The authors discuss key considerations of the anesthetic management of the shock/trauma patient. Specific goals to strive for in the clinical setting are provided.

Anesthetic management of the shock/trauma patient begins in the emergency room. The majority of shock/trauma patients seen in the ER have multi-system injuries involving the head, neck, chest, abdomen, or limbs. An assessment of the patient’s respiratory, cardiovascular, and hemodynamic systems should be performed. Particular attention should be paid to an evaluation of the patient’s airway. Is the airway clear? Can air movement be felt or heard? Are there injuries to the mouth, head, or neck? Are facial fractures involved?

In facial trauma, no single priority is more urgent than establishing patency of the airway. Even treatment of hypovolemia and shock, definitely a priority in trauma, is secondary to establishing an airway.¹

After the airway is established, the systems assessment must be performed as rapidly as possible. Ask key questions: Does the patient have any known allergies? Does he use medications, drugs, or alcohol? Does he have major medical problems such as a history of myocardial infarction, hypertension, diabetes, or seizure disorder?

The anesthetist must keep in mind that the thoroughness of the evaluation must be determined by the urgency of the situation. Typically, only a few minutes can be afforded. Table I outlines steps in evaluation in order of priority. Table II lists the information that should be obtained from the ER staff if the anesthetist cannot attend the patient in the ER. This information should enable the anesthetist to formulate the initial actions to be taken in the management of the patient.

### Considerations for airway management
Lacerations of the mouth and/or nose may result in large amounts of bleeding, possibly resulting in clots in the nasopharynx and oropharynx and increasing the risk of aspiration. Soft tissue tears and pedicle formations may prolapse into the air-

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<tr>
<td>Steps in evaluation of the shock/trauma patient in order of priority</td>
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<tr>
<td>1. Airway problems</td>
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<td>2. Ventilation problems</td>
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<td>7. Laboratory studies, type and crossmatch blood</td>
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<td>8. Documentation of care</td>
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way. The buccal fat pad can herniate out of its compartment and obstruct the airway. A prolapsed fat pad which is obstructing the airway or interfering with intubation should be grasped with a forceps or hemostat, trimmed with scissors, and removed.  

Positioning for intubation may be difficult. The type of injury may dictate that the patient remain supine. Manipulation of the head and neck may be dangerous. Patients with facial trauma should not be put in a supine position. If possible, the patient should be turned to a lateral position to permit gravity to keep the airway open.

Table II
Information needed from emergency room staff

1. Initial injury description
2. Status of airway management
3. Status of vascular system
4. Level of consciousness, presence of head injury
5. History of alcohol or drug intake
6. Number of IVs, volume of fluids given
7. Laboratory and x-ray study results
8. Past medical history (if available)
9. Known allergies
10. Prescribed medications used

Table III
Indications for tracheal intubation

1. Patency of airway if repositioning fails to correct the obstruction
2. Facial injuries demanding prompt airway management
3. Tracheobronchial suctioning for aspirated material
4. Protection of airway from further complication such as obstruction or aspiration
5. Possibility of tracheotomy
6. Ventilatory assistance required

Table IV
Airway maintenance

Equipment needed

1. Suction
2. Mask and breathing bag
3. Oxygen source and delivery tubes
4. Laryngoscope with assorted sizes of blades
5. Oral and nasal airways
6. Tracheal tubes in assorted sizes

Key points

1. Positioning of head and neck—support on folded towel
2. Clearing the airway of foreign material
3. Adequate light source for inspection of oral cavity
4. Intubate under direct vision whenever possible
5. Watch chest for movement
6. Listen bilaterally for air movement

The authors do not recommend the use of only an oral or nasal airway to maintain airway patency because of the probability of a full stomach. If ventilatory assistance is required, tracheal intubation is indicated. Table III lists other conditions that indicate the need for intubation.

Continuous observation of the patient by the entire trauma team cannot be overstressed. A patient can be awake and talking one moment, and the next moment he may wretch, vomit, and aspirate. This is especially true of the inebriated patient. Without warning, an inebriated patient suddenly can become uncontrollably violent. If restrained in a supine position, the inebriated patient becomes a prime candidate for aspiration.

The performance of a tracheotomy as a means of intubating or establishing an airway is rarely indicated. The best means of management in trauma—especially maxillofacial trauma—is oral intubation or rapid cricothyrotomy. A tracheotomy is best performed in a controlled setting in the operating room or another sterile environment. An endotracheal tube should be already in place for the sake of safety. The rapid performance of a tracheotomy should not be attempted on a trauma patient unless attempts at intubation or cricothyrotomy have failed. Table IV lists key points in airway management and the minimum equipment that is necessary.

Hemodynamics

The next step in anesthetic management is continuous hemodynamic monitoring. This monitoring includes blood pressure (BP), pulse (P), respiration (R), central venous pressure (CVP), urinary output (UO), and possibly pulmonary artery pressure (PAP). The patient is connected to an ECG monitor, a peripheral artery is cannulated and the arterial line is transduced to an electronic monitor. The CVP is measured with either an electronic monitor and transducer or a water column manometer, and a stethoscope is placed...
to auscultate heart and lung sounds. An esophageal stethoscope is preferable to a precordial chest piece because it offers superior sound transmission qualities and does not interfere with the surgical site. The urine drainage bag connected to the Foley® catheter is placed near the head of the table so that both the quantity and quality of urine can be continuously observed. In some cases, a pulmonary artery catheter may be needed to assess left ventricular function and to measure pulmonary artery pressures.

Invasive monitoring is essential because it offers distinct advantages over non-invasive techniques in the shock/trauma patient.® The advantages of invasive monitoring are that it:
- Allows continuous monitoring;
- Frees the anesthetist’s hands for other purposes;
- Allows changes to be seen and noted instantly;
- Allows trends to be more readily observed;
- Facilitates postoperative management;
- Allows frequent blood sampling with minimal vessel trauma.

Even when the patient arrives in what appears to be stable condition, placement of invasive monitors, including an arterial line and CVP, is still favored. Although these monitors may be placed after induction of anesthesia, it is best to place them at the earliest opportunity. It is easy to be misled by the action of bodily compensatory mechanisms into thinking that the patient is better off than he really is. Invasive monitors allow assessment and management of the consequences of, for example, acute blood loss occurring during surgery or prior to the patient’s arrival in the operating room.

Establishment of monitoring parameters and initial lab studies

In the ER, the trauma team routinely should insert three or more large bore IV catheters, one of which should monitor the CVP. Blood should be drawn for arterial blood gases (ABGs), hematocrit (Hct), hemoglobin (Hb), electrolytes, prothrombin time (PT), partial thromboplastin time (PTT), type and crossmatch, and toxicity/drug screen. A Foley® catheter is inserted into the patient’s bladder and connected to a graduated, closed drainage system. The arterial line may be placed while the patient is in the ER; if it is not, it should be placed at the first opportunity in the OR. Most commonly, the radial artery is cannulated percutaneously. Patients in severe shock may require a cutdown. The arterial catheter should be no larger than 20 gauge.® When inserting an arterial line percutaneously, the following technique is recommended:
- Place a small towel or gauze roll under the patient’s wrist so that it is slightly hyperextended.
- Palpate the pulse, then prep the site with povidone-iodine solution.
- Approach the artery at approximately a 30° angle to the skin until the artery is entered and blood is detected, then stop.
- Lay the catheter placement unit flat against the skin, then advance the entire unit 1 or 2 mm and stop.
- Hold the needle firmly and, without moving it, slide only the catheter forward into the lumen of the artery.
- When the catheter has been guided its full length into the artery, remove the needle, connect the monitoring line, and secure the catheter in place.

It is specifically recommended that the needle guide not be removed before the catheter is advanced. The technique of going through the artery and then backing up until blood is seen is not recommended. Both of these procedures are associated with higher rates of failure and increased risk of arterial thrombosis.®

CVP catheters are used to assess intravascular volume and venous return to the right side of the heart (preload). CVP catheters also provide access to the vascular compartment when peripheral veins are collapsed, providing a baseline measurement for decision making where large volumes of fluid are to be administered, and for aspirating air from the superior vena cava or right atrium when the patient’s head is positioned above the level of the heart.®

Sites of insertion for central venous catheters are antecubital, basilic, cephalic, external jugular, internal jugular, and subclavian veins. Of the peripheral sites, the basilic is preferred because it offers the least resistance when the catheter is passed through the axilla. The external jugular is easily entered but forms an acute angle as it joins the subclavian vein. The internal jugular forms no acute angles and can be safely used when the insertion is properly performed. The right internal jugular is preferred because it lies in a near straight line with the innominate and superior vena cava.® The subclavian veins are excellent sites, especially for long term placement, and they are associated with a relatively low incidence of complication. Catheter placement should be verified by x-ray.
The trauma team may also insert a nasogastric sump tube in the ER to decompress the stomach and search for gastric bleeding. During surgery, the stomach tube should be set either for open drainage or continuous low suction. It should not be clamped. Whether or not to temporarily remove the nasogastric tube during induction and intubation is a controversial issue which will be addressed later.

The accuracy of monitored information depends upon properly placed and functioning equipment. Blood pressure and heart rate provide essential information about cardiovascular dynamics. From these, inferences can be made concerning intravascular volume, cardiac output, and stroke volume. The stroke volume is approximately equal to the pulse pressure (pulse pressure = systolic — diastolic BP). The stroke volume multiplied by the heart rate yields the cardiac output in liters per minute (stroke volume × heart rate = cardiac output).\(^2\)

**Volume management**

The degree of fluid translocation from the intravascular space to the interstitial space varies with the severity of the trauma. Initially, not less than two liters of fluid should be infused, after which a balance of crystalloid and colloid fluids is infused until vital signs start to return to acceptable values and the cause of the hypovolemia is under control. Major internal bleeding may be discovered upon peritoneal lavage, placement of a chest tube, or surgical incision of the abdomen, and a sudden hypotensive crisis could result if the patient has not been adequately fluid loaded.

The amount and rate of infusion is based upon the principle of “appropriate dose for desired effect”: there is no fixed rate of infusion or specific dose to be infused. Clinical judgment must be applied. If volume infusion alone fails to produce the desired effect, then a direct-acting vasopressor may be needed for a brief period of time. The vasopressor is not a substitute for adequate volume replacement, but it should serve to maintain adequate perfusion pressure until satisfactory volume replacement is achieved and the source of volume loss controlled. Refractory hypotension may be an indication that inotropic agents such as calcium chloride, digoxin, or dobutamine should be administered. The measures taken to achieve and maintain values for BP, P, CVP, and UO within acceptable limits are dependent upon the etiology of the abnormality: volume for hypovolemia, vasopressors to restore peripheral vascular resistance, inotropes for a failing pump. In actual practice, a combination of two or perhaps all three of the above therapies may be indicated.

The only crystalloid fluids acceptable for infusion are balanced electrolyte solutions and physiologic saline solutions. Infusion of IV fluids that contain dextrose or salts in less than physiologic concentrations can be disastrous. Resuscitative fluids containing dextrose should not be routinely administered. Trauma victims are hyperglycemic from stress gluconeogenesis, and exogenous glucose would aggravate the situation and promote osmotic diuresis. Balanced electrolyte solutions are best used in this situation; isotonic saline solution is next in order of preference. Solutions with lesser concentrations of electrolytes serve to dilute the patient’s electrolytes and volume load him with “free” water, which could result

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<td><strong>Recommended ratios of crystalloid, colloid and blood products</strong> (^5,8,9,10,13)</td>
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1. **Crystalloid.** Balanced electrolyte solution (Ringer’s, Plasma-Lyte®, Normosol R®) q.s. to maintain CVP between 5-15 cm H₂O and UO between 1-2 ml/kg/hour.

2. **Colloid (other than blood products)**
   a. Hetastarch (Hespan®), 500 ml initially, up to total of 1500 ml if needed to maintain intravascular volume, or
   b. Albumin, 25 gm/5 liters of crystalloid, up to 100 gm.

3. **Colloid (as blood or blood product derivatives)**
   a. Packed red blood cells/whole blood: q.s. to achieve and maintain hematocrit of approximately 30% or Hb of 10 gm/dl. The plasma portion of a unit of whole blood replaces one unit of non-blood product colloid.
   b. Fresh frozen plasma (FFP): 2 units for every 10 units of blood. Whole blood, if fresh, could replace 1 unit blood + 1 unit FFP. FFP provides all clotting factors except platelets.
   c. Platelets: 6 to 10 “packs” of platelets for every 10 units of blood. There are no active platelets in “banked” blood. High volume transfusion with blood and crystalloid rapidly deplete the patient’s platelet count.
in hyponatremia, hypokalemia, arrhythmias, coma, or death.\textsuperscript{8,9,10}

Packed red blood cells are the product that is most readily supplied by blood banks for use when it is necessary to administer blood. Fresh whole blood may be considered ideal because it provides clotting factors (except platelets) and protein and has oxygen-carrying capacity. However, whole blood is costly to provide, is slightly more likely to carry a hepatitis virus, and is not readily available (because whole blood is usually broken down into components soon after the blood bank receives it).\textsuperscript{8,9,10}

The volume of whole blood or packed red blood cells to be infused is best determined by measuring serial Hct/Hb values intraoperatively. Estimating blood loss following trauma is nearly impossible by other means, because the patient loses blood preoperatively at the scene of the trauma, while en route to the hospital, and in the ER. The first blood available is usually either universal donor blood (O-negative) or type-specific blood (typed to the patient's blood type and Rh factor, but not crossmatched), because there is often not time to wait for complete crossmatching.

The severity of the trauma, apparent amount of blood lost, and hematologic lab values all will influence the balance of colloids to be given. Efficient use of resources means balancing colloid and crystalloid components to meet the patient's requirements. Table V shows some recommended ratios of crystalloid to colloid/blood products.

Techniques and adjuncts

If the patient is not intubated upon arrival in the OR, it must first be determined if an awake intubation is indicated. If the airway is not unduly compromised and the patient is volume resuscitated and stable, induction and intubation with thiopental and succinylcholine is acceptable. If hemodynamic stability is questionable, ketamine 1-2 mg/kg\textsuperscript{a} with succinylcholine, or succinylcholine alone, may be appropriate. There is also the question of what to do with a nasogastric tube placed by the ER staff. The authors prefer to aspirate and remove the tube, proceed with intubation, and secure the airway. The nasogastric tube is then replaced as soon as it is convenient. Antacids are not instilled prior to removal of the nasogastric tube, because they might leak into the peritoneal cavity during trauma or surgical incision of the stomach.

The patient should be given 100% oxygen via a properly placed and secured tracheal tube, with the breathing circuit connected to a volume-controlled ventilator set to deliver a tidal volume of 10 cc/kg and a rate of 10 breaths per minute. The patient should be paralyzed using a long-acting, nondepolarizing muscle relaxant such as pancuronium bromide in doses of 0.1 to 0.15 mg/kg. This higher dose range is necessary because of poor peripheral flow which hampers distribution of the drug to receptors at the neuromuscular junction.

Additional anesthetic agents, such as nitrous oxide, enflurane, isoflurane, or intravenous narcotics, may be titrated in quantities sufficient to maintain physiologic vital signs and suppress sympathetic reflex activity. As a precaution, halothane should not be used because of its potent myocardial depressant effects. There is some controversy over halothane’s effects on a patient with a possible liver injury.

Adjunctive drugs include vasopressors, vaso-dilators, electrolyte additives, cardiotonics, alkalinizing agents, and occasionally diuretics. The vasopressors of choice are phenylephrine (Neo-Synephrine\textsuperscript{®}), norepinephrine (Levophed\textsuperscript{®}), and epinephrine. Ephedrine is not generally used because the patient’s catecholamine reserves may already be depleted. Dopamine is not a drug of first choice, because its action on alpha receptors is weak to moderate, and the benefit of preservation of renal blood flow is valid only at low dose rates, after hypovolemia has been corrected.\textsuperscript{6}

Neo-Synephrine\textsuperscript{®} is diluted to 40 \(\mu\)g/ml. Levophed\textsuperscript{®} is diluted to 16 \(\mu\)g/ml. (These are the concentrations that result when one ampoule of either drug is added to 250 cc of IV fluid.) Initial doses of either drug should be drawn into a 10 cc syringe and given in 1 cc IV fluid, followed by incremental doses of 0.5 to 1.0 cc until the desired effect is achieved. Of these two drugs the first choice is Neo-Synephrine\textsuperscript{®}. In some instances, a continuous IV drip can be started, using the same concentrations previously described.

Calcium chloride (CaCl\textsubscript{2}), while not a vasopressor, can also be used to boost the BP. Given in IV bolus doses of 300-500 mg, it acts as a cardio-tonic to increase contractile force of the myocardium, increasing the cardiac output and systemic BP. If dopamine is to be used, it is recommended that it be diluted to a concentration of 1600 \(\mu\)g/ml and given by IV infusion at a rate of 5 \(\mu\)g/kg/min.\textsuperscript{8}

In those patients who require a vasodilator to control hypertension, a solution of sodium nitroprusside, 50 \(\mu\)g/ml is recommended. The initial
IV drip rate should be 0.5 μg/kg/min. This can be increased to a maximum rate of 10 μg/kg/min.

The use of diuretics such as mannitol or furosemide is rare. It is well known that the trauma patient whose urine output is scant usually is hypovolemic and/or hypotensive. When these conditions are corrected, urine output returns to normal levels. Giving the patient a diuretic pharmacologically alters one of the key monitoring parameters so that other measurements must be relied on to determine hemodynamic status. It cannot be over-emphasized that a low urinary output should not be considered an indication that diuretics are needed.

Acid-base and electrolyte management

After hemodynamic stability, the most critical problem is acid-base and electrolyte management. ABG's, Hct, Hb, and electrolytes should have been drawn and sent to the lab from the ER. They will be the first of several samples sent. These values change more rapidly than the same values measured in non-trauma patients. The trauma victim is in a hypermetabolic state, and because of hypotension and peripheral vasoconstriction, is sequestering large amounts of lactic acid in the tissues. As BP and peripheral perfusion improve, this lactic acid is picked up and added to the systemic circulation. It is therefore not unusual to give 8-10 ampuls of NaHCO₃ during a single case just to keep pH and HCO₃ within acceptable ranges. It is important to remember that both metabolic and respiratory acidosis are being treated. The goals to be achieved are:

- Adequate oxygenation (PaO₂ should be 5 × FIO₂)
- Normocarbia (adjust V/min if not within desired range)
  \[
  \frac{\text{present } \text{PaCO}_2 \times \text{present Vm}}{\text{desired } \text{PaCO}_2} = \text{corrected Vm}
  \]
- Correction of metabolic acidosis by administration of NaHCO₃ as needed:
  \[
  \frac{1/3 \text{ wt. in kg } \times \text{B.E.}}{2} = \text{dose of NaHCO}_3 \text{ in mEq.}
  \]

Determinations of ABG's, Hct, and Hb should be drawn about once per hour. Electrolytes, especially K⁺, should be determined with every other ABG sample. Acceptable ranges of blood values are listed in Table VI.

Equipment preparation

The room designated for trauma surgery should have the necessary equipment prepared and ready for use, and should be checked at the beginning of each shift and after each case is completed. Following is a checklist of tasks that must be performed:

- Breathing circuit on the anesthesia machine cleaned.
- Anesthesia machine pressure tested for leaks, vaporizers filled, all filler caps tightened.
- Ventilator tested.
- Laryngoscope checked, an assortment of blades and tubes and an intubating stylet ready for use.
- A supply of medication syringes for the following drugs filled and labelled:
  atropine
  thiopental
  succinylcholine
  pancuronium
  lidocaine (for arrhythmias)
  CaCl₂
  Epinephrine 1:10,000
  NaHCO₃
  Neo-Synephrine®
- Syringes for the following drugs labelled, but not necessarily filled:
  fentanyl
  diazepam
  ketamine
- 8-10 syringes available for ABG sampling.
- ECG monitor tested, transducer zeroed and calibrated for the arterial line and CVP.
- Two fluid/blood warmers assembled with tubing; IV fluid connected and left switched on.
- At least two (preferably four) inflatable pressure infusion devices (for rapid infusion of blood and IV fluids) available.

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<td>Acceptable laboratory values</td>
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- 10-12 liters of 0.9% NaCl available.
- 12-24 liters of balanced electrolyte (lactated Ringer's) solution available.
- 2-4 bottles of albumin product available.
- Extra IV equipment ready.
- Warming pad or blanket placed under the sheets on the OR table, and left switched on.

The goal is to prepare the room to receive virtually any patient with no advance notice, so that when a patient presents to the OR, adequate supplies are available and the anesthesia machine, ventilator, and monitoring console need only be turned on. No delays should be necessary to gather supplies or ready equipment.

Successful management of anesthesia for the shock/trauma victim depends just as much upon this advance preparation as it does upon the skill of the anesthetist. Even the most skilled anesthetist, without proper preparation, can fail miserably in attempting to manage a trauma victim in an acute situation. There is no time to think about what will be needed in the OR after the patient arrives—the equipment should be there so that the anesthetist need only think about what actions should be taken and which supplies should be used. The anesthetist who takes the time to prepare properly will do very well in the face of even the most critical situation.

Postanesthetic recovery

The importance of postoperative anesthetic management is often underestimated. Very few shock/trauma patients are good candidates for reversal and extubation in the OR. Most should remain intubated for at least several hours following surgery, and many must remain intubated for days. Should these patients be reversed and awakened even though they remain intubated? If the patient is a candidate for extubation within a few hours, often only the muscle relaxant is reversed, thus allowing the anesthetics to wear off gradually. This provides some assistance in assessing spontaneous ventilatory efforts prior to extubation. If the patient is likely to remain intubated for one or more days, the authors prefer to avoid any reversal, so that the patient is less likely to fight or buck against the ventilator and also so that postanesthetic shivering, which increases oxygen consumption significantly, is minimized. If there is doubt concerning extubation, it is best to wait: don't extubate prematurely.

As soon as the patient arrives in the recovery area, ventilation should be assured and vital signs verified and recorded. A complete report to the personnel assuming care must be given: this should include the nature of the trauma, operation performed, drugs and anesthetic agents used, and significant medical history. Full and accurate documentation is a must for all cases.

Summary

The fundamental principles for successful anesthesia management of the shock/trauma patient are based upon (1) organization and preparation; (2) assessment of the patient's injuries and prioritization of needs; (3) maintenance of a secure airway; (4) steps to achieve hemodynamic stability; (5) continuous monitoring; (6) correction of hypovolemia; (7) correction of acid-base and electrolyte abnormalities; and (8) careful titration of anesthetic and adjunctive drugs.

The exact actions taken to achieve the goals discussed in this brief paper will vary, but the fundamental principles of sound, safe practice should remain the same. It is true that most anesthetists do not work at major trauma centers. This does not mean, however, that major trauma could not be seen in any ER from time to time, and anesthetists must be well prepared to manage victims of trauma.

REFERENCES

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