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Restoring Core Blood Volume in Severe Haemorrhagic Shock - What are the Options? - A Review

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Abstract

Restoring core blood volume is key to survival in severe haemorrhagic shock (SHS). Matching blood volume to vascular volume facilitates venous return to the heart, adequate cardiac output, blood pressure and perfusion of the essential organs. This is a review of the available practical options of doing so in the pre-hospital and in-hospital settings. We evaluate critically the use of blood products transfusion; pneumatic antishock garment (PASG), auto-transfusion tourniquet (A-TT) and pharmaceutical vasoconstrictors.

Keywords: Severe Shock; Pneumatic Antishock Garment; PASG; Auto-Transfusion Tourniquet (A-TT); Emergency Blood Transfusion

Abbreviations: 2,3-DPG: 2,3-Bisphosphoglycerate; ATLS: Advance Trauma Life Support; A-TT: Auto-Transfusion Tourniquet; BLS: Basic Life Support; DVT: Deep Vein Thrombosis; Hgb: Haemoglobin; I/O: Intra-Osseous; IV: Intravenous; mmHg: Millimetres of Mercury; PASG: Pneumatic Antishock Garment; PCO_2: Partial Pressure of Carbon Dioxide; RBC: Red Blood Cells; SHS: Severe Haemorrhagic Shock; SPO_2: Oxygen Saturation

Introduction

Severe haemorrhagic shock (SHS) is the cause of death of nearly 2 million persons each year. Seventy eight percent of these cases are due to trauma and the balance are caused by ruptured aneurysms (10.2%), gastro-intestinal bleeding (7.5%) and pregnancy-related haemorrhages (3.7%) [1]. About a third of patients who suffer SHS die before they make it to the hospital and about 10% more die in the first 24 hours in the hospital. The concept of the “Golden Hour” has been shown by A Q Alarhayem, et al to be incorrect [2]. They stated that “...future efforts should be directed toward the development of therapies to increase the window of survival in the prehospital environment.”, particularly when evacuation and transport times are longer than 30 minutes. In this review we compare the pros and cons of methods that can be used to restore core blood volume in pre-hospital SHS.

Core blood volume restoration in SHS aims to keep systolic blood pressure above 90 mmHg, to keep heart rate below 120 beats per minute and to maintain the patient alert in the absence of head trauma and/or mental functions altering drugs. The goals of therapy are also common to all methods. They are to keep sufficient perfusion of the vital tissues (heart, brain, viscera, kidneys). Minute-to-minute monitoring of the SHS patient is commonly done by repeated measurements of vital signs: blood pressure, heart rate, SPO_2 and if the patient is intubated - end-tidal PCO_2. These parameters are useful but can miss deficiencies of tissue perfusion. As such, monitoring of lactate and urine output are also done to assess the extent of shock.

Discussion

The SHS hemodynamics restoration methods

We review here 4 diverse methods for restoring core blood volume and pressure as follows:

1. Expansion of blood volume by infusion or transfusion of blood products.

2. Constriction of peripheral blood vessels by infusing vasoactive drugs.

3. Compression of the lower body legs (and abdomen) by pneumatic or non-pneumatic antishock trousers.

4. Shifting the blood from the legs to the core by the auto-transfusion tourniquet.

We first describe the technologies and then summarize the pros and cons of each. The final section is a comparison table aimed to identify the most suitable for each scenario (Table 1).

Table 1: Comparison table between the methods for increasing core blood volume in severe haemorrhagic shock (SHS).

Parameter	Auto-Transfusion Tourniquet (A-TT)	Whole Blood	Antishock Garment (PASG)	Vasoactive Drugs
Route of Administration	Immediate (i.e. < 1 minute) application on legs	Requires starting large bore IV or intra-osseous port	Applied by 2 skilled caregivers.	Requires starting IV or intra-osseous port
Time to Onset of Action	Immediate (20 seconds per each leg)	3-5 minutes to start IV + 4-10 minutes for transfusion of a blood unit	At least 5 min for inflation of air bladders	3-5 minutes to start IV + 1-2 minutes for infusion
Required Skill Level	BLS	ACLS/ATLS paramedic	BLS	ACLS/ATLS paramedic
Core Blood Volume	Increases	Increases, but also legs blood volume	No documented effect	No effect
Vascular Resistance	Increases	No effect	Increases	Increases
Preload	Increases	Increases	No effect	No known effect
Afterload	Increases	No effect	Increases	Increases
Oxygen Carrying Capacity	Normal	Low (shift to left of O2-Hgb dissociation curve due to low 2.3.DPG)	Normal	Normal
Coagulation	Normal	Reduced due to added citrate to blood units	Normal	Normal
Titration of Effect	Possible by rolling A-TT up or down for desired blood pressure	Possible by adjusting infusion rate.	Not possible	Possible by adjusting dose and/or infusion rate.
Contraindications	Deep Vein Thrombosis (DVT)	Known sensitivity	DVT, chest injury	Known sensitivity
Adverse Effects	None	Anaphylaxis, serum sickness, blood groups incompatibility,	Respiratory depression	Reduced cerebral blood flow. Increases cardiac O2 needs.
Logistics	Package weighs 650 grams	Needs IV and/or I/O starting set, refrigerator, warmer, pressure injector,	5 kg suitcase	Needs IV and/or I/O starting set, infusion pump.
Limitations	Time limit is 2 hours max.	Availability, cost and skilled personnel.	Cannot be removed gradually	Skilled personnel needed at scene.

Infusion and Transfusion

The timeline of in-hospital massive transfusion (i.e., > 4 units of blood and blood products) was found to be 20 minutes from admission for red blood cells (RBC), 26 minutes for plasma and 72 minutes for platelets [3]. The information on pre-hospital initiation of blood transfusion is scarce; it typically requires starting two large bore IVs or an IV plus an intra-osseous (I/O) line [4]. The blood, which is typically O- (O negative) is transported cold and needs to be warmed up with a dedicated warmer. The transfusion itself can be quite quick, about 2-4 minutes per unit. Transfusion of whole fresh blood is considered better than transfusion of components (i.e., RBC + plasma + platelets). Infusion of crystalloids is least desirable, but is still widely used given its logistical simplicity and much lower cost.

The drawbacks of massive transfusion of "fresh" whole blood are related to its not really being fresh. The blood is anticoagulated as soon as it is taken from the blood donor. Citrate, a calcium binder, is mixed with the blood and remains active throughout. When the blood is transfused into the recipient, so does the citrate and massive transfusion is often associated with reduced clotting and increased bleeding. In addition, storing donated blood 14-21 days, nearly depletes 2,3-DPG and causes a substantial shift to the left of the oxyhemoglobin dissociation curve [5]. The result is that for 24-72 hours after transfusing the blood to a patient it does not supply oxygen to the tissue. The blood is loaded with oxygen, as can be seen by the high level of saturation, but the oxygen remains in the blood and is not available for mitochondrial tissue metabolism. Other drawbacks are the risk of developing antibodies and allergic reactions against allogenic blood.

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Vasoconstricting Drugs

The use of vasoactive drugs in SHS is controversial [6] and in fact discouraged by the teaching of the ATLS (Advance Trauma Life Support). Unlike distributive shocks (e.g. septic shock, anaphylactic shock) where vasoactive drugs such as noradrenaline and adrenaline are widely indicated and used, the blood vessels in the early stages of haemorrhagic shock (i.e., "compensated" phase) are maximally constricted by endogenous sympathetic activity. As such, adding external vasoconstrictors have not been shown to provide a benefit. That said, we have observed the use of vasoactive drugs in haemorrhagic shock that did not respond to quick infusion of crystalloids. Furthermore, once tissue hypoperfusion results in anaerobic metabolism, acidemia with release of sympathetic vasoconstriction, there may be room for vasoactive supplement. In a recent study Sims et al [7] evaluated the effect of low-dose supplementation of arginine vasopressin on need for blood product transfusions in patients with trauma and haemorrhagic shock and found a significant reduction in need for blood and blood products. The inclusion of vasoactive drugs in this review is for the sake of completion and should not be construed as a recommendation to do so indiscriminately.

Lower Body Compression by Pneumatic Antishock Garment (PASG)

PASG apply external pressure by inflating air bladders around the legs and abdomen to a pressure of up to 104 mm Hg. When the patient is in severe shock this pressure compresses the blood vessels and stops the blood flow. The physiological logic behind the introduction of PASG to widespread clinical use for treatment of shock in the early 1970s was based on the following arguments:

1. Compression of blood vessels causes shifting of blood from the less essential tissues of the extremities to the central circulation - the 'auto-transfusion' effect.

2. Inflation of the PASG to the maximum level (104 mmHg) completely collapses the arteries in the lower body and redirects the cardiac output to the essential organs.

3. External counter-pressure reduces bleeding from severed blood vessels beneath it. This confirmed beneficial effect of PASG is most apparent when the bleeding is due to blunt or penetrating abdominal injury [8].

4. PASG can be used to support and stabilize fractures of the pelvis with or without shock. It reduces blood loss and provides temporary splinting of the bones during transport [9].

Pitfalls of using the PASG: Contrary to these potential advantages of PASG, several concerns were presented regarding its use:

1. Delay in transport. The application of PASG was shown to extend the time of transport by approximately 5 minutes when used by well-trained paramedics [10].

2. When PASG is applied to patients with chest trauma, especially when there is bleeding into the pleural space, multiple rib fractures, cardiac tamponade etc. it interferes with breathing and may reduce cardiac output due to increased afterload [11].

3. Use of PASG during air transport, where ambient air pressures change significantly, is not desired [12].

4. Most importantly, sudden removal of the PASG or loss of bladder pressure is associated with rapid deterioration of the patient's condition.

5. PASG application limits the access to the lower body of the patient. It must be removed before diagnostic and/or surgical procedures are performed on the abdomen, groin area (e.g. femoral vein access) and the legs.

- **Clinical Evidence:** Studies conducted in the mid- to late- 1980s evaluated the outcome of shock victims when PASG was used or avoided. Over 900 patients were enrolled in one of the studies [10]. The data showed no advantage of PASG use in terms of overall survival. This study included patients with chest trauma and intrathoracic haemorrhage, a condition in which PASG was known to be detrimental from early on [8]. Indeed, this group had worse results when PASG was used which biased the overall statistics. Another study where PASG was used for victims of abdominal trauma with profound shock (blood pressure < 70 mmHg) showed that use of PASG tended to improve the outcome [10,13,14].

Auto-Transfusion Tourniquet

The auto-transfusion tourniquet (A-TT) is an elastic ring, wrapped around by a stockinet and straps. When the A-TT is placed on the toes and the straps are pulled, the ring rolls up the leg while applying concentric pressure on the tissues beneath it. This pressure is greater than the patient's systolic blood pressure so that the blood in the leg is squeezed to the core and the blood flow to the leg is blocked. Applying the A-TT on an adult's leg shifts more than 500 cc of blood from each leg to the central circulation [15]. The application of the A-TT is done by a single basic life support (BLS) caregiver and takes 10-20 seconds per leg.

- **Clinical Evidence:** The result is elevation of core blood volume and blood pressure [16,17]. It is used when the patient is in severe shock (i.e., systolic blood pressure < 80 mmHg with reduced cognition). It is recommended to apply it first on one leg and if blood pressure is still less than 80, apply to the other leg. The A-TT can stay on the patient for up to 120 minutes, giving extra time for surgical repair of the bleeding. Removal of the A-TT is done in small, 20 cm, steps, while monitoring vital signs. Deep vein thrombosis is an absolute contraindication of applying the A-TT to prevent dislodging of a thrombus and pulmonary infarct.

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Conclusion

Transfusion of fresh whole blood is the treatment of choice for severe haemorrhagic shock when it is available and logistically feasible. Else, applying the A-TT as "bridge to blood" and as a method to extend the window of survival is suggested. More clinical data is needed to validate this conclusion.

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