OPEN ACCESS Freely available online

Journal of Anesthesia & Clinical Research

ISSN: 2155-6148

Mini Review

Perioperative Fluid Management as a Component of Early Recovery after Surgery (ERAS) Protocols for Pediatric Patients

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ABSTRACT

Sentinel studies by Bartram and Kehlet challenged the acceptance of the inevitable consequences of the adverse physiologic effects of the stress response to surgery. This led to the evolution of Enhanced Recovery after Surgery (ERAS) protocols. ERAS is a multi-disciplinary approach aimed at improving care of the surgical patient? ERAS protocols/pathways were developed by the application of sound scientific knowledge to perioperative care. ERAS protocols have been shown to reduce postoperative complications, reduce hospital length of stay, and reduce costs. Although some ERAS protocols are highly specific to the type of surgery, issues common to most of the protocols are pain management, perioperative nutrition, control of nausea and emesis, antimicrobial therapy, thromboembolism prophylaxis, and precise perioperative fluid administration. Protocols often introduce multiple changes to clinical practice simultaneously and, if a positive effect is found, it is difficult to determine the contribution of each component.

Keywords: Absorbable hemostatic; Oxidized regenerated cellulose; Hemostatic effect; Hemostatic mechanism

INTRODUCTION

Intraoperative fluid administration is one component of the ERAS protocol over which anesthesiologists have primary responsibility. Research has demonstrated that excessive intraoperative fluid administration can cause postoperative cardiopulmonary dysfunction, interstitial edema, gastrointestinal dysfunction, and impair healing of surgical anastomoses [1]. Alternatively, inadequate fluid administration, in contrast, can lead to Acute Kidney Injury (AKI) [2,3]. Thus, precise application of Goal-Directed Therapy (GDT) concepts to intraoperative fluid administration protocols is required to maintain euvolemia [4].

Due to the risk of fluid overload and the inconstant efficacy of fluid expansion, the decision to give a fluid challenge cannot be taken lightly. The response is complex and is influenced by cardiovascular disease. Fluid challenges can lead to significant or negligible increases in stroke volume and cardiac output. It has been demonstrated that, in a population of critically ill patients, only half (50%) are fluid responsive [5,6]. Monnet provides a summary of methods predicting fluid responsiveness with diagnostic threshold and limitations [7].

For our study, we chose PLR for our fluid challenge test because it is easily performed, reproducible and has minimal complications. The hemodynamic effect of passive leg raise (PLR) is similar to the intravenous infusions of fluids [8]. When the legs are raised, blood is auto transfused into the central circulation from the venous system of the legs. The effects of this auto transfusion occur in as little as thirty seconds and return to baseline values within 7-10 minutes following lowering of the legs [9,10]. Monnet demonstrated a sensitivity of 97% and specificity of 94% [11]. Indeed, the use of PLR is suited to a much wider range of patients without causing complications. Consequently, we chose passive leg raises to determine fluid responsiveness in our pediatric patients [12-14]. Although fluid responsiveness is somewhat arbitrary, it is generally accepted that a 10% increase in SVI with passive leg lift is indicative of fluid responsiveness [15].

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Received: August 16, 2021; **Accepted**: August 31, 2021; **Published**: September 07, 2021

Citation: Stasic AF, Dierdorf SF (2021) Perioperative Fluid Management as a Component of Early Recovery after Surgery (ERAS) Protocols for Pediatric Patients. J Anesth Clin Res. 12: 1020.

LITERATURE REVIEW

Despite wide application of ERAS concepts to adult surgical patients, there is a paucity of information concerning ERAS for pediatric surgical patients [16]. We decided to embark on a series of studies in pediatric patients to determine the effect of perioperative fluid administration on ERAS [17]. The measurement of fluid responsiveness requires the continuous monitoring of cardiac output. Non-invasive monitors of cardiac output have been studied and proven to be clinically accurate. These include esophageal Doppler, echocardiography, pulse contour analysis, thoracic bioimpedance, and bioreactance (e.g., Cheetah NICOM™). Discussion of the applicability of these methods can be found in articles by Jakovljevic[21] and Marik [18]. Studies in adult patients have shown the bioreactance method of cardiac output measurement to correlate well with thermodilution cardiac output and stroke volume measured by MRI. Subsequently, we chose the Cheetah NICOM™ (non-invasive cardiac output monitor) (Newton Center, MA, USA) based on the system's correlation with other monitors of cardiac output and its simplicity of use.

Since the 1970s, cardiac output measurement with thermodilution *via* a pulmonary artery catheter has been the "gold standard" for comparison with other methods [19]. However, invasive methods add unacceptable risk and complications to routine measurement of cardiac output. Thermodilution is not applicable because it is a point measurement and not continuous. Although the Cheetah NICOM™ is an FDA approved device in adults, there is no current indication for use in children. There are, however, a number of reports of the use of non-invasive cardiac output monitors employing a bio reactance method as a monitor of cardiac output in children undergoing different types of surgery [20]. A significant advantage of the Cheetah NICOM™ for children and adults is that the system is totally noninvasive. However, it was first necessary to establish a reliable method of determining fluid responsiveness in normal children with a non-invasive cardiac output monitor. We found that measuring changes in SVI before and after passive leg lift to be feasible in normal children between the ages of 11 and 17 years using the Cheetah NICOM™ system. Although there are several studies of fluid responsiveness in adults, there are very few studies in children [21].

As noted previously, the definition of fluid responsiveness is somewhat arbitrary, however, it is generally accepted that a 10% increase in SVI with passive leg lift is indicative of fluid responsiveness [22-26]. Twenty-one of the 24 patients demonstrated a 10% or greater increases in SVI with passive leg left when awake. Two subjects had SVI increases between 1.5% and 4.3% and one subject had a 4.8% decrease. Nineteen of the 24 subjects showed a 10% or greater increase in SVI with passive leg lift after induction of anesthesia. Three subjects had SVI increases between 2.4% and 7.4%. Two subjects had SVI decreases between 13.9% and 16.7% with passive leg lift after induction of anesthesia. SVI increased from 54.8 ml/m2 to 68.0 ml/m2 ($p<0.001$) (25% increase) with passive leg lift when awake. After induction of anesthesia, passive leg lift increased SVI from 42.6 ml/m2 to 53.5 ml/m2 ($p<0.003$) (25.6% increase) [27].

This review demonstrates that 96% of normal 11 to 17-year-old children undergoing elective surgery were fluid responsive when awake and 79% were fluid responsive after the induction of general anesthesia [28].

Intravenous fluid administration during the perioperative period is not precise and is usually guided by a number of clinical assumptions, i.e., heart rate, blood pressure, central venous pressure, etc. Liberal fluid administration has been the method of choice for decades for hypovolemia in low-risk patients [29]. However, for high-risk patients, liberal fluid therapy may cause over-hydration and lead to a higher incidence of post-operative complications (see above). Thus, clinicians must have a reliable method for determining fluid responsiveness to guide fluid therapy. One of the goals of our study was to test PLR as a simple method of determining increases in stroke volume and cardiac output [30]. We have found that the Cheetah NICOM cardiac output monitor (stroke volume/cardiac output) was easy to use, well tolerated by children and produced consistent cardiac output results. We concluded that SVI as measured with the Cheetah NICOM™ device increases after passive leg rising in fluid responsive subjects while awake and immediately after induction of general anesthesia. Almost all of the patients were fluid responsive [31].

DISCUSSION

Furthermore, implementation of a Pediatric ERAS Protocol is different and abbreviated from adult protocols [15]. Rove10 et al have proposed several elements of the Pediatric ERAS Protocol. These elements include 1) minimization of fasting and 2) administration of a pre-operative clear-liquid carbohydrate load, 3) avoidance of preoperative, hyperosmotic bowel preparation, 4) multimodal, opioid-sparing analgesic techniques, 5) early postoperative feeding, and lastly, 6) maintenance of the euvolemic state, both operatively and post-operatively. They demonstrated that length of stay was reduced, and complication rates were lower. However, they noted that further improvement necessitates comprehensive reporting on complications, clinically relevant outcome measures, protocol compliance, and reasonable and complete follow-up. One of the limitations of this study was the lack of control of variables during anesthesia with regards to type of induction (intravenous versus inhalation) and airway management (spontaneous versus controlled ventilation). Other studies have, however, demonstrated that fluid responsiveness can be predicted in spontaneously breathing patients as well as those with controlled ventilation [32].

Perioperative fluid management has generated controversy for decades with respect to type and quantity of intravenous fluids. It has, however, become clear that too restrictive or too liberal fluid regimens both contribute to adverse outcomes. In the past, most fluid management was determined by assumptions based on type of surgery and preoperative status of the patient. Goal-Directed Therapy (GDT) mandates a more patient- specific approach. GDT, however, requires a method for monitoring hemodynamic parameters to guide fluid administration as noted above. Invasive hemodynamic monitors are readily available for high-risk patients but are not appropriate for healthy patients undergoing routine surgeries. Although GDT studies have been performed in adult patients, there is a paucity of comparable studies in pediatric patients. Pediatric patients are more susceptible to hyponatremia, hypoglycemia, and hyperglycemia from perioperative fluid administration. Any fluid recommendations for pediatric patients must consider electrolyte and acid-base aberrations. Outcome metrics with respect to pain management and nausea and vomiting are easy to measure. Outcomes from different fluid management protocols are not as easy to measure. Multiple sequential, incremental studies are consequently required in order to formulate rational perioperative fluid management protocols in pediatric patients. Fortunately, electronic medical records collect a large amount of data. Hopefully, these data will aid the development of evidence-based protocols. Further analysis can also be used to identify unnecessary medical costs.

CONCLUSION

Developing a Pediatric ERAS protocol has to account for differences between pediatric and adult surgery. For example, the majority of the patients are outpatients (up to 80%); there is a low postoperative mortality rate; there is a wide age variety in patients from newborns to young adults; and finally, there is an expanded role of parents and child psychology in the success of the program. Many of the elements of adult ERAS protocols simply do not apply to pediatric patients. Although controversial, the routine use of non-invasive cardiac output monitors has considerable merit for GDT in pediatric patients, both in the operating room and the pediatric intensive care unit. In conclusion, our study evaluated the use of a noninvasive cardiac monitor in patients undergoing elective surgery. We selected the passive leg lift as the method of determining fluid responsiveness. The Cheetah NICOM™ monitor was easy to use, well tolerated by children and produced consistent cardiac output results. The next logical studies should evaluate the effect of liberal NPO guidelines on preoperative fluid responsiveness.

CONFLICT OF INTEREST

There was no conflict of interests in this study.

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