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RESEARCH PAPER

Comparison of acid–base and electrolyte changes following administration of 6% hydroxyethyl starch 130/0.42 in a saline and a polyionic solution in anaesthetized dogs

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Abstract

Objective To evaluate the effects of a 6% hydroxyethyl starch (130/0.42) in either a buffered, electrolyte-balanced (HES-BAL) or saline (HES-SAL) carrier solution on electrolyte concentrations and acid–base parameters in healthy anaesthetized dogs.

Study design Prospective randomised clinical study.

Animals A group of 40 client-owned dogs undergoing general anaesthesia for elective surgical procedures or diagnostic imaging.

Methods During anaesthesia, dogs were intravenously administered 15 mL kg^{-1} of either HES-SAL ($n = 20$) or HES-BAL ($n = 20$) over 30–40 minutes. Jugular blood samples were analysed before (T_0) and 5 minutes (T_5), 1 hour (T_{60}) and 3 hours (T_{180}) after fluid administration. Sodium, potassium, chloride, ionised calcium, phosphate, albumin, pH, venous partial pressure of carbon dioxide, base excess (BE), bicarbonate and anion gap were determined and strong ion difference (SID) and total quantity of weak nonvolatile acids were calculated for each time point.

Results Chloride was significantly increased at T_5, T_{60} and T_{180} compared with T_0 after HES-SAL, and was significantly greater after HES-SAL than after HES-BAL at T_5 ($p = 0.042$). Ionised calcium was significantly decreased at T_5 compared with T_0 after HES-SAL, and was significantly lower after HES-SAL than after HES-BAL at T_5 ($p < 0.001$). Bicarbonate was significantly lower after HES-SAL than after HES-BAL at T_5 ($p = 0.004$) and T_{60} ($p = 0.032$). BE was significantly lower after HES-SAL than after HES-BAL at T_5 ($p < 0.001$) and T_{60} ($p = 0.007$). SID was significantly decreased after HES-SAL at T_5 and T_{60} compared with T_0, and was significantly lower after HES-SAL than after HES-BAL at T_5 ($p = 0.027$). Mean electrolyte and acid–base parameters remained within or marginally outside of reference intervals.

Conclusions and clinical relevance Changes in both groups were minor and short-lived with either fluid in healthy individuals, but might become clinically relevant with higher fluid doses or in critically ill dogs.

Keywords acid–base, anaesthesia, dogs, electrolyte, hydroxyethyl starch.

Introduction

Hydroxyethyl starch (HES) preparations are synthetic colloids that differ in their physicochemical properties by the type of starch (potato or waxy maize), mean molecular weight, degree of hydroxyethylation (molar substitution), C2:C6 ratio and carrier solution. According to Westphal et al. (2009), third-generation tetrastarch products (HES 130/0.4 and 130/0.42) with lower mean molecular weights and

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lower molar substitutions than previous HES generations were developed to improve the pharmacological properties and safety of HES products. In addition, saline-based carrier solutions were replaced by more plasma-adapted solutions that are electrolyte balanced and buffered to minimise potential electrolyte and acid–base disturbances. In particular, the plasma-adapted solutions were believed to minimise the risk of hyperchloraemic metabolic acidosis (Westphal et al., 2009). Nevertheless, owing to a questionable risk-to-benefit ratio, the use of HES remains controversial (Adamik et al., 2015).

In animal studies, hyperchloraemic acidosis is associated with decreased renal blood flow (Wilcox 1983; Hansen et al., 1998) and immune dysfunction (Kellum et al., 2004). In critically ill people, hyperchloraemic acidosis is associated with an increased risk of acute kidney injury (AKI; Yunos et al., 2012; Marttinen et al., 2016) and decreased survival (Raghunathan et al., 2014; Sen et al., 2017).

A recent study in dogs demonstrated a significant increase in plasma chloride concentration after intraoperative administration of 0.9% saline (West et al., 2013). However, because HES may affect the distribution of water and electrolytes between the intravascular and extravascular compartments, acid–base and electrolyte changes that may be observed after administration of electrolyte solutions alone may not be identical to those found after administration of electrolytes with HES. Trials in adults and children showed an association between saline-based colloids and acid–base and electrolyte disturbances, including hyperchloraemia and decreased base excess (BE), bicarbonate and strong ion difference (SID; Rehm et al., 2000; Witt et al., 2008; Sümpelmann et al., 2012). We were unable to find a published study comparing the effects of different HES carrier solutions on electrolytes and acid–base parameters in dogs.

The objective of this study was to evaluate using the Henderson–Hasselbalch and the Stewart approach alterations in acid–base parameters and electrolyte concentrations following administration of a saline-based HES solution (HES-SAL) and an electrolyte-balanced, buffered HES solution (HES-BAL) to healthy anaesthetized dogs (Hopper et al., 2014). The hypothesis was that HES-SAL would cause more significant alterations in acid–base and electrolyte parameters than HES-BAL.

Materials and methods

Animals

A total of 40 client-owned dogs were prospectively recruited from animals presented for elective procedures requiring general anaesthesia between May 2013 and December 2014. Procedures included arthroscopy, diagnostic imaging for various orthopaedic conditions or castration. The trial was approved by the University of Bern and the Animal Experiment Committees of the Swiss Federal Veterinary Office (No. 23453). Informed owner consent was obtained prior to enrolment of dogs in the study. Dogs were included if they were judged to be healthy [American Society of Anesthesiologists (ASA) classification I] based on the medical history, clinical examination and unremarkable results of a complete blood count and biochemistry panel. Exclusion criteria were body weight <10 kg, age <6 months or >12 years, ASA classification ≥ II and any acute or chronic disorder other than orthopaedic conditions.

Anaesthesia protocol

All dogs were anaesthetized using a standard protocol. Premedication was achieved with intramuscular acepromazine (0.01–0.02 mg kg^{-1}; Prequillan; AROVET AG, Switzerland) and methadone (0.2 mg kg^{-1}; Methadon Streuli; Streuli Pharma AG, Switzerland). Anaesthesia was induced with intravenous (IV) diazepam (0.2 mg kg^{-1}; Valium; Roche Pharma AG, Switzerland) and ketamine (1.5 mg kg^{-1}; Ketasol-100; Dr. E. Graeub AG, Switzerland) to effect. After endotracheal intubation, anaesthesia was maintained with isoflurane in an oxygen-air mixture (inspired oxygen concentration of 60%) via a circle system (Aespire View; Datex Ohmeda, Germany). The initial end-tidal isoflurane concentration (F_E'Iso) was set at 1.2% and the concentration was adjusted according to the response of the dog to the procedure. Mechanical ventilation was initiated at the discretion of the anaesthetist [apnoea > 30 seconds and/or end-tidal carbon dioxide partial pressure ($P_E'CO_2$) > 45 mmHg (6.0 kPa)]. Once initiated, the target $P_E'CO_2$ was 35–45 mmHg (4.7–6.0 kPa). Heart rate, electrocardiogram, oscillometric arterial blood pressure, pulse oximetry, $P_E'CO_2$, F_E'Iso and rectal temperature were monitored throughout anaesthesia (Compact AS/3; Datex Ohmeda). The monitor was calibrated according to

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