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Abdominal compartment syndrome in traumatic hemorrhagic shock: is there a fluid resuscitation inflection point associated with increased risk?

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Abstract

BACKGROUND: The volume of fluid administered during trauma resuscitation correlates with the risk of abdominal compartment syndrome (ACS). The exact volume at which this risk rises is uncertain. We established the inflection point for ACS risk during shock resuscitation.

METHODS: Using the Glue Grant database, patients aged ≥16 years with ACS were compared with those without ACS (no-ACS). Stepwise analysis of the sum or difference of the mean total fluid volume (TV)/kg, TV and/or body weight, (μ) and standard deviations (σ) vs % ACS at each point was used to determine the fluid inflection point.

RESULTS: A total of 1,976 patients were included, of which 122 (6.2%) had ACS. Compared with no-ACS, ACS patients had a higher emergency room lactate (5.8 ± 3.0 vs 4.5 ± 2.8, $P < .001$), international normalized ratio (1.8 ± 1.5 vs 1.4 ± .8, $P < .001$), and mortality (37.7% vs 14.6%, $P < .001$). ACS group received a higher TV/kg (498 ± 268 mL/kg vs 293 ± 171 mL/kg, $P < .001$) than no-ACS. The % ACS increased exponentially with the sum of μ and incremental σ, with the sharpest increase occurring at TV and/or body weight = μ + 3σ or 1,302 mL/kg.

CONCLUSIONS: There is a dramatic rise in ACS risk after 1,302 mL/kg of fluid is administered. This plot could serve as a guide in limiting the ACS risk during resuscitation.

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The World Society of the abdominal compartment syndrome (ACS), in its 2013 clinical practice guidelines, defined ACS as a sustained intra-abdominal pressure greater than 20 mm Hg that is associated with new organ dysfunction or failure.[1] Common-associated organ failure includes either one or a combination of the pulmonary, cardiovascular, cerebral, renal, splanchnic and/or abdominal, and renal systems. ACS is associated with significant morbidity and mortality

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despite appropriate treatment. Therefore, in the appropriate clinical setting, a high index of suspicion, judicious measurement of intra-abdominal pressure; and early evaluation for organ dysfunction are necessary for early identification and intervention, with the goal of reducing the associated morbidity and mortality.[2]

The risk factors for ACS are diverse. Saggi et al[3] classified these risk factors based on whether the ACS was acute and chronic. According to this classification scheme, risk factors for acute ACS include retroperitoneal (pancreatitis, pelvic or retroperitoneal bleeding, contained abdominal aortic aneurysm rupture, aortic surgery, abscess, and visceral edema), intraperitoneal (intraperitoneal bleeding, free abdominal aortic aneurysm rupture, acute gastric dilatation, bowel obstruction, ileus, mesenteric venous obstruction, pneumoperitoneum, abdominal packing, abscess, and visceral edema), and abdominal wall (burn eschar, repair of gastroschisis or omphalocele, reduction of large hernias, military antishock garments, and laparotomy closure under extreme tension) origins. Risk factors for chronic ACS include central obesity, ascites, large abdominal tumors, chronic ambulatory peritoneal dialysis, and pregnancy.

In the trauma setting, hemorrhagic shock requiring laparotomy for hemorrhage control is a major risk factor for ACS. Resuscitation with large amounts of crystalloids, activation of inflammatory mediators leading to capillary leakage, and reperfusion injury contribute to intestinal edema, which may increase the risk of intra-abdominal hypertension and subsequent ACS.[4] The volume of resuscitative fluid administered during trauma-associated shock, typically hemorrhagic shock is believed to correlate with the risk of ACS, with crystalloid resuscitation in particular being singled out as a major culprit.[5] Despite recognition of this association, the exact resuscitative fluid volume at which the risk of ACS rises sharply has been hardly defined. The goal of our study was to establish an inflection point for escalated risk of ACS during traumatic hemorrhagic shock resuscitation.

Methods

Study design and patient selection

This is a retrospective analysis of the Inflammation and the Host Response to Injury (Glue Grant) database, a large scale collaborative trauma relational database prospectively populated with clinical and laboratory data from blunt trauma patients in hemorrhagic shock. The original study was funded by the National Institutes of General Medical Sciences and involved multiple level I trauma centers in the United States.

The inclusion and exclusion criteria have been described previously,[6] but briefly include patient who met criteria for hemorrhagic shock after blunt trauma and had a good chance of survival. Specifically, patients must have a systolic blood pressure less than 90 mm Hg or a base deficit $\geq$ 6 within 60 minutes of arrival in the emergency room (ER), transfusion with blood or blood products within 12 hours of injury, absence of severe traumatic brain injury, and anticipated survival greater than 24 hours from injury. Those who were not expected to survive for more than 28 days as a result of pre-existing medical conditions were excluded. In our analysis, all patients aged $\geq$16 years whose injuries or hospital course were complicated by ACS were identified and compared with those who did not develop this complication (no-ACS).

Data variables and end point

Demographic (age, ethnicity, and gender), hemodynamic (ER systolic blood pressure and ER heart rate), injury-related (injury severity score [ISS]), and shock-related (ER lactate, Marshall's multiple organ dysfunction score [MODS]) variables were abstracted from the database. Additional variables abstracted include preinjury comorbidities, in-hospital complications, types and volumes of resuscitative fluids, and outcome variables (hospital length of stay, intensive care unit [ICU] length of stay, ICU ventilation days, and mortality). The primary end point was the fluid resuscitation inflection point, defined as the volume of fluid resuscitation at which there is a sharp increase in the proportion of patients developing ACS.

Statistical analyses and determination of fluid resuscitation inflection point

Continuous variables were described with summary statistics, whereas percentages were used to describe categorical variables. The statistical analyses were performed in 3 steps. In the 1st step, the ACS group (defined as those who developed ACS) was compared with those who did not have this complication (no-ACS) using univariate analyses. In this step, categorical variables were compared using either the chi-square test or the Fisher's exact test as appropriate, whereas continuous variables were compared with the Student *t*-test or the Mann–Whitney *U*-test.

In the 2nd step, the total volume of any type of fluid (colloids, crystalloids, and blood products) administered was first standardized by dividing this with the weight of the patient, yielding a new variable–total fluid volume (TV) and/or body weight (BW; mL/kg). The mean (μ) and standard deviation (σ) of this new variable were calculated. In a stepwise manner, the proportion of patients developing ACS when a volume of fluid/kg equal to each of μ, $\mu + 1\sigma$, $\mu + 2\sigma$, $\mu + 3\sigma$, $\mu + 3.1\sigma$, $\mu + 3.2\sigma$, $\mu - 1\sigma$, $\mu - 1.5\sigma$, $\mu - 1.75\sigma$, $\mu - \sigma 1.85$ was determined. Using this stepwise analysis, the fluid resuscitation inflection point was determined. To determine if this was a true inflection point, an ACS vs TV and/or BW curve was drawn and slopes of the different TV and/or BW values used in the previous step were compared in a stepwise manner using the chi-square test.