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Variation in crystalloid administration: an analysis of 6248 patients undergoing major elective surgery

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ABSTRACT

Background: Large variations exist regarding the type and volume of fluid to be administered to patients. This study aimed to quantitate variations in the administration of crystalloid fluids at the level of the patient, provider, and procedure at a large, tertiary care center.

Method: Patients who underwent major cardiac, thoracic, or abdominal procedures between 2011 and 2014 were identified. Variations in crystalloid administration were compared by procedure and provider using a coefficient of variation (CV). Multivariable hierarchical linear modeling was performed to identify factors predictive of fluid administration and quantitate variation at the level of the patient and provider.

Results: Among 6248 patients who met inclusion criteria, the average crystalloid volume was 25.8 mL kg^{-1} m^2 h^{-1}, corresponding to a CV of 55%. Patients who underwent pancreatectomy received the highest corrected crystalloid volume (32.7 mL kg^{-1} m^2 h^{-1}), whereas those who underwent coronary artery bypass grafting received the lowest corrected crystalloid volume (14.7 mL kg^{-1} m^2 h^{-1}). Variations in fluid practices were noted between providers (corrected CV; 14.7%-97.1%) and within the practices of the same provider (corrected CV range; 24.1%-87.9%). On multivariable analysis, age and changes in hemoglobin concentration were associated with a higher crystalloid volume (both $P < 0.05$). Although over 90% of the variation was attributed to patient-level factors, approximately 10% was due to factors at level of the provider (surgeon: 5.8% *versus* anesthesiologist: 3.4%).

Conclusions: Wide variations were noted in crystalloid administration between procedures, providers, and within providers. Evidence-based practices and goal-directed therapies should be incorporated to avoid unwanted variations.

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Introduction

Fluid resuscitation is an integral component of intraoperative care.[1-4] The maintenance of appropriate intravascular volume involves achieving the balance between inadequate fluid resuscitation and excess fluid administration both of which can have potentially detrimental effects for the patient.[5,6] Although recent evidence-based studies have questioned traditional fluid practices of administering large volumes of crystalloid to the surgical patient, evidence-based guidelines regarding the composition and volume of fluid to be administered are still lacking.[7-9] Not surprisingly, therefore, recent reports have demonstrated large variations in fluid administration practices between hospitals, providers, and perhaps more interestingly even within the practices of individual providers.[6,10] Although some variation is of utmost importance and extensively pervades health care processes, unwanted variability has been identified as a major driver for unnecessary health care utilization and a contributor to suboptimal health care outcomes.[11-14] With an increasing body of evidence demonstrating that surgical outcomes may be affected by intraoperative fluid administration, it is critical to identify the factors associated with unwanted variation in fluid practices and thereby develop relevant interventions at the levels of the patient and provider.[1,2]

Therefore, the objective of the present study was to characterize the variability in crystalloid administration among patients undergoing major surgery at a large, tertiary care hospital. Specifically, we sought to describe factors associated with greater crystalloid administration and to quantify the variability in crystalloid practices attributable to the patient, surgeon, and anesthesiologist.

Methods

Data sources and study population

Patients undergoing coronary artery bypass grafting (CABG), aortic valve replacement or mitral valve replacement (AVR/MVR), lung resection, esophagectomy, hepatectomy, gastrectomy, pancreatectomy, or colorectal resection between 2011 and 2014 at the Johns Hopkins Hospital were identified using International Classification of Diseases, Ninth Revision, Clinical Modification procedure codes. Patients were subsequently categorized into one of three homogenous procedure groups based on surgical subspecialty; cardiac surgery (CABG, AVR/MVR), thoracic surgery (lung resection, esophagectomy), and abdominal surgery (gastrectomy, hepatectomy, pancreatectomy, colorectal resection). Data pertaining to patient age, gender, American Society of Anesthesiologists (ASA) physical classification grade, and body mass index (BMI) were recorded for each patient.[15,16] Comorbidity was classified according to the Charlson comorbidity index categorizing patients into two groups: 0-3 and $\geq$4.[17] Intraoperative details such as operative time, estimated blood loss, and fluid and blood administration were extracted using an Anesthesia Information Management System (MetaVision, iMdSoft, Needham, MA), whereas patient laboratory and transfusion data were collected using a comprehensive blood management business intelligence portal (IMPACT Online, Haemonetics Corp, Braintree, MA). Information within both interfaces is prospectively maintained and updated monthly, and it undergoes institutional quality review to ensure data accuracy.[18,19] To account for potential confounding by height, weight, and operative time, crystalloid fluid volume was corrected for BMI and operative time and where appropriate reported in milliliters per kilogram per m^2 per hour (mL kg^{-1} m^2 h^{-1}).

Patient records with missing or incomplete information for fluid volumes, BMI, or operative time and procedures performed on an emergent basis were excluded from analysis. For each provider (surgeon and anesthesiologist), an annual case volume was calculated by dividing the total number of cases performed by the total number of years active. To avoid outlier bias, all cases performed by providers (anesthesiologists and surgeons) with a caseload <6 were excluded from further analyses.

Statistical analysis

Descriptive statistics for continuous variables were performed using the Student t-test or Wilcoxon rank-sum test, whereas categorical variables were compared using the chi-square or Fisher's exact test as necessary. As no end points for the appropriate amount of intraoperative fluid exists, corrected crystalloid volume was dichotomized as "high" or "low" using values corresponding to the 75th percentile of corrected crystalloid fluid administered among each surgical subgroup (cardiac, 20 mL kg^{-1} m^2 h^{-1}; thoracic, 31 mL kg^{-1} m^2 h^{-1}; and abdominal surgery, 40 mL kg^{-1} m^2 h^{-1}). Variation in crystalloid administration between procedures and providers was quantified using the coefficient of variation (CV), which is a measure of dispersion and calculated by dividing the standard deviation of a distribution by its mean.[20]

Multivariable linear regression analyses were performed to identify potential factors associated with variations in crystalloid administration practices. Following the natural hierarchical structure whereby patients (level 1) were clustered to providers (level 2), a crossed random-effects intercept was specified at the level of the provider (anesthesiologists and surgeons) to account for any potential interactions that may occur between providers with regard to crystalloid administration.[21] As data were positively skewed, crystalloid fluid volumes were log transformed and defined as the dependent variable within the multivariable linear regression model. The normality of residuals of log-transformed values and plausible interaction terms were tested. Results from the regression analysis are presented as exponentiated coefficients and can be interpreted as the percent change in the volume of crystalloid administered per unit change within the variable included in the model. Intraclass correlation coefficients were then used to calculate the relative proportions of variance attributed to each level of care (patient *versus* provider) within the hierarchical structure.[21,22] Statistical significance for all tests was defined by $P < 0.05$. All analyses were conducted using STATA statistical software, version 12.0 for Windows (StataCorp, College Station, TX).