Inability to Easily Predict Individual Deaths in a Hemorrhage and Resuscitation Model

P Butler, M Byers, P Wall, J Devey, J Hopkins, L Henderson, C Buising. Surgery Education & Trauma Departments, Iowa Methodist Medical Center and Biology & Chemistry Departments, Drake University, Des Moines, IA 50309

Introduction

In the US, the leading cause of death in people under 44 is trauma. Many of these deaths occur from hemorrhage. Currently, patients can be placed within mortality risk groups based on severity of trauma but individual mortality cannot be accurately predicted.

Predicted 70% Clinical Mortality Model

By investigating trends in individuals within a high risk group, using those same variables that are used for patient population separation (high risk of death versus low risk of death), we hoped to definitively identify eventual non-survivors from survivors early, during hemorrhage (well before cardiovascular collapse occurs).

Methods

8 anesthetized (thiopental infusion, cephalic vein), ventilated (end-tidal PCO₂ 30-35 mmHg for arterial PCO₂ 35-40 mmHg at baseline), instrumented, purpose bred hound dogs subjected to pressure titrated severe hemorrhage, low-pressure stabilization, and resuscitation protocol.

Pressure driven protocol – standardizes hemorrhages between trials to achieve low blood flows associated with a high risk of immediate cardiovascular collapse and systemic metabolic debts associated with irreversible shock

Methods (continued)

Formulas:

$$\text{Stroke Volume} = \frac{\text{Cardiac Output}}{\text{Heart Rate}}$$
$$\text{Shock Index} = \frac{\text{Heart Rate}}{\text{Systolic Pressure}}$$
$$\text{Pulse Pressure} = \text{Systolic} - \text{Diastolic}$$

Systolic blood pressure - maximum blood pressure during cardiac cycle

Diastolic blood pressure - minimum blood pressure during cardiac cycle

Mean blood pressure - average blood pressure during cardiac cycle

Results

2 non-survivors, both graphed in red: NS1 (1 of 5 HBOC, died 117min into S) and NS2 (1 of 3 HSD, died 9min into S). Survivors are graphed in blue.

Both mean arterial pressures (MAP) and end-tidal PCO₂ values are intermingled. Survivors and non-survivors are indistinguishable from each other.

NS2 had the highest heart rate, and NS1 had the second lowest heart rate. At the end of hemorrhage, NS1 had a base excess of -18.8 mmol/L and NS2 = -19.2 mmol/L; however, two survivors had base excess values of -19.0 mmol/L. The other four survivors were between -13.9 mmol/L and -17.5 mmol/L.

NS1 had the highest stroke volume index, while NS2 had a stroke volume index that was in the middle of the six survivors. End hemorrhage SvO₂ percentages were indistinguishable from each other.

Results (continued)

NS1 consistently had the highest StO₂ percentage at around 80%, while NS2 was intermingled with the four lowest survivors. NS1 and NS2 shed 38 mL/kg and 40 mL/kg of blood respectively, which coincided with two survivors, but less than the other four survivors that ranged 45-56 mL/kg of blood shed by the end of hemorrhage.

NS1 had the third highest shock index at the end of hemorrhage, while NS2's shock index was intermingled with 4 survivors. NS1 and NS2 pulse pressures were both mixed in with the 4 survivors.

Discussion

We consistently observe an 20% mortality following our hemorrhage protocol regardless of resuscitation interventions. This confirms the suitability of the protocol for seeking early trend differences between eventual survivors and non-survivors.

Others have reported on many of the same variables we investigated, but in the clinical, shortly post-trauma setting. For example, Holcomb et al. found a blood pressure threshold value useful for indicating the need for a life saving intervention. But only 88% of trauma patients with below threshold values required a life saving intervention while 26% of non-indicated patients also needed a life saving intervention.

Looking at a large number of flow, pressure, and metabolic related variables in our known high mortality risk group, we determined that definitive trend differences during hemorrhage for indicating eventual individual non-survivors were not present.

References

1. Crookes BA, Cohn SM, Bloch S, et al.: Can near-infrared spectroscopy identify the severity of shock in trauma patients. J Trauma 58:806-816, 2005.
2. Holcomb, John B., Jose Salinas, John M. McManus, and Charles C. Miller. "Manual Vital Signs Reliably Predict Need for Life-Saving Interventions in Trauma Patients." The Journal of Trauma October 2005: 821-829.

Support

Surgery Education and Trauma at Iowa Methodist Medical Center, Veterans Administration Central Iowa Health Care System, Drake University, Fraternal Order of the Eagles, Iowa Space Grant Consortium