank cross-matching.[5] Failure to find peripheral IV access is an indication for central venous access, utilizing a pulmonary-artery introducer sheath or special trauma access line. At least one access site should be above the diaphragm in any patient with the possibility of abdominal or pelvic bleeding.

Once access is established, all IV fluids and blood products should be administered in defined doses, just as any other anesthetic drug, titrated to the patient's vital signs, the clinical scenario, and the available laboratory data. The anesthesiologist should be concerned with both the volume of fluids infused and the resulting composition of the patient's blood.

Fluid volume should be titrated by administration of 200- to 500-mL boluses to maintain cardiac output and blood pressure at a low, but sustainable, level.[9] Deliberate hypotensive resuscitation has been shown to enhance hemostasis in numerous animal studies, and was supported by two large prospective clinical trials.[10,11] Fluid restriction facilitates hemorrhage control in numerous ways: lower blood pressure enhances regional vasoconstriction and facilitates clot formation and stabilization. Controlled volume administration reduces the development of hypothermia and limits dilution of red cell mass, platelets, and clotting factors. Weighed against this is the potential for worsening hypoperfusion, with a risk for increased acidosis and organ system injury. The anesthesiologist must steer a careful course between the Scylla of shock and the Charybdis of rebleeding, understanding that deliberate hypotension in the face of ongoing hemorrhage is an inherently unstable situation (Figure 2). This is why fluids should be administered in small boluses, with close attention to the rate of surgical bleeding, to the vital signs, and to frequent laboratory studies.

Maintenance of blood composition is at least as important to achieving hemostasis as careful control of the vital signs. Logistical restraints in the trauma system (i.e., the speed with which blood products can be prepared and delivered to the bedside; the turnaround time for laboratory assays) make it likely that any trauma patient who is bleeding heavily will experience at least transient derangements in blood composition. Use of crystalloid solutions in prehospital and early emergency department care will lead to a rapid drop in hematocrit. Aggressive replacement of red blood cells (RBCs) will lead in turn to deficiency of clotting factors and platelets, especially as these are consumed at the site of vascular injury (and reconsumed when rebleeding occurs). Many institutions maintain massive transfusion protocols that recommend the administration of defined ratios of RBCs, plasma, and platelets. In reality, even the use of 1 unit of RBC matched to 1 unit of plasma and 1 unit of platelets will maintain only a barely acceptable blood composition, as illustrated in Figure 3. Fresh whole blood has obvious advantages as a resuscitative fluid for the actively bleeding patient. Because it is viable after collection for less time than is usually needed for viral screening, whole blood is available in only a few of the world's trauma systems (e.g., Israel, the U.S. military).
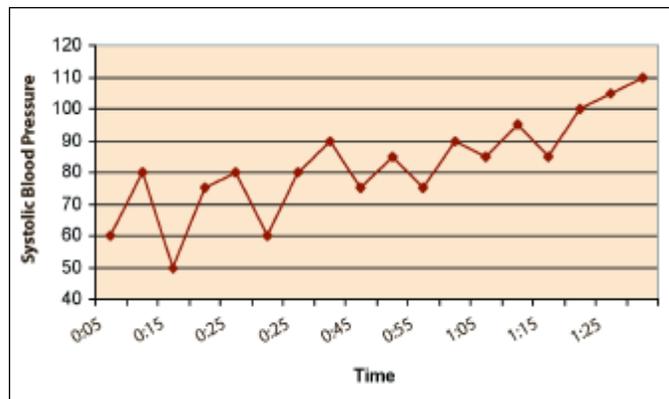

Figure 2. Typical variations in blood pressure seen during damage control surgery. Ongoing hemorrhage, fluid therapy, and administration of anesthetic drugs cause swings in blood pressure. Stability is achieved when bleeding is controlled, a deep anesthetic level is attained, and the patient is euvolemic.
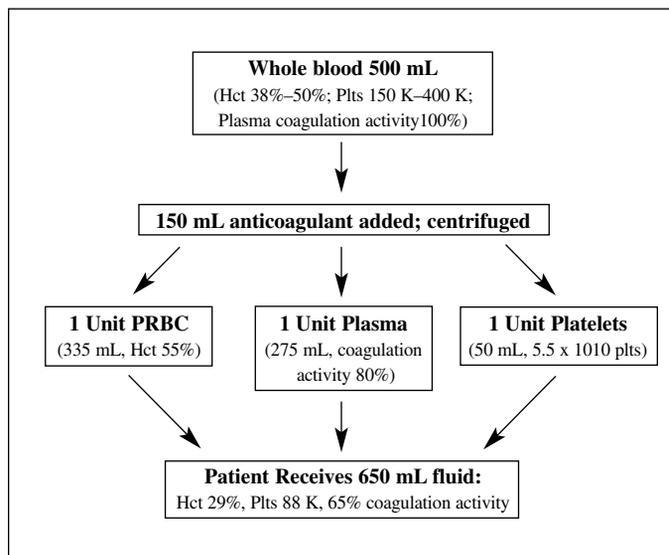

Figure 3. Final administered concentrations of red cells, clotting factors, and platelets achieved when a unit of whole blood is donated and fractionated, then given as separate components during damage control anesthesia. Hct, hematocrit; Plts, platelets; PRBC, packed red blood cells.

Recommendations for fluid resuscitation during damage control are listed in Table 3. Sustained hypotension is desirable unless contraindicated by patient history, by injury to the brain or spinal cord, or by laboratory evidence of increasing acidosis. Stabilization of blood pressure without recourse to ongoing fluid administration is the best clinical sign of successful hemostasis (see Figure 2). Blood products should be administered as early as possible, with uncross-matched type-O RBC recommended at the time of admission in patients who are obviously unstable.[12] Plasma and platelets should follow as soon as they are available from the blood bank. In the patient with significant ongoing blood loss, ratios of blood products similar to whole blood will be required to reach simultaneously acceptable levels of hematocrit, clotting factor concentration, and platelet count. Crystalloid administration should be reduced or eliminated all together once blood products are available. Frequent laboratory assay (every 1 hour or even more often) is indicated in the patient who is actively hemorrhaging.

Table 3. Resuscitation Goals *During* Damage Control Surgery*
• Systolic blood pressure 90 mm Hg • Heart rate <120 beats per minute • Pulse oximeter functioning, SaO_2 >95% • Urine output present • $PaCO_2$ <50 torr • pH >7.25 • Hematocrit >25% • Lactate stable or decreasing • Ionized calcium >1.0 • International normalized ratio <1.6 • Platelets >50,000 • Normothermia • Deep anesthesia *Lower blood pressure may be tolerated as long as acidosis is not worsening.

Table 4. Resuscitation Goals *After* Damage Control Surgery*
• Systolic blood pressure >100 mm Hg • Heart rate <90 beats per minute • Pulse oximeter functioning, SaO_2 >97% • Urine output >0.5 mL/kg/hr • $PaCO_2$ <40 torr • pH >7.35 • Hematocrit >20% • Lactate normal • Ionized calcium >1.0 • International normalized ratio <2 • Platelets >50,000 • Normothermia • Cardiac output normal or high • Light sedation (comfortable, able to initiate spontaneous ventilation) * Normal lactate is the best marker for adequacy of resuscitation. A lower hematocrit can be tolerated in a patient who is not actively bleeding.

Close attention is required to maintain blood composition and chemical equilibrium. Serum ionized calcium levels will fall rapidly during massive transfusion, caused by both acidemia and the chelating effects of sodium citrate administered with banked blood products. Calcium replacement will be necessary in any patient receiving more than 4 to 6 units of RBC in an hour.[13] Increase in blood pressure in response to calcium injection is an empiric indication of its value, and calcium administration should be considered while awaiting laboratory confirmation in any bleeding patient with hypotension who is unresponsive to bolus fluid administration. Other electrolytes will seldom become deranged during ongoing resuscitation with isotonic crystalloids and blood products. Although bicarbonate administration may have a transient pressor effect in the patient with extreme acidosis, it is unlikely that this therapy offers any benefit over further fluid administration and improvement of tissue perfusion. Similarly, derangements in sodium, potassium, or chloride levels indicate either a profound failure of resuscitation (such as disproportionate use of normal saline or hemolysis of mismatched RBC) or a state of shock so deep that survival is unlikely.

A final role of the anesthesiologist in achieving hemostasis is the decision to administer systemic procoagulant agents. Recent experience with the use of recombinant activated human clotting factor VII (FVIIa) has shown promise in reversing traumatic coagulopathy and improving long-term outcomes from hemorrhagic shock.[14,15] Although there is substantial enthusiasm in the trauma community for the "off-label" use of this agent, a definitive understanding of the potential risks (e.g., inappropriate thrombosis) and benefits (e.g., earlier hemostasis) of this approach will depend on the outcome of the multicenter international trials now underway. At the Shock Trauma Center we consider the use of FVIIa when severe hemorrhagic shock persists beyond the administration of the first 6 to 8 units of RBC and plasma, or when an underlying coagulopathy, such as warfarin use, is complicating the clinical picture.

Preservation of Homeostasis

The anesthesiologist's responsibility to the critically injured patient does not end when bleeding is controlled. Resuscitation must be completed, and the patient's physiology returned as close to normal as possible, or as close to the optimum for recovery as can be arranged.

End points for resuscitation are listed in Table 4. Once bleeding is definitively controlled, fluid administration should be continued until the patient is demonstrably euvolemic. Simple normalization of vital signs should not be equated with restoration of tissue perfusion. The phenomenon of occult hypoperfusion is common in young trauma patients; vasoconstriction to compensate for inadequate fluid volume may produce a normal blood pressure even in the presence of ongoing organ system ischemia.[16] Resolution of metabolic acidosis on arterial blood gas analysis and normalization of serum lactate indicate a systemic return to aerobic metabolism and recovery from hemorrhagic shock. Multiple studies have shown that the faster lactate clears, the lower the patient's subsequent incidence of multiple organ system failure and death.[17,18] Other means to confirm recovery from shock include maximization of cardiac output in response to fluid administration, normalization of gastric or sublingual tissue acidosis (measured by minimally invasive tonometry or capnometry),[19] and tolerance of a normal level of anesthesia and analgesia.

Although deliberate hypothermia has been suggested as a treatment for hemorrhagic shock and has demonstrated good results in animal trials, this therapy is not yet recommended for trauma patients.[20] Hypothermia potentiates coagulopathy and increases the incidence of infection and sepsis. Further, the process of warming from hypothermia may impose additional cardiac stress on patients with limited reserve. Until hypothermia management protocols that avoid these risks are developed and validated, the clinical practitioner is better served by keeping the patient warm throughout the resuscitation. Fluid boluses should be administered through a warming system, a forced hot-air surface warmer should be used whenever possible, and the operating room (OR) environment should be kept warmer than usual.

Homeostasis is especially important to the brain-injured patient because outcomes are significantly worse following similar levels of TBI when a second hit is allowed to occur.[21] Retrospective data suggest that any single episode of hypotension or hypoxia increases the mortality from TBI by fourfold, and the occurrence of both in the same patient leads to a tenfold greater chance of dying. The effect appears to be mediated by increased inflammation in the vicinity of the brain tissue injured in the original trauma; this phenomenon is probably a representative model for effects throughout the body. Future

resuscitation research is closely focused on this point, and active manipulation of the postshock inflammatory cascade is likely to be part of the anesthesiologist's available resources a decade from now.

Analgesia and Sedation

The final task of the anesthesiologist in the damage control scenario is also the most obvious: the provision of pain relief and unconsciousness for the patient. Despite the fact that this is the most basic of goals for the anesthesiologist, there is often a reluctance to medicate the patient with ongoing hemorrhagic shock because of hemodynamic instability. It is true that any analgesic or sedative medication is likely to lower the unstable patient's blood pressure; in fact, an unexpected decline in blood pressure may help to suggest a decrease in blood volume. Hypotension is caused both by the direct vasodilatory and negative inotropic effects of the medication itself (as with propofol, midazolam, or isoflurane) and the indirect decrease in serum catecholamines that accompanies analgesia and sedation (as with fentanyl, etomidate, or ketamine).

Exacerbation of hypotension should not be a contraindication to anesthesia, however, but only a sign that it should be used with caution. Hemorrhage volumes and the duration of bleeding are known to be worse in the vasoconstricted subject. Vasoconstriction also reduces end-organ perfusion and contributes to exaggerated up-and-down swings in blood pressure. For these reasons, vasopressor agents have long been avoided in hypotensive trauma patients, with the thought that fluid administration was a more physiologic therapy. Although the concept has not been systematically studied in humans, it is logical to extend this thinking to the active use of anesthetic agents to move from a vasoconstricted state to a vasodilated one. It is known, for example, that similar blood loss is much better tolerated in the anesthetized human or animal than in one who is awake and alert.[22]

For these reasons, it is our customary practice to achieve a deep and stable level of anesthesia as early as possible in the care of the unstable trauma patient. We will begin loading the patient with fentanyl early in the resuscitation, using small doses at first and responding to drops in blood pressure (below our desired hypotensive target) with boluses of fluid. Our goal is to achieve a "cardiac anesthetic": 50 to 100 mcg/kg over the first few hours. Because fentanyl lacks any direct effect on the cardiovascular system, we expect the patient to sustain a low, stable blood pressure once hemorrhage is resolved and intravascular volume restored. We are not intending to awaken and extubate the patient at the end of resuscitation, and have little concern with inducing a long-lasting anesthetic. Indeed, the deeply narcotized patient is easier to manage through periods of early transport outside the OR to CT scan, angiography, magnetic resonance imaging, and the intensive care unit. Deep anesthesia also makes it easier to assess the patient's fluid volume over the remainder of the resuscitation because hypovolemia will cause an immediate decrease in blood pressure in the patient in whom catecholamine release has been blocked. Our anecdotal experience with this technique has been good, and we are presently exploring methods for a controlled prospective trial.

Conclusion

Conduct of anesthesia and fluid resuscitation is integral to the damage control approach to the patient with ongoing traumatic hemorrhage, and the actions of the anesthesiologist can have a profound impact on the patient's ultimate outcome. In addition to facilitating rapid transport to diagnostic studies and the OR, the anesthesiologist is best positioned to oversee the process of fluid resuscitation, adjusting the kind and quantity of fluid administered to optimize hemostasis and long-term survival. The anesthesiologist is also critical to avoidance of a second hit caused by recurrent shock, and may further benefit the patient by the careful, reasoned administration of analgesics and sedatives. Understanding the concepts of damage control anesthesia is important to any anesthesiologist who cares for unstable trauma patients.

References

1. Osterwalder JJ. Can the "golden hour of shock" safely be extended in blunt polytrauma patients? Prospective cohort study at a level I hospital in eastern Switzerland. *Prehospital Disaster Med* 2002;17:75-80.
2. Dunham CM, Bosse MJ, Clancy TV, et al. Practice management guidelines for the optimal timing of long-bone fracture stabilization in polytrauma patients: the EAST practice management guidelines work group. *J Trauma* 2001;50: 958-67.
3. Cowley RA, Turney SZ, Hankins JR, et al. Rupture of thoracic aorta caused by blunt trauma. A fifteen-year experience. *J Thorac Cardiovasc Surg* 1990;100: 652-61.
4. Scalea TM, Boswell SA, Scott JD, et al. External fixation as a bridge to intramedullary nailing for patients with multiple injuries and femur fractures: damage control orthopedics. *J Trauma* 2000;48:613-23.
5. Committee on Trauma, American College of Surgeons: *Advanced Trauma Life Support Program for Doctors.* Chicago: American College of Surgeons, 1997.
6. Dutton RP, McCunn M. Anesthesia for trauma. In: Miller RD, ed. *Miller's Anesthesia*. Philadelphia: Elsevier Churchill Livingstone, 2005;2451-95.
7. Sydow M, Burchardi H, Ephraim E, et al. Long-term effects of two different ventilatory modes on oxygenation in acute lung injury. Comparison of airway pressure release ventilation and volume-controlled inverse ratio ventilation. *Am J Respir Crit Care Med* 1994;149:1550-6.
8. Shoemaker WC, Peitzman AB, Bellamy R, et al. Resuscitation from severe hemorrhage. *Crit Care Med* 1996;24:S12-23.
9. Dutton RP. Initial resuscitation of the hemorrhaging patient. In: Speiss B, Shander A, eds. *Perioperative Transfusion Medicine*. Philadelphia: Lippincott, Williams & Wilkins; 2005.
10. Bickell WH, Wall MJ Jr, Pepe PE, et al. Immediate versus delayed resuscitation for hypotensive patients with penetrating torso injuries. *N Engl J Med* 1994;331:1105-9.
11. Dutton RP, Mackenzie CF, Scalea TM. Hypotensive resuscitation during active hemorrhage: impact on in-hospital mortality. *J Trauma* 2002;52:1141-6.
12. Dutton RP, Shih D, Edelman BB, Hess JR, Scalea TM. Safety of uncrossmatched type-O red cells for resuscitation from hemorrhagic shock. *J Trauma* 2006, in press.
13. Irving GA. Perioperative blood and component therapy. *Can J Anaesth* 1992;39:1105-15.
14. Boffard KD, Riou B, Warren B, et al. Recombinant factor VIIa as adjunctive therapy for bleeding control in severely injured trauma patients: two parallel randomized, placebo-controlled, double-blind clinical trials. *J Trauma* 2005;59:8-18
15. Dutton RP, McCunn M, Hyder M et al. Factor VIIa for correction of traumatic coagulopathy. *J Trauma* 2004;57:709-19.
16. 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;47:964-9.
17. Abramson D, Scalea TM, Hitchcock R, et al. Lactate clearance and survival following injury. *J Trauma* 1993;35:584-9.
18. Scalea TM, Henry SM. Assessment and initial management in the trauma patient. *Probl Anesth* 2001;13: 271-8.
19. McKinley BA, Butler BD. Comparison of skeletal muscle PO_2, PCO_2, and pH with gastric tonometric $P(CO_2)$ and pH in hemorrhagic shock. *Crit Care Med* 1999;27:1869-77.
20. Dutton RP. Hypothermia and hemorrhage. In: Speiss B, Shander A, eds. *Perioperative Transfusion Medicine*. Philadelphia: Lippincott, Williams & Wilkins, 2005.
21. Chestnut RM, Marshall LF, Klauber MR, et al. The role of secondary brain injury in determining outcome from severe head injury. *J Trauma* 1993;34:216-22.
22. Shibata K, Yamamoto Y, Murakami S. Effects of epidural anesthesia on cardiovascular response and survival in experimental hemorrhagic shock in dogs. *Anesthesiology* 1989;71:953-9.