Clinical

Occult Hypoperfusion – Should the Military Surgeon Care?

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Introduction

Occult hypoperfusion is insufficient tissue perfusion and oxygenation for metabolic demands that is not apparent during normal clinical evaluation due to the presence of normal vital signs(1, 2). Its presence is linked with increased length of hospital stay and increased mortality(3, 4). Hypovolaemia secondary to traumatic blood loss is the precipitating factor in the process we now know as the acute coagulopathy of trauma(5).

Our understanding of this process at a biochemical level has progressed over the past decade and, although not completely understood, is thought to revolve around the activation of Protein C(6). Occult hypoperfusion can exist as an entity of its own in 25% of trauma patients and can be further perpetuated by the ‘lethal triad’ of coagulopathy, hypothermia and acidosis which, unless blood loss is stopped and normal physiology restored, can lead to an irreversible cascade and inevitable death(6).

The military trauma surgeon should be involved from the outset in cases of this nature to assist prompt decision making. Excluding head injury, the most frequent cause of death and disability after trauma is multiple system organ failure (MSOF) (3). The initial damage control procedure is only the beginning of surgical input and, in many cases, further definitive operations are required. Therefore it is essential that the military trauma surgeon has an appreciation of these biochemical processes in order to judge when, and how, to proceed.

Occult Hypoperfusion – the physiology

In general terms, traumatic blood loss leads to homeostatic compensation to maintain perfusion of central organs at the expense of more distal tissues. Initially, normal vital signs are maintained and this masks the true distal hypoperfusion.

At a cellular level the process is best summarised as cell injury occurring from ischaemia. Mitochondrial dysfunction leads to selective membrane permeability and vice versa. This vicious circle leads to cellular swelling which leads to anaerobic glycolysis and subsequent raised lactate levels and acidosis. Increased oxygen consumption compounds the issue(7). Machiedo et al. investigated the role of red blood cell (RBC) damage through this mechanism leading to decreased microcirculatory blood flow(8). Deformability is required by a RBC, which has a resting diameter of 7 micrometres while the diameter of a capillary is 4-4.5 micrometres.

Evidence had already existed to show that in shock there was impaired RBC deformability and RBC damage(9, 10) but Machiedo was able to demonstrate with a laboratory model that the traumatic blood loss was the cause of the RBC dysfunction and that this led to reduced microcirculatory blood flow (8). This reduction in microcirculatory blood flow has an effect on all body systems but is most marked in the splanchnic circulation(11). The small bowel is exposed to mucosal infarction and haemorrhage which can lead to malabsorption and bacterial translocation therefore bringing in a ‘second hit’ of sepsis.

Haemorrhage has been shown to activate leukocyte-endothelial adhesion which leads to sequestration and activation of neutrophils(12). These release active substances which, in the lungs, increase endothelial permeability leading to tissue oedema and increased distance for oxygen diffusion(13). This, together with a coagulative necrosis in cardiac tissue, leads to a further drop in oxygenation which compounds the shock state. Infarction and necrosis can also occur in the brain, renal system, pancreas and liver causing multiple organ dysfunction and a worsening of the acidosis(14). The net effects of all these changes result in increased length of hospital stay and an increase in mortality(3, 4). They also increase the infection rate(15) and induce the systemic anticoagulation pathway and hyperfibrinolysis that the initial state of shock triggers(5).

Current markers

The extent of tissue hypoperfusion has traditionally been defined and assessed by haemodynamic markers but it is known that this tissue hypoperfusion is not well defined by these parameters. Detecting occult hypoperfusion is difficult as a patient’s central haemodynamic status cannot
be determined by examination and even the definition of normal vital signs in the trauma patient is under debate(16).

Indirect markers such as potassium, which accumulates outside cells in anaerobic metabolism, and glucose, are sensitive in predicting major injury but not very specific. We have therefore used upstream function measurement tools such as pulmonary artery catheters with traditional observations and the downstream measurements of serum lactic acid (LA) and base excess. Serum lactic acid rises reflect the increase in anaerobic metabolism and several reports have demonstrated the link with injury severity(17, 18).

Blow et al. explored the link between LA levels, MOF and adult respiratory distress syndrome (ARDS). He found that an initial LA rise resulted in higher morbidity and mortality while a persistent hypoperfusion state resulted in a higher number of respiratory complications, MOF and death after severe trauma. This has also been demonstrated in the Intensive Care environment for all causes of occult hypoperfusion. Jansen et al. have shown that the duration and level of high LA estimated the risk of organ failure(19).

Durham et al found that, in an Intensive Care environment, raised LA at 24 hours was the best indicator of MOF together with APACHE score >50 and 6 unit transfusion at 24 hours(20).

Two studies found base excess to be a better predictor of outcome than blood pressure(2, 16). A study by Thom et al. looked at base excess, non-invasive cardiac index, shock index and rate over pressure evaluation(1). It found that base excess was the best of these four markers at detecting occult hypoperfusion and that it was present in 16% of major trauma patients. However this paper had significant limitations. The true incidence of occult hypoperfusion is unknown, and therefore the assessment of detection markers is limited. There was also very little agreement found between tests. A benefit with base excess is that it is not affected by the intake of alcohol and illicit drugs by a patient(21). While a base excess of less than -6 has been found to be the best predictor of outcome(22) a level of less than -2 has been linked with increased mortality(2, 16). It has also been found to correlate with ARDS and transfusion requirements.

Why is this important to the deployed surgeon?
The ability to measure microcirculatory changes is only worthwhile if we are able to influence outcome. From initial damage control resuscitation continuing through to goal directed therapy in the critical care environment it is difficult to see, with our current knowledge and available treatment tools, how we would change much of what we do. However, the one thing that measurement really could influence is not how we treat, but when.

The military trauma patient can require multiple surgical interventions which have a detrimental effect on body physiology even though their ultimate aim is to restore normal function. The ability to measure microcirculatory changes and therefore occult hypoperfusion can assist with the timing of surgery. This can work both ways. It can help prevent the patient being brought back to theatre too early but also enable the trauma surgeon and critical care team to have more confidence to proceed with revisit surgery ahead of time if the patient’s progress has been insufficient. Clinical judgment and not surgical dogma should guide the timing of these procedures.

New markers
Laser doppler of red blood cell velocities was first suggested ten years ago. Orthogonal polarization spectroscopy in side stream dark field (SDF) has been suggested as a possible microcirculation measurement tool by directly visualizing the blood flowing in thin mucosa such as under the tongue(23). However, as mentioned above, this area is not the first to be affected, or to suffer the worst consequences of the shock state. Another complicating factor is that a reduction in blood flow under the tongue could be the body’s physiological response to redistribute blood flow to more important vascular beds. Other similar monitoring systems such as the Licox® polarographic tissue oxygen monitor and the InSpectra™ near infrared spectrometer demonstrate that myocardial oxygenation and haemoglobin oxygenation are promising candidates for the early detection of occult under-resuscitation(24, 25).

Given that the coagulation state of the trauma patient has been shown to have many interactions with body physiology, changes in the measurement of coagulopathy may also be a surrogate marker of the true status of the microcirculation. Thromboelastography provides information on the whole kinetics of haemostasis and can give a window into all contributing components. These include the activity of the plasmatic coagulation system, platelet function, fibrinolysis and contributing factors such as hypothermia, acidosis and hypoperfusion. Thromboelastometry is being used with combat casualties in the deployed setting in Afghanistan(26). Rotational Thromboelastometry (ROTEM®) and Near Infrared Spectroscopy (NIRS) are currently active areas of research by the Academic Department of Military Surgery and Trauma both in the deployed setting and in normal volunteers rendered hypoxic.

Summary
The treatment of traumatic shock has changed unrecognizably over the past decade as the combination of targeted research and lessons learnt from conflict have combined with a common goal. The term damage control resuscitation has emerged as the most likely strategy to treat the underlying cause, restore normal physiology and ultimately return to normal function. However, there is still a great deal that we do not understand as to the underlying mechanisms which control the traumatic shock process.
Military surgeons have an integral part to play at every step of this process. Their role does not end once the initial damage control surgery is complete and indeed the decisions that are made during the initial resuscitation will have an effect on all future stages of care. The patient’s physiology is delicately balanced with the possibility that a wrong treatment decision may be a fatal one. It is essential that the surgeon has an understanding of these underlying processes so that an informed decision can be made at the right time.

References
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