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Perioperative fluid balance in children: an observational study for elective surgery in a daycare setting

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Keypoints

The Holliday´s and Segar´s 4-2-1 ml/kg/h rule remains the most commonly used formula for calculating the volume of perioperative fluid maintenance in children. In our daily practice we tend to underestimate the IV fluid balance in comparison with the theoretical calculated IV fluid according to the current guidelines. No clear side effects could be demonstrated with our perioperative intravenous fluid policy.

Abstract

Introduction

The Holliday´s and Segar´s 4-2-1 ml/kg/h rule remains the commonly used formula for calculating the volume of perioperative fluid maintenance in children. In this observational study, our goal is to determine differences between the administered amount of fluid during elective surgery and the current guidelines.

Material and methods

Children (0-6 years) undergoing elective surgery for urologic or otolaryngologic procedures with need for an IV-line placement, were enrolled between February and April 2017. At start of the procedure, the fasting period and body weight was assessed to calculate the theoretical IV fluid. At discharge of the recovery, the amount of the given fluid was determined. PAED scores (pediatric anesthesia emergence delirium scores) were taken at emergence of anesthesia and at dismissal out of the hospital. Other outcomes like nausea and vomiting were recorded throughout the process.

Results

121 children were included during this period. They had an average fasting period of 13 hours. The total amount of fluids (375 ml; IQR: 256-500) given to children was less compared to the theoretical amount of fluids (795ml; IQR: 625-920) ($p<0.0001$). Moreover, Bland-Altman analysis revealed that the difference between the theoretical and the given IV fluid increases with increasing average values. No differences were observed for the total amount of IV fluids depending on body weight or PAED score. None of the patients demonstrated signs of nausea.

Conclusions

We conclude an underestimation of the IV fluid balance in comparison with the theoretical calculated IV fluid according to the current guidelines.

Keywords

pediatrics, infant, fluid therapy, water-electrolyte balance, general surgery, surgical procedures.

Introduction

Perioperative fluid therapy consists out of four items: replacing the fluid deficit due to the preoperative fasting period, providing a fluid maintenance therapy, correcting perioperative fluid loss and treating hypovolemia. The ultimate goal of perioperative fluid therapy is to maintain a normal physiological state of the patient. Since half a century maintenance fluid therapy has been based on the 4-2-1 ml/ kg/h rule of Holliday and Segar.

They set up a simple formula to calculate the amount of maintenance fluid, namely 4 ml/kg/h for the first 10 kg, plus 2 ml/kg/h for the next 10 kg and plus 1 ml/kg/h for each additional kg. This formula was based on the caloric needs of the average pediatric patient (1). However intravenous therapy is not without risks in children. Several cases were described of increased mortality and morbidity in preterm healthy children after administration of intravenous fluid. The main reason for this is iatrogenic hyponatremia with the occurrence of encephalopathy, cerebral edema and respiratory insufficiency (2–4). This was mostly due to the administration of hypotonic perfusion solutions and the administration of incorrect amounts of fluid (5–6). Perioperatively, the risk of developing hyponatremia is increased due to the stress-induced secretion of the antidiuretic hormone (7). In a revision of their previous guideline, Holliday and Segar state that the child should be euvolemic as soon as possible by administering 10 to 40 ml/kg of isotonic fluid during the perioperative period and thus preventing the secretion of antidiuretic hormone. In their revision they also recommended to postoperatively limit the amount of fluid to 2-1-0.5 ml/kg/h given the low output of urine during this period (8).

Recent guidelines such as the NICE guidelines, that appeared in 2015, recommend the classic 4-2-1 ml/kg/h formula (9) for providing maintenance fluid therapy followed by a good follow-up. The guidelines of Sümpelmann et al. recommend administering an initial bolus of 10 ml/kg/h in order to dock the deficiency through the fasting period (10). As you can see there are various guidelines for administering intravenous maintenance fluid therapy in the pediatric patient. In this study our goal is to find out how much intravenous fluid we are administering in the daily practice in children during elective surgery in a daycare setting. We will also determine differences between our fluid policy and the known 4-2-1 ml/kg/h rule of Holliday and Segar. Do we give more or less intravenous fluid to the pediatric patient? What is the effect of our fluid policy on the wellbeing of the child? We will try to answer these questions in this study.

Material and Methods

Study design. This prospective observational study was conducted in our hospital 'Ziekenhuis Oost-Limburg' (ZOL, Campus St-Jan, Schiepse Bos 6 3600 Genk). The study took place between February 15, 2017 and April 26, 2017. The goal of this study was firstly to determine how much fluid we currently administer to pediatric patients during elective surgery in a daycare setting, secondly to compare our fluid policy against the 4-2-1 ml/kg/h rule of Holliday and Segar and thirdly to determine the effect of our fluid therapy on the wellbeing of the child. We did limit this study to urological and otolaryngologic procedures in a daycare setting. These interventions have a limited invasiveness thus the hemodynamic parameters and blood loss of the child were of little relevance to evaluate the wellbeing of the child. As postoperative outcome parameters for evaluating the wellbeing of the child, we determined the occurrence of emergence delirium and postoperative nausea and vomiting (PONV). These outcome parameters were taken because they can slow down discharge out of the hospital. Ethical approval was obtained by the East Limburg Ethics Committee for conducting this study.

Selection and description of the participants. Children aged between 0 and 6 years who were undergoing elective surgery for the disciplines urology and otolaryngology were included. An additional requirement was that the placement of an intravenous line was necessary. We planned to include about a total of a hundred children in order to have a reliable image of our fluid therapy in our center. Children who underwent elective surgery in a daycare setting and had to be hospitalized due to anticipated or unanticipated circumstances were excluded. A signed informed consent was obtained from the parents of the child prior to inclusion.

Technical information. Before this study started, a standardized form was set up that was to be completed on the day of the procedure by the anesthesiologist, the nurse of the recovery and the nurse of the ward. The anesthesiologist was mainly asked for the anesthetic technique that was used and the child's preoperative fasting period. The nurses were mainly asked for postoperative outcome parameters such as emergence delirium and postoperative PONV. As infusion solution we used a balanced isotonic electrolyte solution (NaCl baxter 0.9% of 500 ml) for each child. This solution was chosen as maintenance fluid since the benefit of using an isotonic solution versus a hypotonic solution has been demonstrated in several studies with less occurrence of hyponatraemia (11–13). Because the duration of the interventions was limited and thus the risk for developing postoperative hypoglycaemia was relatively low, a glucose-free solution was chosen. The incidence of hypoglycaemia at induction of anesthesia is indeed low if the current guidelines for preoperative fasting of the child are respected (14). Prior to the study, the weight of a full infusion bag of NaCL 0.9% 500 ml was measured. This was 550 grams. The weight of this baxter was then determined twice at predetermined times: on arrival at the recovery and at discharge out of the hospital. In this way, the volume of the administered fluid could be accurately determined at any time during the entire course of the admission. As postoperative outcome parameters, the occurrence of PONV and the occurrence of emergence delirium were determined. Postoperative delirium is defined as a dissociated state of consciousness in which the child is weeping, uncompromising, non-cooperative, incoherent and inconsolable crying, groaning, kicking or striking (15). To diagnose emergence delirium the Pediatric Anesthesia Emergence Delirium (PAED) scale was used. This is a scale that consists out of 5 items that are scored at 5 points each time. A score of more than 10 indicates that emergence delirium is present (16). This scale was used because of the high sensitivity (91%) and high specificity (98%) when compared to the gold standard for diagnosing emergence delirium (17). This scale was taken at three fixed moments, upon arrival at the recovery, when leaving the recovery and upon discharge out of the hospital.

Statistics. All the data obtained during the pre-, per- and postoperative stay were accurately recorded. To check the differences in our fluid policy versus the 4-2-1 ml/kg/hr rule, the Mann-Whitney U test was used that compares the two groups. Results are represented as the median and the interquartile distance (IQR). A p-value <0.05 was seen as statistically significant. A Bland-Altman analysis was used to determine the similarity between the two methods. The difference between two values is plotted against the average of the two values. The analysis shows the systematic error in this way. The distance from the points to the line indicates how large the measurement errors are. By definition, 95% of the differences between the measurements are between the limits of agreement, calculated on the basis of the average difference and the standard deviation (SD) (18).

Results

In total 121 children were included, 78 children underwent an otolaryngologic procedure and 43 children underwent an urological procedure. No child was excluded due to unforeseen circumstances. What immediately struck us were the long fasting periods of the children with an average of 13 hours (11-14 hours). Another notable fact was that the children who underwent an urological procedure had a significantly longer operation time than the children who underwent an otolaryngologic procedure. However, this finding had no clear effect on the wellbeing of the child. In comparison with the theoretically calculated 4-2-1 ml/kg/h rule of Holliday and Segar (795ml; IQR: 625-920) we administered less intravenous fluid during the entire course of the admission (375 ml; IQR: 256- 500) (P <0.0001) (Figure 1).

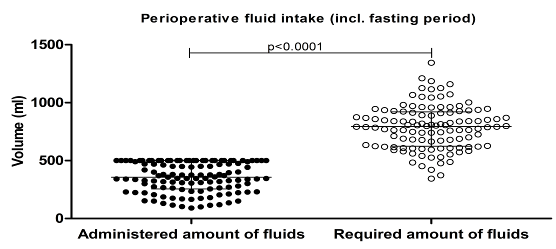

Figure 1. Total amount of IV fluid administered compared to the required amount of IV fluid during the whole admission.

Only 3 children received more intravenous fluid compared to the theoretical calculated amount of intravenous fluid according to the Holliday & Segar formula. Bland-Altman plots that were made verified the difference between the administered intravenous fluid and the theoretical calculated amount of fluid (Figure 2).

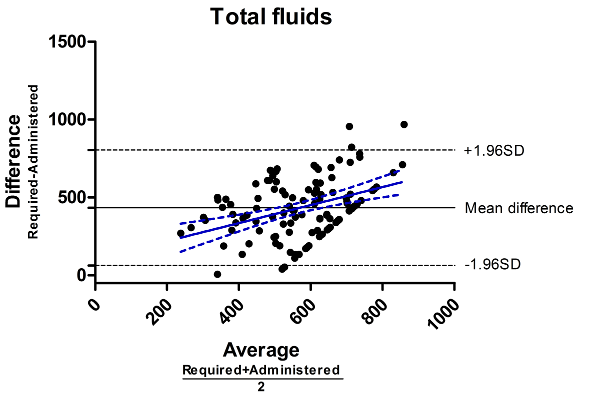

Figure 2. Bland-altman analysis. Administered IV fluid versus theoretically calculated IV fluid according the Holliday & Segar's 4-2-1 ml/kg/u formula.

Even if we only made this comparison for the children who weighed less than 15 kg, there was an underestimation of our intravenous fluid regimen. However, when we only took the perioperative period into account, with exclusion of the fasting periods, we administered more intravenous fluid (357 ml, IQR 256-500) in comparison with the theoretically calculated volume (171 ml, IQR 105-192) ($p < 0.0001$). Although our volume policy did not match the theoretically calculated intravenous fluid, there was no difference in outcome of the wellbeing of the child. We could not demonstrate a correlation between the administered intravenous fluid and the PAED scores (Figure 3). There was no difference in administered fluid in children who scored more than 10 on the PAED scale and children who scored less than 10 on the PAED scale. No correlation could be demonstrated between the PAED scores and the operation times. Also, no correlation could be demonstrated between the PAED scores and the duration of the preoperative fasting times. It is also notable that no child showed any signs of PONV during the entire course of the admission, this is remarkable since in 120 of the 121 cases N20 was used.

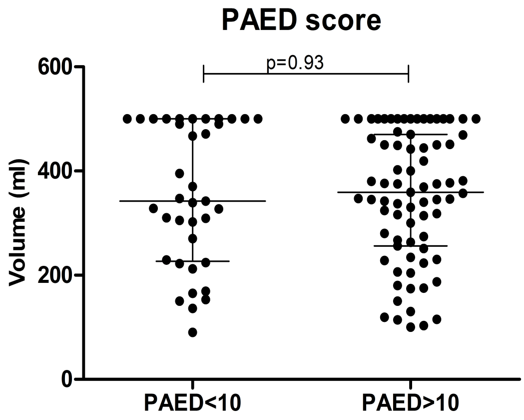

Figure 3. Administered IV fluid and PAED scores.

Discussion

We can conclude from the results of this study that we underestimate our intravenous fluid management in children between the ages of 0 and 6 years in comparison with the Holliday and Segar guidelines if we take the long fasting periods into account. This could be due to the fact that we are very careful when we are administering fluid to children in order to avoid the harmful effects of intravenous fluid such as the risk of hyponatremia. Striking are the long fasting periods of the included children with an average of 13 hours. This fact contributes to the reason why our fluid therapy in daily practice is underestimated compared to the guidelines of Holliday and Segar as the average fasting periods were very long. The theoretically calculated volume of fluid is probably an overestimation due to the long fasting times. There are several studies (19–21) which also show that the current recommended guidelines (6 hours for solid food, 4-6 hours for infant formula, 4 hours for breastfeeding and 2 hours for clear liquids (22)) are amply exceeded. Children with clear liquids up to 2 hours before the procedure are more comfortable and there is no difference demonstrable in stomach contents in children who were kept fasting up to 6 hours before the procedure (23). The fasting period of the child should therefore be kept as short as possible. This not only limits the risk of hypoglycemia at induction but could also reduce the risk of administering too much fluid by taking the long fasting periods into account. After all, when we only look at the perioperative period with exclusion from the fasting period of the child, we clearly provide more fluid compared to the theoretically calculated volume of Holliday and Segar. The question remains, ofcourse, to what extent do we have to include the deficit caused by the fasting period in our fluid therapy? In any case, we were unable to demonstrate any clear side effects caused by our fluid therapy in our current daily practice. Given the large variability of our intravenous administered fluid volumes, we will use a more physiological IV solution (such as plasmalyte) for future pediatric cases. An interesting study for the future could be a study in which the fasting period is kept as short as possible according to the current state of the art and whereby the guidelines of Sümpelmann et al. are compared with those of Holliday & Segar (including fasting periods) so that we can establish a clear picture of the optimal fluid therapy in children in the perioperative period.

Ethics approval

Ethical approval was obtained by the East Limburg Ethics Committee for conducting this study.

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The study received no external funding.

Conflict of interest

There was no conflict of interes

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