EFFECTS OF LIBERAL VS. CONVENTIONAL VOLUME REGIMEN ON PULMONARY FUNCTION IN POSTERIOR SCOLIOSIS SURGERY

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Abstract

Background: We observed an increased rate of pulmonary complications (hypoxemia, pulmonary edema, re-intubation) in some patients after posterior spinal fusion, though standardized intraoperative volume regimens for major surgery were used. Therefore, we focused on the effects of two different standardized fluid regimens (liberal vs. conventional) as well as on two different types of postoperative pain management (thoracic epidural catheter vs. intravenous analgesia) concerning pulmonary function in patients undergoing posterior spinal fusion.

Methods: 23 patients received a conventional intraoperative fluid management (crystalloids ≈ 5.5ml/kg/h), whereas 22 patients obtained a liberal regimen (crystalloids ≈ 11ml/kg/h) during surgery. After surgery a thoracic epidural catheter was used in 29 patients, whereas 16 patients got a conventional intravenous analgesia. Regarding pulmonary outcome, the re-intubation rate, the postoperative oxygen saturations as well as delivery volumes and retention times of pleural drainages were evaluated.

Results: Patients with conventional intraoperative fluid management had a less frequent re-intubation rate ($p= 0.015$), better postoperative oxygen saturations ($p= 0.043$) and lower delivery volumes of pleural drainages ($p= 0.027$) compared to those patients with liberal volume regimen. Patients with thoracic epidural catheter had improved oxygen saturations on pulse oximetry at the first day after surgery ($p<0.001$) and lower delivery volumes of pleural drainages than patients with intravenous analgesia ($p= 0.008$).

Conclusions: The combination of a more restrictive fluid management (better pulmonary oxygen uptake and ventilation, less pulmonary edema) and a thoracic epidural catheter (sympatholysis, pain management) in posterior spinal fusion may be advantageous as both factors can improve pulmonary outcome.

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Introduction

The adolescent idiopathic scoliosis is defined as a lateral curvature of the spine with simultaneous vertebral rotation that occurs in children aged 10 years to maturity. Children undergoing posterior spinal fusions are usually due to their young age in good health condition, though the long duration of surgery, the occasionally high blood loss and the considerable damage of soft tissue are often accompanied by a high peri- and postoperative morbidity. In particular, pulmonary complications are frequent problems. First, the patient's prone position causes reduced lung compliance and rising airway pressures[1]. Secondly, a heaped incidence of atelectasis can occur, leading to a ventilation-perfusion-mismatch with right-left-shunt and arterial hypoxia[2]. Thirdly, pulmonary edema often occur as a result of arterial hypoxia and intraoperative fluid replacements[3,4]. Therefore, a lung protective intraoperative volume regimen is of particular importance. Interestingly, at our institution we observed an increased rate of re-intubations in some patients after posterior spinal fusion, though standardized volume regimens for major surgery were used on a regular basis (restrictive-conventional ≈5ml.kg^{-1}/h or liberal ≈10ml.kg^{-1}/h). Hence, this study focused on the effects of two different intraoperative volume regimens concerning pulmonary outcome (oxygen saturation, re-intubation rate, delivery volume and retention time of pleural drainages) in patients undergoing posterior spinal fusion.

Methods

Ethical approval for this study was provided by the Ethical Committee (Registration: 2009-350-f-S, University of Muenster).

We analyzed retrospectively 45 patients after posterior spinal fusion in adolescent idiopathic scoliosis. Data collected included patients' age, gender, body size and body weight, ASA physical status classification, Cobb-angle, number of operated segments, duration of surgery, duration of ventilation, intraoperative volume regimen, postoperative pain management (with or without thoracic epidural catheter), oxygen saturation on pulse oximetry at the

first day after surgery (highest value throughout the day), re-intubation rate, delivery volume and retention time of pleural drainages as well as the length of ICU stay. Older patients (> 25 years), patients with severe scoliosis (Cobb angle > 100°) as well as patients with any kind of pre-existing pulmonary disease, renal disease or heart failure were excluded.

The posterior spinal fusions were performed by surgeons from the Department of Orthopedics and Tumor Orthopedics, Muenster University Hospital, during the period 2003-2009. Data were collected from the hospital information systems Medico//s (Siemens), Centricity Critical Care (GE Medical Systems) and Orbis (Agfa HealthCare), as well as from anesthesia protocols and documentation in ICU.

Intraoperative management

For induction of general anesthesia Sufentanil (Sufenta mite®, JANSSEN-CILAG GmbH, Neuss, Germany; 0.5-2µg.kg^{-1}) and Propofol (Propofol Fresenius 1%®, Fresenius Kabi Austria, Graz, Austria; 1.5-2.5mg.kg^{-1}) were used. Muscle relaxation was performed with Cis-Atracurium (Nimbex®, GlaxoSmithKline Pharma, Vienna, Austria; 0.2mg/kg). During surgery, all 45 patients received a balanced anesthesia with Sufentanil (0.15-0.7µg.kg^{-1}/h) and the volatile anesthetic Sevoflurane (Sevorane®, Abbott, Vienna, Austria; MAC 2.2%-2.8%).

Ventilation was volume-controlled with a tidal volume of 7-8ml per kilogram body weight. The inspiratory oxygen concentration was adjusted to maintain the arterial oxygen partial pressure above 150 mmHg and the oxygen saturation per pulse oximetry reached values above 95%. Each patient was ventilated with a positive end-expiratory pressure of 5 cm H2O.

During surgery all patients received crystalloids however with either restrictive-conventional approach (5ml.kg^{-1}/h) or liberal approach (10ml.kg^{-1}/h). The anesthesiologist's decision for a more conventional or more liberal intraoperative volume regimen depended primarily on the clinical performance of the patient and on the anesthesiologist's preference. The total volume of given crystalloids was heterogeneous, mainly influenced by the patient's body weight, duration of surgery and intraoperative blood loss. Colloids, cell

saver blood, packed red blood cells (RBC) and fresh frozen plasma (FFP) were given if necessary (distinct hypovolemia, high blood loss and hemoglobin concentration < 7mg/dl, coagulopathy). To ensure that differences in pulmonary outcome didn't appear as a result of a higher blood loss, the hemoglobin concentration was measured at least at the beginning and at the end of surgery.

Pleural drainages were fit by surgeons in every patient at the end of surgery. They were removed when the residual flows were less than 150ml per day.

Postoperative management

After completion of surgery patients were brought mechanically ventilated to the recovery room. The Train of Four testing was performed in every patient to measure the degree of neuromuscular blockade before weaning started. Shortly before extubation an arterial blood gas analysis was done to ensure an adequate gas exchange. Extubation criteria included an adequate respiratory rate ($\geq$ 10/min) with a sufficient tidal volume (> 5ml.kg^{-1}), an adequate gas exchange ([PaO$_2$/FIO$_2$] ratio > 150-200) with a normal arterial partial pressure of carbon dioxide during spontaneous ventilation, an appropriate level of consciousness and sufficient airway protective reflexes (cough, swallow). Every patient received oxygen (2l / min) via a nasal cannula directly after extubation for two hours. Whenever oxygen saturation on pulse oximetry was < 95%, patients received oxygen again. Criteria for re-intubation included an inadequate respiratory rate (> 35/min), an impaired gas exchange ([PaO$_2$/FIO$_2$] ratio < 150) with an arterial oxygen partial pressure < 55mmHg and a PaCO2 > 60mmHg or rising levels of PaCO2 > 10mmHg / h, as well as clinical signs of dyspnea and increased work for breathing.

A thoracic epidural catheter (TEC) for postoperative pain management and sympatholysis was offered to every patient and fixed by the surgeons before the wound was closed, so that its correct position could be ensured. Patients obtained a mixture of 5ml Bupivacaine and Sufentanil (Bucain®, Actavis Group, Hafnarfjördur, Island; 0.175% and Sufenta mite®, 1µg.ml^{-1}) per hour as soon as they left the recovery room. Those patients who had to be reintubated or rejected the TEC received a conventional intravenous analgesia with Sufentanil (Sufenta mite®, 0.1-0.5µg. kg^{-1}/h) or Piritramid (Dipidolor®, Janssen - Cilag Pharma, Vienna, Austria; 0.04-0.15mg.kg^{-1}/h) and Paracetamol (Perfalgan®, Bristol-Myers Squibb, Vienna, Austria; 15mg.kg^{-1}, 4x/day) for postoperative pain management. Pain nurses ensured that no patient had a pain score of $\geq$4 (out of 10) using a numerical rating scale during their stay in hospital.

Statistical analysis

All statistical evaluations were performed using the program IBM SPSS version 20. Categorical patient characteristics were presented in frequencies or percentages and continuous variables as mean ± standard deviation. Categorical traits were checked for independence from each other by using the chi - square test according to Pearson or Fisher's exact test (cell size less than 5). Continuous variables were prior to statistical analysis tested for normal distribution by using the Kolmogorov - Smirnov - Test. Group differences were either performed with the parametric t test for independent samples or with the non-parametric Mann-Whitney-Wilcoxon-test. The significance level was set as a two-sided test with an error probability less than 5% (p - value <0.05).

Results

1. Patient characteristics

Among the analyzed 45 patients were 12 men and 33 women. They were 16.5 ± 2.9 years old, had a body size of 168 ± 23 cm and a body weight of 58.5 ± 9.69kg. All patients were of ASA-class I or II. The preoperative average measured Cobb angle was 66 ± 13°. The posterior fusion covered ordinary 8.7 ± 2.5 vertebrae with duration of surgery of 317 ± 119 minutes (Table 1).

2. Pulmonary function outcome

Patients who received a conventional intraoperative volume regimen had a less frequent re-intubation rate than those patients with a liberal

Table 1
Patient characteristics

	Conventional fluid regimen n = 23 (5.5 ± 1.3ml.kg^{-1}/h)	Liberal fluid regimen n = 22 (11 ± 2.6ml.kg^{-1}/h)	p-value
Patient characteristics			
Age (years)	16.9 ± 3.53	16.1 ± 2.84	p= 0.438
Gender ♂:♀ (n)	6:17 (n = 23)	6:16 (n = 22)	
Body size (m)	1.66 ± 0.39	1.70 ± 0.07	p= 0.632
Body weight (kg)	57.5 ± 9.77	59.4 ± 9.61	p= 0.514
ASA (Score)	1.45 ± 0.51	1.41 ± 0.51	p= 0.796
Surgery			
Cobb-angle (°)	66.8 ± 15.7	65.5 ± 10.2	p= 0.083
Operated segments	9.1 ± 3.28	8.4 ± 1.64	p= 0.37
Duration of surgery (min)	306 ± 111	327 ± 127	p= 0.559

volume management (conventional: 0% vs. liberal: 22.7%; p= 0.015).

The postoperative oxygen saturation at the first day after surgery was higher in the patients with a conventional regimen compared to patients in the liberal regimen (Table 2).

The need for oxygen therapy two hours after extubation was higher in the liberal group, although the difference was not statistically significant (Table 2).

The volumes of pleural drainages were lower in patients with a more conventional regimen than in those patients with a liberal volume management (Table 2).

The patients' stay in the ICU was not statistically significant between the two groups (Table 2).

Patients with a TEC had improved oxygen saturations at the first day after surgery compared to those patients with a conventional analgesia, statistically smaller volumes of pleural drainages, but similar duration of ICU stay (Table 3).

Table 2
Intraoperative volume regimen and outcome

	Conventional fluid regimen n = 23 (5.5 ± 1.3ml.kg^{-1}/h)	Liberal fluid regimen n = 22 (11 ± 2.6ml.kg^{-1}/h)	p-value
Outcome			
Re-intubated patients (n)	0	5	p= 0.015
Need for oxygen therapy 2h after extubation (%)	39.1	50	p= 0.463
Oxygen sat. 1st day after surgery (%)	98.96 ± 1.19	97.59 ± 2.9	p= 0.043
Volume pleural drainage (ml)	661 ± 295	946 ± 514	p= 0.027
Length of ICU stay (days)	4.78 ± 1.45	5.45 ± 1.26	p= 0.104

Table 3
Postoperative pain management and outcome

	TEC n = 29	Intravenous analgesia n = 16	p-value
Outcome			
Crystalloids during surgery (ml.kg^{-1}/h)	6.8 ± 2.5	10.6 ± 3.5	p< 0.001
Re-intubated patients (n)	0	5	p< 0.001
Oxygen sat. 1st day after surgery (%)	99.1 ± 0.94	96.9 ± 3.0	p< 0.001
Volume pleural drainage (ml)	674 ± 248	1028 ± 597	p= 0.008
Length of ICU stay (days)	4.55 ± 0.94	4.75 ± 1.39	p= 0.573

3. Intraoperative volume regime

The amounts of given colloids (conventional: 3.6 ± 9.5ml.kg^{-1}/h vs. liberal: 4.6 ± 11.5ml.kg^{-1}/h; p= 0.75), RBC units (conventional: 1.1 ± 0.5ml.kg^{-1}/h vs. liberal: 0.8 ± 0.6ml.kg^{-1}/h; p= 0.08) and FFP (conventional: 0.7 ± 0.7ml.kg^{-1}/h vs. liberal: 0.5 ± 0.7ml.kg^{-1}/h; p= 0.34) were similar in both groups. Accordingly, observed blood losses were nearly identical (conventional: 1258 ± 310ml vs. liberal: 1236 ± 295ml; p= 0,215). None of the patients had a hemoglobin concentration of less than 7.5g/dl or a hemoglobin difference of >4g/dl (pre- vs. postoperatively) after completion of surgery.

4. Postoperative management

Time till extubation (period between completion of surgery and extubation) was slightly longer in the conventional group, though the difference did not reach statistical significance (conventional: 154 ± 54 min vs. liberal: 114 ± 68 min; p= 0.06). Five patients who had obtained a liberal intraoperative fluid management developed some kind of respiratory failure (mainly pulmonary edema) and had to be reintubated. Those patients received diuretics and were transferred to the ICU.

Discussion

Our data show that pulmonary outcome in young patients undergoing spinal fusion can be improved by using a conventional (5.5 ml/kg/h) versus a liberal (11

ml/kg/h) crystalloids infusion regimen.

The intraoperative volume management has because of its diverse effects on the patients' overall morbidity a particular priority. Unfortunately, an ideal volume management is difficult to achieve.

On the one hand, a high volume fluid management (> 4-6 liters of crystalloids during surgery apart from replacement of blood losses) in major surgery is generally less advantageous as it may lead to overhydration, including reduced pulmonary functions and decreased cardiac output[5]. Reduced pulmonary functions after isotonic saline infusions occur even in healthy volunteers, as infusions of 1 liter crystalloids decrease functional residual capacity, reduce diffusing capacity and can lead to an increase in pulmonary blood-flow[6]. This higher blood flow through pulmonary capillaries increases pulmonary vascular pressure and is associated with increasing fluid transudation, resulting finally in impaired gas exchange[7]. Furthermore, rapid crystalloid infusions can cause mild airflow obstruction, thus resulting probably from airway wall edema on the bronchial lumen[8]. Therefore, it is not surprising that patients undergoing major posterior scoliosis surgery are at high risk for developing pulmonary complications such as pulmonary edema or hypoxemia. Additionally, impaired cardiac output can occur, as high fluid regimens may generate a shift to the right on the Starling myocardial performance curve, resulting in a depression of ventricular function, leading secondary to fluid accumulation in the lungs[5].

On the other hand, restrictive fluid regimens are

often equally complicated. Again, the Frank-Starling mechanism is of importance, as hypovolemia results in a shift to the left on the Starling performance curve, caused by decreased ventricular filling (preload), which impairs the cardiac output. This reduced cardiac output is accompanied by increased plasma norepinephrine (stress response) and declined mean arterial pressure (clinical signs of hypovolemia)[9]. Additionally, dehydration from preoperative fasting and intraoperative blood losses have to be corrected.

Summarized, there are still no data concerning a pulmonary protective intraoperative volume regimen in adolescent idiopathic scoliosis surgery.

In this study patients in the conventional group received significantly less crystalloids than those in the liberal group. We assume that the better pulmonary outcome of patients in the conventional group (less frequent re-intubation rate, better postoperative oxygen saturation at the first day after surgery, lower delivery volumes of pleural drainages) can be primarily explained by avoidance of fluid overload and less pulmonary edema. We furthermore suppose that the tendency of prolonged mechanical ventilation after surgery in the conventional group (conventional: 154 ± 54 min. vs. liberal: 114 ± 68 min.) might have additional lung protective effects by faster elimination of intraoperatively formed atelectasis (ventilation with PEEP).

Several studies reported improvement in pulmonary function in patients receiving TEC after surgery compared to patients with intravenous analgesia. Movafegh and Tenenbein showed that patients with TEC had significantly better lung functions reflected by forced expiratory volume in 1 second (FEV1) and FEV1/FCV (FEV 1/forced vital capacity) compared to patients receiving conventional analgesia within the first two days after surgery and less atelectasis already four hours after suregry[10,11]. Our data show that other pulmonary functions such as SpO2 and rate of re-intubation can also be improved with the use of TEC while maintaining adequate analgesia.

Effects of TEC include sympatholysis and reduced activations of physiological stress responses. It was previously shown that epinephrine and cortisol concentrations under combined anesthesia (patients with TEC) were considerably lower during surgery compared to general anesthesia without TEC[12]. These higher concentrations of catecholamines, glucocorticoids as well as proinflammatory cytokines may potentially lead to an upregulation of sodium channels, which are involved in the pathogenesis of pulmonary edema[13]. Therefore, the smaller volume of pleural drainages with TEC could also be explained by lower stress responses and less inflammatory reaction.

Most likely, the intraoperative volume regimen is the most important factor for pulmonary function outcome after posterior scoliosis surgery. Nevertheless, a TEC should be seen as "gold standard" for postoperative pain management in posterior spinal fusion as it might have additional lung protective effects.

There are two limitations that need to be acknowledged and addressed regarding the present study. One limitation was the relatively small sample size (n = 45). Although posterior spinal fusions were performed regularly, we had to exclude all patients with structural pulmonal or cardiac disorders, with severe scoliosis (Cobb angle > 100°), those patients with an ASA Score ≥3 as well as all patients whose scoliosis didn't result from adolescent idiopathic scoliosis in order to ensure comparability. Nevertheless, significant differences between the groups could be detected although the sample size of this study is small.

The second limitation concerns the selectivity of observed lung protective effects, since 20 patients with a TEC received a more restrictive volume regimen, whereas 9 patients obtained a liberal volume management. Additionally only 5 out of 16 patients with a conventional analgesia got a restrictive intraoperative volume regimen. It must be considered that high volume fluid regimens do not always cause pulmonary complications, though they can probably make them worse.

In summary, our results indicate that the combination of a more restrictive fluid management and a TEC in posterior spinal fusions may be advantageous as both factors can improve pulmonary outcome even in young and generally healthy patients.

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