Hunterian Society Prize

From Boats in Belle Île to the 21st Century Battlefield – a Narrative Description of Coagulation and Haemorrhage Control

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Through philosophical, theological and medicinal reverence, blood has captivated humans since antiquity[1]. Despite its instinctive intrigue, human understanding of the purpose and function of blood, and consequently the deleterious effect of blood loss, remained largely primitive until the 17th century. Indeed, when the King of England, Charles II, suffered a sudden seizure in 1685 his court of physicians immediately prescribed a rigorous regime of bloodletting which culminated in the King losing approximately a quarter of his total blood circulating volume. However, the 17th century marked a turning point in our understanding of blood within the human body. In 1615 the English physician William Harvey conducted a series of experiments that would, for the first time, correctly acknowledge the flow of a finite supply of blood through a closed circulatory system[3]. This renewed conceptual understanding of blood and its circulation informed practises aimed at abating blood loss, with the first use of the modern tourniquet in 1674[4].

John Hunter, born in East Kilbride in 1728, possessed a scientific mind tempered with a fiercely inquisitive nature[5]. The fortuitous timing of John Hunters admittance into the medical community, a time of rapidly evolving understanding of blood and circulation, allowed him to apply his hunger for innovation to developing the understanding forged by those who came before him. His early work focussed on the wider circulation; demonstrating the separation between the fetal and maternal circulation as well as the utilisation of collateral circulation in the management of popliteal artery aneurysms[6]. In 1761, John Hunter was deployed overseas as an Army surgeon during the Seven Years War. It might be fair to assume that such an enterprise would thwart any further study or discovery. However, history serves as a constant reminder that war and conflict, whether through necessity or unique circumstance, has consistently provided the catalyst for medical innovation and technological advancement[7]. John Hunter's war-time observations proved to be no exception.

Laying the Foundations of Understanding

"There is, I think, more to be learned of the use of blood in the animal economy, from its coagulation, than from its fluidity"[8]

John Hunter, 1792

In April 1761, John Hunter comprised part of the landing party in the amphibious assault on the strategically important French island Belle Île, led by General Studholme Hodgson (Figure 1). The topography of the island and its heavy fortification resulted in a fraught initial assault that was subsequently abandoned.

While a second attempt was launched and the island was successfully captured, British forces suffered heavy losses: 282 people are estimated to have been killed and 533 wounded[9]. Such heavy conflict exposed John Hunter to the brutal reality of tending to the sick and wounded in war time. His experiences and findings were chronicled in his posthumous publication 'A Treatise on the Blood, Inflammation and Gun-Shot Wounds'. In his final publication, John Hunter explores in detail the management of abscesses and gunshot wounds[8]. However, it is his observations of coagulation and haemorrhage control that would provide the foundations of an understanding that continues to be applied to the 21st century battlefield. When considering the horrors of war seen in abundance by an 18th century deployed Army surgeon, such as John Hunter, these findings were observed in an unlikely subject. While anchored off the coast of Belle Île, John Hunter observed that the blood of those fish who are immediately dissected after being caught flowed more freely than those fish who are left to warm up to atmospheric temperature prior to dissection. Therefore, it was concluded that the process of blood coagulation, and consequently bleeding cessation, is less effective at colder body temperatures.

Figure 1 – 'An exact representation of the attack by the British fleet, under the command of Adm. Keppel, the 8th of April 1761, at Port Andre, on the island of Belle Isle[10]'

Traumatic Haemorrhage Control in the 21st Century

The management of traumatic haemorrhage has evolved since John Hunter described the effects of temperature on coagulation in the 18th century. In 1829, the first successful blood transfusion was administered to treat post-partum haemorrhage, with the first successful blood transfusions for traumatic injury being used in the American Civil War in 1861[11]. In addition, in the 1960's tranexamic acid was first utilised to control haemorrhage through the inhibition of blood clot breakdown[12]. However, despite these advances, haemorrhage both on the battlefield and in civilian medicine continued to be the most common cause of preventable trauma related death throughout the 20th century. In the Vietnam War (November 1955 – April 1975) the most common cause of preventable death was haemorrhage[13]. Therefore, there remained a requirement to better understand trauma-related haemorrhage and its management both on the battlefield and in the civilian setting. It wasn't until the 1980s, 200 years after John Hunter published his

findings related to the effect of temperature on coagulation, that the significance of hypothermia in trauma was understood.

The Evolution of the 'Lethal Triad' – Returning to the Principles of the 18th Century

In 1987, the Journal of Trauma and Acute Care Surgery published a study that found 100% mortality in trauma patients with a temperature below 32°C, compared to a mortality of 7% in those patients with a temperature above 34°C[14]. The justification for such a stark difference in mortality based on the patient's temperature was attributed to the 'lethal triad[15]. The 'lethal triad' is a conceptual representation of the effects of trauma and haemorrhage on the pathophysiology of hypothermia, acidosis and coagulopathy (Figure 2). Following trauma, hypothermia (defined as a body temperature below 35°C) is caused by blood loss, administration of cooled intravenous fluids and environmental exposure. Just as John Hunter had observed in the fish of Belle Île, coagulation and clotting of blood that is hypothermic is demonstrably reduced. Acidosis (defined as a blood pH less than 7.35) is caused by lactic acid accumulation secondary to the poor perfusion of body tissues that follows haemorrhage and hypothermia. Acidosis has a similarly deleterious effect on blood clotting as seen in hypothermia. Finally, the effects of traumatic injury itself result in a consumption and loss of coagulation factors that further compound the deleterious effects on blood clotting caused by hypothermia and acidosis. As coagulation is precipitously impaired, continued bleeding occurs which further exacerbates the evolving hypothermia and acidosis. Therefore, the lethal triad resembles a self-perpetuating cascade of synergistic events and as such has been described as the "bloody vicious cycle"[16].

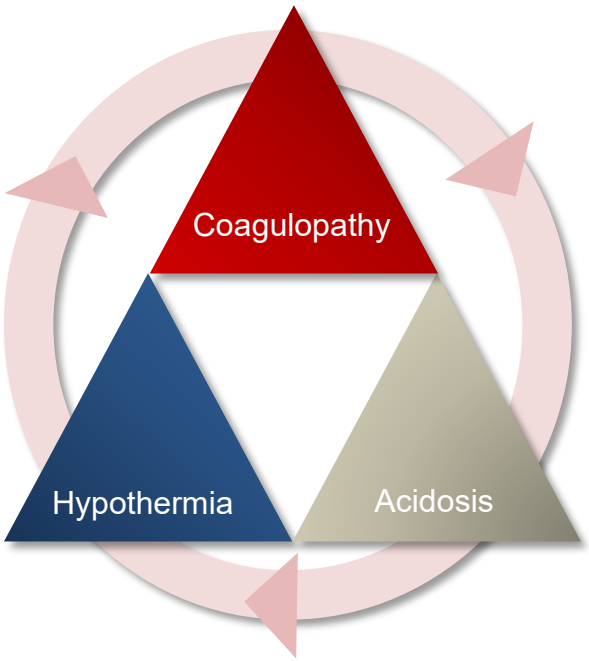

Figure 2 – The 'Lethal Triad'

Once the lethal triad is established, it is often refractory to intervention with a mortality rate approaching 100%[17]. Through a wider understanding of the lethal triad, the management of traumatic haemorrhage in the 21st century battlefield has evolved to adopt a raison d'être of 'prevention is better than cure'. Warming of the patient, as well as any intravenous fluids or blood products prior to administration, is essential. Advancements in transfusable blood products have increased their accessibility and safety so that they may be administered as soon as required and practically possible. Packed red blood cells, plasma and platelets should be given in a ratio of 1:1:1 in order to mitigate the formation of trauma coagulopathy[18]. Damage control surgery must occur in a timely manner in order to abate ongoing exsanguination. Technological advancements in the modern battlespace have permitted surgical teams to be deployed far forward in order to commence damage control surgery as close to the point of injury as possible[19].

Conclusion

John Hunter's modest observations of the effect of temperature on coagulation from the seas of Belle Île are perhaps overshadowed by his other, more notable, contributions to medical innovation. However, the origins of our understanding of the 'lethal triad' in civilian and battlefield trauma may be traced back to this very observation. It is therefore worth considering the sizeable contribution this may have made to the evolution of our understanding of blood and the cessation of bleeding in those who have sustained traumatic injuries.

However, over the last century the fatality rate of traumatic injury on the battlefield has remained stable[20]. In addition, despite a wider understanding of the lethal triad and ways to mitigate the poor prognosis it yields, haemorrhage continues to be the most common cause of preventable trauma related death[21,22]. This implies that such advances in technology and our understanding have been counteracted by similar increases in the lethality of war and combat operations. It is therefore essential that we utilise the Hunterian principles of scientific endeavour and intrigue in order to innovate and prepare for the future.

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