Trauma Anesthesia Plan for Non-Permissive Environments

Maj Joshua M. Tobin, MD

Abstract

The current war has, like past conflicts, presented the medical community with opportunities to innovate novel approaches to old problems. Although trauma anesthesia is provided adequately in the majority of cases, a standardized approach for treating these complex and critically ill patients is lacking. While this technique was developed for anesthesia in non-permissive environments, the principles suggested here could serve as a template for trauma anesthesia in other environments as well. The algorithm is designed as a standardized protocol in an effort to simplify the approach to these complex patients who often present in a dynamic environment. A list of required equipment is included to serve as a guide for preparation prior to employment of the algorithm.

Introduction

Napoleon's Aide-Surgeon-Major Dominique Jean-Larrey was one of the first to propose advanced medical care in the field, followed by evacuation to higher levels of care by dedicated military assets. In his case, horse drawn carriages called "flying ambulances" were used. Recent conflicts have proven no exception to the concept of advanced medical care in the forward environment.[1] Inclusive in the concept of forward surgery is the provision for battlefield anesthesia. For teams operating in the far forward, non-permissive environment such a plan must provide anesthesia for a major abdominal case (e.g. exploratory laparotomy for trauma) with equipment that can be carried on the back of the individual physician. The anesthetic plan must account for surgical anesthesia, as well as the initial and on-going resuscitation of a major trauma case. This includes adequate sedation, hypnosis, and analgesia for the surgery, as well as muscle relaxation. Potential emergencies and resuscitation must also be anticipated. Some concerns unique to the austere environment include limiting the weight of the equipment needed, providing power to any electronic equipment used, and carrying all of the medication required for the case in a backpack.

A review of the literature finds little that discusses possible methods for providing the anesthetic for trauma and emergency surgery in austere environments.[2,3] Although some of the guidelines proposed here may be basic (e.g. have your emergency medications immediately available), these techniques are included because they have sometimes been neglected in the past with disastrous results. It is important to note that these suggestions are intended for austere environments with patients *in extremis* where laboratory, radiology, and other support services are not available.

The equipment referenced here can be carried in a standard ruck sack at a weight under approximately 45 pounds, not including oxygen supply. It is convenient to pre-package the gear that will be used together in vacuum sealed, zip lock-type bags (e.g. IV/IO bag, intubation bag, monitoring equipment bag, etc). Their retrieval from the ruck sack and employment can thereby be made more efficient. Medications can be carried in a small, hard-plastic pelican-type case. Although these medications will potentially be exposed to temperature extremes, it is unclear what the clinical significance of these temperature extremes is.[4] Keeping medical gear in a temperature controlled environment is obviously preferred if possible.

The algorithm is designed as a standardized protocol (see Figure 1) in an effort to simplify the approach to these complex patients who often present in a dynamic environment. A list of required equipment is included to serve as a guide for preparation prior to employment of the algorithm (see Table 1). Included below is a proposed algorithm for the anesthesia and resuscitation of trauma patients in non-permissive environments.

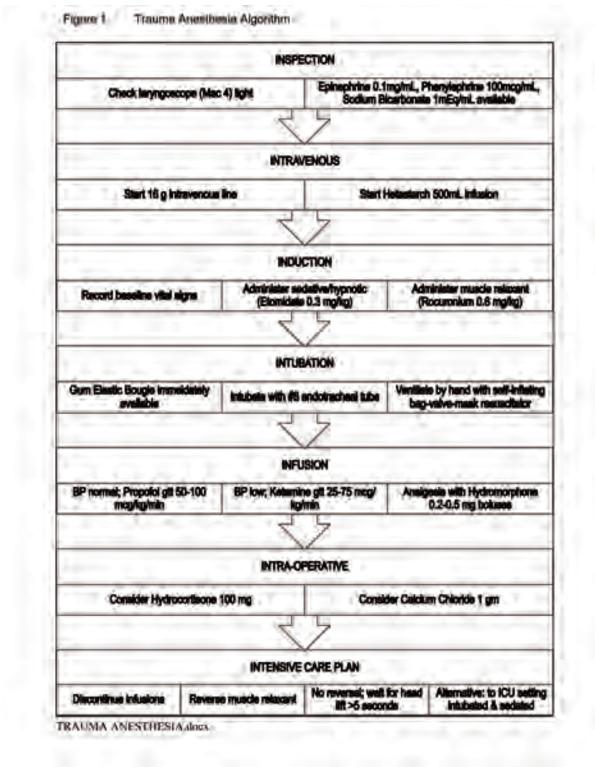

Table 1 **<u>Trauma Anesthesia Equipment List</u>**

1-	Laryngoscope handle with AA batteries
1-	Macintosh 4 laryngoscope blade
4-	AA batteries
1-	Gum elastic bougie
2-	Endotracheal tube stylet
2-	#8 Endotracheal tube
2-	#7 Endotracheal tube
1-	Self-inflating bag-valve-mask resuscitator
1-	Electrocardiogram monitor with oxygen saturation and non-invasive blood pressure capability
1-	Sphygmomanometer (if monitor unavailable)
1-	Stethoscope
2-	16 gauge angiocatheter
2-	14 gauge angiocatheter
2-	15 gauge intraosseous needle
30-	Alcohol swabs
4-	Occlusive intravenous site dressing
1-	1 inch roll medical tape
2-	Intravenous tourniquet
4-	Macro-drip intravenous tubing
2-	Hetastarch (500ml)
2-	Normal Saline (1000ml)
2-	Lactated Ringer's (1000ml)
1-	Battery-powered, rechargeable syringe infusion pump
4-	Microbore intravenous extension tubing (for use with syringe pump)
2-	Lever lock cannula (to attach syringe pump tubing to intravenous line)
3-	Syringe (60ml)
6-	Syringe (20ml)
15-	Syringe (10ml)
25-	18 gauge needle
3-	Epinephrine pre-filled syringe (10ml at 0.1mg/ml)
3-	Phenylephrine (1ml at 10mg/ml)
3-	Normal Saline (100ml)
3-	Sodium Bicarbonate pre-filled syringe (50ml at 1meq/ml)
2-	Etomidate (20ml at 2mg/ml)
3-	Rocuronium (5ml at 10mg/ml)
2-	Propofol (100ml at 10mg/ml)
2-	Ketamine (10ml at 50mg/ml)
4-	Hydromorphone (1ml at 2mg/ml)
1-	Hydrocortisone (2ml at 50mg/ml)
2-	Calcium Chloride (10ml at 100mg/ml)
1-	Standard ruck sack

INSPECTION

Have airway equipment prepared at all times. This includes inspecting the quality of the light at the end of the laryngoscope blade on a regular basis and ensuring that endotracheal tubes are available. If only one laryngoscope blade is to be carried due to weight restrictions, take a Macintosh 4. It can be appropriately placed in the vallecula as designed, or used as a "modified Miller" blade to manipulate the epiglottis in difficult airways. A gum elastic bougie is useful in difficult airways without adding much weight. Use a laryngoscope handle with AA batteries, rather than C batteries. AA batteries are more readily available in the austere environment, thus streamlining the re-supply needs of the team and decreasing overall equipment weight.

Prepare emergency medications for immediate use at all times. Potent medications that support hemodynamics are important to any resuscitation. The potent vasopressor and inotropic effects of epinephrine are well known. Sodium bicarbonate supports cardiac contractility[5] and can be useful in cardiopulmonary collapse. Phenylephrine supports systemic vascular resistance via direct alpha agonist activity without an increase in heart rate, making it useful for hypotension at induction of anesthesia. Valuable preparatory time is saved when these medications are carried in pre-packaged syringes. One can add phenylephrine 10mg in 100ml of normal saline for a concentration of 100mcg/ml. A single 10ml syringe can be prepared for immediate use.

INTRAVENOUS

Obtain vascular access with a 16 gauge angiocatheter, or larger. The flow rates possible through a 16 gauge angiocatheter (220ml/min) are double those of an 18 gauge catheter (105ml/min). If it is not possible to quickly establish intravenous access, place an intraosseous line. Administer 500ml of hetastarch. Although hetastarch can inhibit factor VII and von Willebrand factor, resulting in impaired platelet function, this effect is generally seen with volumes over one liter.[6,7] Importantly, the use of colloid allows a minimum volume of resuscitation fluid to be carried in the physician's backpack. Administer a second 500ml of hetastarch at a slower rate, then resuscitate as needed with crystalloid. Titrate fluid administration to blood pressure, and more importantly, urine output. The goal urine output is 1-2ml/kg/hr. Place a second intravenous line as time permits.

Although blood bank facilities are unlikely to be available in the austere environment, the "walking blood bank" has been used in the past. Team members with an appropriate blood type, who have been prescreened for communicable diseases, donate whole blood for use in surgery. There is an emerging body of literature regarding the appropriate ratio of blood products for use in trauma,[8] as well as novel applications in the trauma patient of medications useful in massive hemorrhage.[9,10] A detailed discussion of these practices, however, is beyond the scope of this communication.

Monitor electrocardiogram and blood pressure if available; however, a monitor may be prohibitively heavy. If a non-invasive blood pressure monitor is not available, the following rule has proven useful. A palpable carotid pulse suggests a systolic blood pressure of roughly 60mmHg, a femoral pulse 70mmHg, and a radial pulse 80mmHg. A manual sphygmomanometer is useful for interval measurement of vital signs without adding much weight.

Induction

Induce anesthesia using etomidate at a dose of 0.3mg/kg as a sedative/hypnotic and rocuronium at a dose of 0.6mg/kg as a muscle relaxant. There is a slightly longer onset of action for rocuronium than succinylcholine (60-90 sec v. 30-60 sec). The side effects of succinylcholine, such as increase in intracranial pressure and hyperkalemia; however, are avoided with the use of a non-depolarizing agent. Furthermore, rocuronium can remain out of refrigeration (60 days) significantly longer than succinylcholine (14 days) making it more suitable for use in the austere environment. Additionally, a longer acting non-depolarizing muscle relaxant is needed for abdominal wall muscle relaxation in a major abdominal case.

Intubation

Intubate the trachea with a #8 endotracheal tube and ventilate by hand with a self-inflating bag-valve resuscitator. Administration of oxygen is obviously ideal; however, large oxygen cylinders are prohibitively heavy. Smaller liquid oxygen systems under development (Backpack Medical Oxygen System; Essex Cryogenics of Missouri, Inc.; St. Louis, MO) may allow administration of oxygen concentrations greater than 40% for shorter duration "damage control" surgery.

Infusion

Start a propofol infusion at 50-100mcg/kg/min. A variety of small syringe pumps that have rechargeable battery packs are readily available for accurate delivery of intravenous anesthesia. In the event of battery failure, intermittent bolus dosing can be used. Titrate the infusion to blood pressure and sedation/hypnosis. If the blood pressure is low, start a ketamine infusion at 25-75mcg/kg/min. Advantages of ketamine include support of the sympathetic nervous system (most notably blood pressure) and bronchodilation. Airway reflexes are maintained with ketamine. Side-effects of ketamine include dissociative anesthesia and a theoretical increase in risk of seizures.

Maintain analgesia with hydromorphone in 0.2-0.5mg intravenous boluses. Hydromorphone is significantly more potent than morphine and is not associated with the histamine release, and resultant hypotension, of morphine. Hydromorphone is packaged in concentrated 2mg vials, again saving weight.

Intra-Operative

Administer hydrocortisone 100mg; so called "stress dose steroids." The intense mineralocorticoid activity of hydrocortisone improves sensitivity to catecholamines, decreases inflammatory markers, and decreases vasopressor requirements while avoiding some of the unwanted side effects of glucocorticoid administration. While it is ideal to verify a cortisol level before administration of hydrocortisone,[11] this is not an option in the austere environment. One can assume some degree of adrenal insufficiency and catecholamine depletion in a major trauma patient.[12]

If the patient experiences hypotension refractory to fluid resuscitation, then administer one gram of calcium chloride. Again, without laboratory facilities this is not ideal; however, the risks of low calcium (most significantly, unremitting hypotension) are greater than the risks of mild hypercalcemia (nausea, vomiting, constipation, ileus, shortened QT interval, nephrocalcinosis).

Intensive Care Plan

At the conclusion of the case, discontinue any sedative-hypnotic infusion. Extubate after reversing the effect of the muscle relaxant with neostigmine and glycopyrrolate. If these medications are not available, wait for the clinical duration of the muscle relaxant to pass (an induction dose of rocuronium will last 35-75 min). A clinical assessment of return of airway reflexes is the evaluation of sustained head lift. A sustained head lift greater than five seconds suggests adequate return of airway reflexes.

Conclusion

The current war has, like past conflicts, presented the medical community with opportunities to innovate novel approaches to old problems. Although trauma anesthesia is provided adequately in the majority of cases; a standardized approach for treating these complex and critically ill patients is lacking. While this technique was developed for anesthesia in non-permissive environments, the principles suggested here could serve as a template for trauma anesthesia in other environments as well.

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Contact Information:

Joshua M. Tobin, MD; Director of Trauma Anesthesia; Santa Clara Valley Medical Center, Department of Anesthesiology, 751 South Bascom Avenue, San Jose, CA 95128; P (408) 885-5745, F (408) 885-5758; joshua.tobin@us.af.mil; Joshua.Tobin@hhs.sccgov.org; josh_tobin@hotmail.com

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Major (Dr.) Joshua M. Tobin is an Individual Mobilization Augmentee assigned to AFSOC. He has deployed as the critical care physician on the Special Operations Critical Care Evacuation Team (SOCCET) and is board certified in both critical care medicine and anesthesiology. On the civilian side, Major Tobin is the director of trauma anesthesia at one of the busiest level I trauma centers in California.