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ORIGINAL ARTICLE

Crystalloid coloading vs. colloid coloading in elective Caesarean section: postspinal hypotension and vasopressor consumption, a prospective, observational clinical trial

Lutz Kaufner[1] · A. Karekla[2] · A. Henkelmann[1] · S. Welfle[2] · K. von Weizsäcker[3] · L. Hellmeyer[4] · C. von Heymann[1,2]

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Abstract

Background Maternal hypotension is a common side effect of spinal anaesthesia for Caesarean section. The combination of colloid coloading and vasopressors was considered our standard for its prevention and treatment. As the safety of hydroxyethyl starch is under debate, we replaced colloid with crystalloid coloading.

Objective We hypothesize that the mean blood pressure drop is greater when coloading with crystalloids.

Design Prospective, observational clinical trial.

Setting Two-centre study conducted in Berlin, Germany.

Patients Parturients scheduled for a Caesarean section were screened for eligibility.

Intervention The study protocol and patient monitoring were based on the standard operating procedure for Caesarean section in both centres. The data from the crystalloid group were prospectively collected between November 2014 and July 2015.

Main outcome measures The primary endpoint was the median drop in mean blood pressure after induction of spinal anaesthesia. Secondary endpoints were incidence of hypotension (drop > 20% of baseline systolic pressure /drop < 100 mmHg), vasopressor and additional fluid requirements (mL), incidence of bradycardia (heart rate < 60 beats per minute), blood loss, Apgar score, and umbilical artery pH. In case of hypotension, patients received phenylephrine or cafedrine/theodrenaline according to their heart rate. A $p < 0.05$ was considered significant.

Results 345 prospectively enrolled patients ($n = 193$ crystalloid group vs. $n = 152$ colloid group) were analysed. The median drop in mean blood pressure was greater in the crystalloid group [34 mmHg (25; 42 mmHg) vs. 21 mmHg (13; 29 mmHg), $p < 0.001$]. Incidences of hypotension [93.3% vs. 83.6%, p: 0.004] and bradycardia [19.7% vs. 9.9%, p: 0.012] were also significantly greater in the crystalloid group. Vasopressor requirements, blood loss and neonatal outcome were not different between the groups.

Conclusions Crystalloid coloading was associated with a greater drop in mean blood pressure and a higher incidence of hypotension when compared with colloid coloading. Neonatal outcome was, however, unaffected by the type of fluid.

Trial registration DRKS00006783 (http://www.drks.de).

Keywords Caesarean section · Spinal anaesthesia · Hypotension · Coloading · Crystalloids · Colloids

Introduction

Spinal anaesthesia (SpA) is considered to be the gold standard for elective Caesarean section (C/S) [1, 2]. The "Spinal Anaesthesia Induced Hypotension" (SAIH) is the most common adverse effect, with an incidence up to 70% [3]. Remaining untreated, SAIH may be associated with significant risks for mother and newborn [4, 5]. Most commonly, SAIH is defined as the decrease of the systolic blood pressure (BP_{syst}) by > 20% from baseline or a drop in BP_{syst} below 100 mmHg [6]. The lack of an internationally

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Lutz Kaufner and A. Karekla contributed equally.

✉ Lutz Kaufner
lutz.kaufner@charite.de

Extended author information available on the last page of the article

accepted definition of SAIH hampers the comparability of study results [7]. Furthermore, the BP_{syst} when compared to mean blood pressure (BP_{mean}) seems to correlate less with the organ perfusion [4].

SpA induces a reversible sympathetic block which leads to a drop in systemic vascular resistance and redistribution of blood volume to the lower extremities due to a loss of arteriolar tone [4, 8, 9]. A decrease in uteroplacental blood flow could influence the foetal circulation [10], leading to an increased risk of foetal acidosis [11]. Replacement of intravascular volume and vasopressors are considered the gold standard for prevention and treatment of SAIH [12, 13]. A multicentre study in 2014 showed a reassuring use of third-generation HES in the obstetric setting and provided maternal and neonatal peripartum safety data [18]. Furthermore, a recent meta-analysis showed that colloid compared with crystalloid loading significantly reduced the incidence of SAIH [3]. Most of the RCT showed a higher incidence of hypotension when using a crystalloid preloading, but did not report results regarding the vasopressor consumption and neonatal outcome. Previous studies have shown crystalloid preloading to be inferior to colloid preloading in the prevention of SAIH, probably due to the rapid redistribution of the infused crystalloid volume [19]. Until now there is only one controlled study left that compares a colloid- with a crystalloid-based coloading regime in combination with phenylephrine infusion to maintain the baseline BP_{syst} in elective C/S [21]. Due to the recent debate on the safety of hydroxyethyl starch (HES) and the impact on renal function [14, 15] in intensive care patients and the decision of European and national authorities [16] to restrict the use of HES solutions for hypovolemia caused by acute blood loss only [17], we changed our standard volume replacement technique for elective C/S from HES-based coloading to crystalloid-based coloading. Therefore, we conducted a trial hypothesizing that the technique of crystalloid coloading compared to colloid coloading is associated with a greater drop of mean of BP (ΔBP_{mean}), a higher incidence of hypotension, and an increased vasopressor consumption. Furthermore, we aimed to identify risk factors for SAIH when coloading with a crystalloid.

Methods

This two-centre, prospective, observational clinical trial (German Registry for Prospective Clinical Studies, DRKS00006783) was conducted at the Departments of Anaesthesiology of the Charité-Universitätsmedizin Berlin and the Vivantes Klinikum im Friedrichshain Berlin, Germany. After the Ethical Committee of Charité-Universitätsmedizin Berlin, Germany (EA1/240/14, Chairperson Prof. Dr. med. R. Uebelhack) approved the trial at both hospitals on 29.09.2014, women scheduled for elective C/S became eligible for inclusion. Written informed consent was obtained from each woman at least 24 h before surgery.

Women were enrolled if they were of age, mentally healthy, American Society of Anaesthesiologists (ASA) physical status Class I–II and scheduled to undergo elective C/S under neuraxial anaesthesia. Exclusion criteria were age < 18, decline of informed consent for spinal anaesthesia, limited ability to understand German, premature birth < 28 weeks of gestation or stillbirth, psychiatric condition or medication, alcohol abuse, chronic or any pregnancy-induced hypertensive disease, HELLP-syndrome, allergies to local anaesthetics and opioids, haemostatic disorders, or any other contraindications for spinal anaesthesia. Patients who required additional anaesthesia/analgesia (epidural top up bolus or general anaesthesia) outside of the defined protocol and patients who delivered after working hours (4 pm) were also excluded from the study.

The study protocol and monitoring of the patients were based on the standard operating procedure (SOP) for C/S in both centres. Coloading with a HES-based fluid was the standard treatment at both institutions until September 2013 and was replaced by a crystalloid-based regimen thereafter. The data from 152 ASA I–II patients treated with colloid coloading who were consecutively enrolled for an earlier prospective randomized study [20] were compared with 193 patients consecutively enrolled and subsequently treated with crystalloid coloading. The data from the crystalloid group were prospectively collected between November 2014 and July 2015 and identical inclusion and exclusion criteria were applied.

The standard monitoring, consisting of non-invasive blood pressure measured every minute, heart rate, ECG, and pulse oximetry were applied, followed by the validation of the baseline BP_{mean} (the median of three measurements). We defined the measurement of lowest mean blood pressure until completion of spinal anaesthesia and before skin incision. Patients included in this study did not receive any other intravenous fluids prior to coloading. The preoperative fasting time was as recommended by the European Society of Anaesthesiology: 2 h for clear fluids and 6 h for solids. Coloading with 1000 mL balanced HES 130/0.4 (Volulyte®, Fresenius-Kabi, Bad Homburg, Germany) or 1000 mL balanced crystalloid solution (Sterofundin Iso®, B.Braun, Melsungen, Germany) was then started through an 18G intravenous cannula using a pressure bag, at the induction of spinal anaesthesia and was completed within 15 min. After coloading, women in both groups received a baseline infusion of 500 mL crystalloid solution until the end of surgery. In case of SIAH, vasopressors were the first-line therapy without giving any additional crystalloid or colloid solution. SpA followed a standardized protocol and was performed by an anaesthetist under standard monitoring and

cardiotocography in a sitting position. After local anaesthesia of the skin with lidocaine 1%, a 27G or 25G pencil point needle was inserted (either as a single shot or combined spinal epidural, in the majority of cases at the lumbar vertebrae level 3–4) until the intrathecal space was identified. Patients were placed on a 30° left-tilted supine position. The sensory level of anaesthesia was tested using loss of cold sensation. A bilateral sensory block height at T6 was required to commence surgery. The dosage of bupivacaine applied related to the patients' height as follows:

< 160 cm:	8 mg of isobaric bupivacaine + 5 µg sufentanil
160–180 cm:	9 mg of isobaric bupivacaine + 5 µg sufentanil
> 180 cm:	10 mg of isobaric bupivacaine + 5 µg sufentanil

Hypotension was defined as a BP_{syst} < 100 mmHg or a drop of BP_{syst} > 20% of baseline. This drop was treated with fractionated boluses of 1 mL (0.1 mg) phenylephrine if the heart rate was ≥ 60 beats per minute or with 1 mL cafedrine/theodrenaline (20 mg cafedrine and 1 mg theodrenaline) if the heart rate was < 60 beats per minute. After umbilical cord clamping, 3 IU of oxytocin were given slowly intravenously, and an infusion of 20 IU oxytocin/500 mL balanced crystalloid at a rate of 63 mL/h was started if necessary. Only after delivery 4 mg ondansetron or 1 mg granisetron was applied in case of nausea.

Data were collected using a case report form (CRF) and statistical analysis was performed with SPSS® Version 23.0. For the calculation of the number of patients, we used the BP_{mean} difference of 26.435 mmHg and the standard deviation of ± 12.918 mmHg from a patient collective of our clinic. Assuming a 10% BP_{mean} difference and a power of 80%, we needed to recruit 190 patients (nQuery Advisor® Release 7.0, Stat. Solutions Ltd. & South Bank, Crosse's Green, Cork, Ireland).

The primary endpoint was the difference between baseline BP_{mean} and lowest BP_{mean} measurements documented from the onset of spinal anaesthesia until the end of surgery (ΔBP_{mean}). Secondary endpoints were incidence of hypotension, vasopressor consumption (mL), additional intraoperative fluid requirements (mL), incidence of bradycardia (heart rate < 60 beats per minute), estimated blood loss (mL), Apgar score, and the umbilical artery pH.

After assessing the normality of the data distributions, the data were expressed as the mean ± standard deviation, median (25% percentile, 75% percentile), or frequency (percentage). Differences between groups were tested with parametric (Student's *t* test) and non-parametric tests (Mann–Whitney *U* test) for independent variables. Frequencies were tested with Chi-square test.

We also looked at possible risk factors for a ΔBP_{mean} > 25%; furthermore, we assessed the correlation co-efficient for BMI/ΔBP_{mean} and baseline BP_{mean}/ΔBP_{mean}.

Two-tailed *p* values < 0.05 were considered statistically significant.

Results

In the crystalloid group, 346 women were screened for eligibility, 262 were enrolled in the study. 204 women received the protocol treatment after 58 women were subsequently excluded due to withdrawal of consent, spontaneous birth, delivery in another hospital, or Caesarean section after 4 pm. Eleven patients needed supplemental treatment (either epidural top up bolus or general anaesthesia) and were, therefore, excluded from the study. Data from 193 patients from the crystalloid group were included in the final analysis. From the colloid group, 179 patients were screened, 27 received additional treatment and were excluded. In the colloid group, 152 patient data that met the inclusion criteria were included in the final analysis (Fig. 1).

With the exception of baseline BP_{mean}, demographic patient characteristics such as age, BMI (body mass index), gravidity, parity, and ASA classification did not significantly differ between the groups. Baseline BP_{mean} was significantly higher in the crystalloid group compared to the colloid group (Table 1).

The ΔBP_{mean} showed a significantly greater drop in the crystalloid compared to the colloid group (Fig. 2). The incidence of hypotension in the crystalloid group was significantly higher than in the colloid group (Table 2). Vasopressor requirements were inhomogeneous between the groups. Significantly more phenylephrine was administered in the colloid group, while cafedrine/theodrenaline consumption was significantly greater in the crystalloid group. The total amount of required vasopressors was not significantly different between the groups (Fig. 3). Intraoperative requirements of additional intravenous fluids were significantly greater in the crystalloid group (Table 2). The incidence of bradycardia differed between crystalloid and colloid groups significantly with the incidence in the crystalloid group being greater compared to that in the colloid group (Table 2). No differences regarding perioperative blood loss were observed (Table 2).

Neonatal outcomes such as umbilical pH and Apgar score did not differ significantly between the groups (Table 3). BMI, baseline BP_{mean}, crystalloid coloading and administration interspace were significantly different in the groups of ΔBP_{mean} </= 25% and ΔBP_{mean} > 25% (Table 4). The sensory block spread was significantly related to the incidence of bradycardia (Table 5).

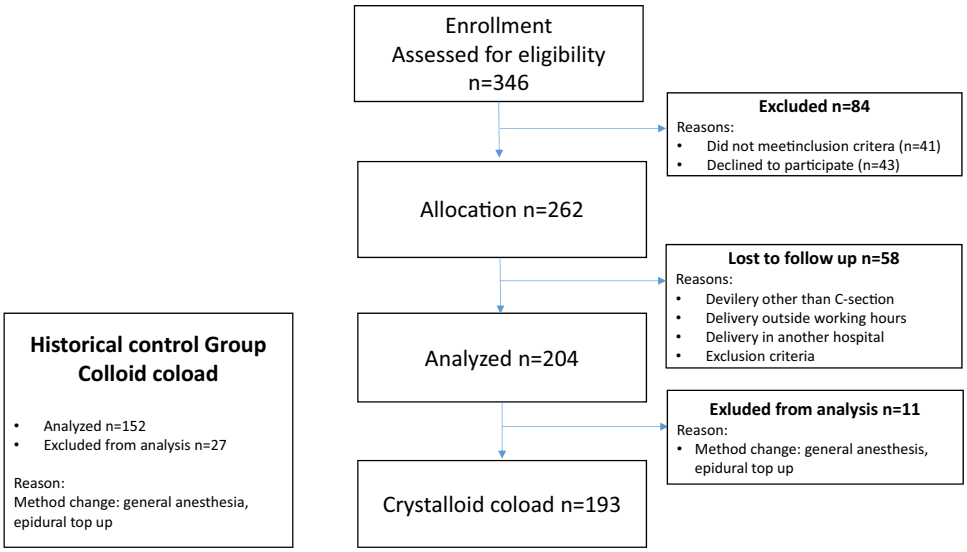

Fig. 1 Flowchart of study population

Table 1 Maternal characteristics and baseline data

Maternal characteristics and baseline data	Crystalloid group ($n=193$)	Colloid group ($n=152$)	p value
Age (years)	33 (28;36)	32 (27;36)	0.149[$]
BMI (kg/m^2)	28 (25;32)	28 (25;32)	0.531[$]
ASA, n (%)			0.440[$$$]
I	190 (98.4%)	151 (99.3%)	
II	3 (1.6%)	1 (0.7%)	
Gemini	6 (3.1%)	10 (6.6%)	0.128[$$$]
Gravidity (n)	2 (1;3)	2 (1;3)	0.237[$]
Parity (n)	1 (0;1)	1 (0;1)	0.980[$]
Gestational week, n (%)			0.427[$$$]
32–37	28 (14.5%)	26 (17.1%)	
38–41	165 (85.5%)	121 (79.6%)	
Missing		5 (3.3%)	
Baseline BP_{mean} (before co-loading/SpA) (mmHg)	95.97 ± 10.57	92.94 ± 10.77	0.009[$$]

BMI body mass index, *ASA* American Society of Anesthesiologists Classification, BP_{mean} mean blood pressure, *SpA* spinal anaesthesia

[$]Mann–Whitney U test

[$$]Student's t test

[$$$]χ^2 test

A significant positive correlation was found for BMI and ΔBP_{mean}, as well as for baseline BP_{mean} and ΔBP_{mean} (Figs. 4, 5).

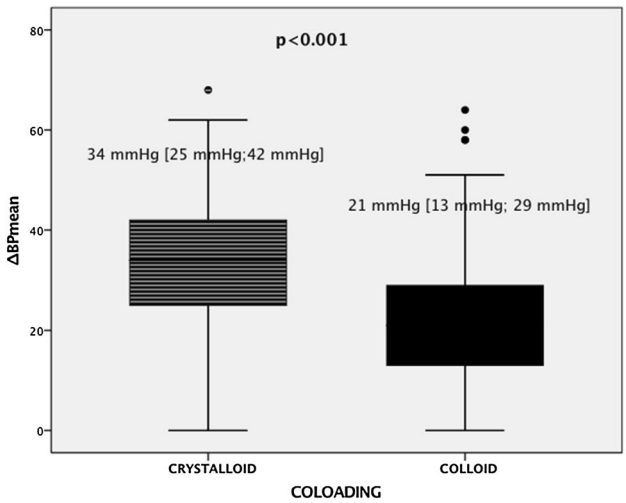

Fig. 2 ΔBP_{mean} crystalloid vs. colloid group. ΔBP_{mean} drop of systolic blood pressure

Discussion

The main result of the investigation is that crystalloid compared to colloid coloading for elective C/S is associated with a greater ΔBP_{mean} and a higher incidence of SAIH. The total amount of vasopressors and blood loss showed no significant differences between the groups. In terms of neonatal outcome, the combination of crystalloid coloading and vasopressors was not found to be inferior to the combination of colloid coloading and vasopressors.

A meta-analysis published by Ripolles et al. compared 11 RCTs, ten of which used a preload and only one a coloading regime as volume replacement technique for SpA in C/S women. The authors concluded that the use

Table 2 Outcome data

Outcome data	Crystalloid group ($n=193$)	Colloid group ($n=152$)	p value
Sensory level at CS beginning, *n* (%)			0.080[$$$]
T2–4	66 (34.2%) 127	66 (43.4%)	
T5–6	(65.8%)	86 (56.6%)	
Time of local anaesthetic injection-maximum BP_{mean} drop (min)	10 (4;21)	9 (5;15)	0.444[$]
Hypotension after SpA, *n* (%)	180 (93.3%)	127 (83.6%)	0.004[$$$]
Lowest BP_{mean} after SpA (mmHg)	61.82 ± 10.58	71.50 ± 9.93	< 0.001[$$]
Pulse pressure (mmHg)	43 (34;51.5)	40 (36;48.75)	0.213[$]
Bradycardia after SpA, *n* (%)	38 (19.7%)	15 (9.9%)	0.012[$$$]
Estimated blood loss, *n* (%)			0.108[$$$]
Up to 500 mL	170 (88.1%)	121 (79.6%)	
501–1000 mL	21 (10.9%)	29 (19.1%)	
1001–1500 mL	2 (1.0%)	1 (0.7%)	
1501–2000 mL	0 (0%)	1 (0.7%)	
Addition to 1000 mL coload intra-operative crystalloid requirements (mL)	600 (500;800)	500 (500;750)	0.001[$]

T thoracic vertebrae, BP_{mean} mean blood pressure, *SpA* spinal anaesthesia

[$]Mann–Whitney *U* test

[$$]Student's *t* test

[$$$]χ^2 test

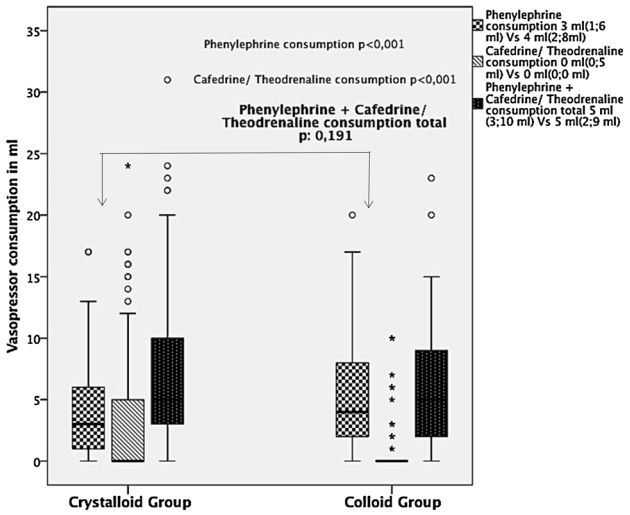

Fig. 3 Vasopressor consumption crystalloid versus colloid group

of colloid compared to crystalloid loading was associated with a significantly lower incidence of SAIH [3]. Different definitions of SAIH and a lack of differentiation between pre- and coloading regimens in this review, however, created a trend in favour of colloid coloading. Only McDonald et al. [21] compared a colloid- (6% w/v hydroxyethyl starch solution) with a crystalloid-based (Hartmann) coloading regime in combination with phenylephrine infusion to maintain the baseline BP_{syst} in elective C/S. After double-blind randomization, the groups consisted of 60 parturients; phenylephrine infusion (0.5 mg/mL) as well as a rescue bolus application (0.1 mg/mL) were titrated to maintain maternal baseline BP_{mean}. No significant differences in the cardiac output, the vasopressor consumption and hemodynamic stability of the two groups were observed. The authors concluded that, with regard to the missing benefit of a colloid coloading and the higher risk profile of colloids, a crystalloid coloading combined with phenylephrine infusion and a rescue bolus application appears to be an equally effective strategy in treating SAIH [21]. Our data point to a greater ΔBP_{mean} and a greater incidence of hypotension using crystalloid coloading which may be related to our bolus application of vasopressors without an early phenylephrine infusion at the beginning of SpA.

The effectiveness of crystalloid preloading as a hydration technique for SpA in C/S has been questioned in recent years and is no longer recommended [13, 19, 22–24]. When preloading, a rapid crystalloid redistribution was observed indicating that only a small amount of the crystalloid fluid remains in the intravascular space at the time of maximum vasodilatation following SpA [24, 25]. Ueyama et al. showed that 30 min after preloading with 1.5 L of fluid, only 28% of crystalloid vs. 100% of colloid fluids remained in the circulation [25]. Based on fluid volume kinetics described by Ewaldsson et al., the rapid administration of intravenous fluids just after the induction of SpA would be the best way to prevent a BP drop [26]. In conclusion, the shorter intravascular volume expansion of crystalloid fluids may be the

Table 3 Neonatal outcome

Neonatal outcome data	Crystalloid group ($n=193$)	Colloid group ($n=152$)	p value
Gender, n (%)			0.964[$$$]
Male	99 (51.3%)	78 (51.3%)	
Female	93 (48.2%)	74 (48.7%)	
Missing	1 (0.5%)	0	
Weight (g)	3319.90 ± 552.32	3215.79 ± 569.29	0.089[$$]
Uterine incision-delivery time (min)	1 (1;2)	1 (1;2)	0.220[$]
Umbilical artery pH	7.29 (7.25;7.32)	7.28 (7.26;7.30)	0.963[$]
Apgar score 1 min, n (%)			0.747[$$$]
0–3	2 (1.0%)	2 (1.3%)	
4–6	3 (1.6%)	4 (2.7%)	
7–10	186 (96.4%)	143 (94.0%)	
Missing	2 (1.0%)	3 (2.0%)	
Apgar score 5 min, n (%)			0.666[$$$]
0–3	1 (0.5%)	0	
4–6	1 (0.5%)	1 (0.7%)	
7–10	189 (98.0%)	148 (97.3%)	
Missing	2 (1.0%)	3 (2.0%)	
Apgar score 10 min, n (%)			0.255[$$$]
0–3	0	0	
4–6	0	1 (0.7%)	
7–10	191 (99.0%)	148 (97,3%)	
Missing	2 (1.0%)	3 (2.0%)	

[$]Mann–Whitney U test

[$$]Student's t test

[$$$]χ^2 test

cause of their inferior effectiveness compared to colloid fluids used in coloading.

To maintain BP_{syst} and BP_{mean} and secure neonatal outcome, fluid coloading is often combined with vasopressors. Phenylephrine, due to its direct α_1-receptor agonist activity, increases the systemic vascular resistance, has a lower placental transfer and is associated with a higher umbilical artery pH when compared with ephedrine [26–28]. Phenylephrine is often used as an infusion to prevent delayed SAIH [29] although an adequate bolus could also be sufficient [4]. Nevertheless, hypotension and reflex bradycardia were observed more often than an associated negative neonatal outcome [29, 30] indicating that at least in some cases, neonatal outcome seems to be unaffected by maternal hypotension. A recent study from Ngan Kee et al. randomized 214 patients into two groups, one receiving computer-controlled continuous infusion or intermittent boluses of phenylephrine in women receiving SpA for elective C/S. The results showed a more precise control of BP when using intermittent boluses with a lower total dose of phenylephrine; however, the differences between the groups were small and not clinically relevant [31].

Cafedrine/theodrenaline (Akrinor®) shows a positive inotropic and chronotropic activity with an almost unchanged vascular resistance, mainly due to its β_2-receptor stimulation and mobilization of blood resources from the venous capacity system [32]. Cafedrine/theodrenaline in a ratio of 20:1 has been widely used as a vasopressor in Germany since its approval in 1963 [33]. Its safety has also been confirmed in women receiving C/S under SpA [32, 34, 35]. Although most of the existing data were obtained from animal studies [36], a retrospective analysis from Clemens et al. showed that the effectiveness of Akrinor® in restoring maternal BP in cases of SAIH had no effect on maternal heart rate, the Apgar score of the newborn, or umbilical pH [35]. The use of cafedrine/theodrenaline in cases of a reduced heart rate < 60/min and phenylephrine when the heart rate was >/= 60 beats/min seems to be an effective therapeutic approach in the treatment of SAIH in our study.

Reflex bradycardia after phenylephrine application may occur due to a decrease in β-mimetic activity. The increased incidence of bradycardia in the crystalloid group is most likely associated with the more pronounced volume deficit after the onset of SpA, causing a reflex bradycardia [37] and resulting in a greater cafedrine/theodrenaline consumption in the crystalloid group. Known risk factors for bradycardia are age, sensory block >/= T4 [38], as well as the intrathecal injection of morphine [39]. Our results also indicate that the

Table 4 Risk factors for $\Delta BP_{mean} > 25\%$

Risk factors	ΔBP_{mean} </= 25% ($n = 125$)	$\Delta BP_{mean} > 25\%$ ($n = 220$)	*p* value
Age (years)	32 (27;36)	32 (28;36)	0.381[$]
BMI (kg/m^2)	28 (25;32)	29 (26;33)	0.042[$]
Parity (*n*)	1 (0;1)	1 (0;1)	0.446[$]
Gravidity (*n*)	2 (1;3)	2 (1;3)	0.530[$]
Gestational week *n* (%)			0.477[$$$]
Missing	1 (0.8%)	4 (1.8%)	
32–37	22 (17.6%)	32 (14.6%)	
38–41	102 (81.6%)	184 (83.6%)	
Baseline BP_{mean} (mmHg)	88.91 ± 10.57	97.89 ± 9.43	< 0.001[$$]
1000 mL coload, *n* (%)			< 0.001[$$$]
Crystalloid	36 (28.8%)	157 (71.4%)	
Colloid	89 (71.2%)	63 (28.6%)	
Administration interspace *n*, (%)			0.011[$$$]
L2–3	8.8%(11)	10.5%(23)	
L3–4	79.2%(99)	85.9%(189)	
L4–5	12.0%(15)	3.6%(8)	
Bradycardia	10.4%(13)	18.2%(40)	0.054[$$$]
Sensory level at C/S beginning *n*, (%)			0.465[$$$]
T2–4	51 (40.8%)	81 (36.8%)	
T5–6	74 (59.2%)	139 (63.2%)	
Estimated blood loss *n*, (%)			0.620[$$$]
<500 mL	105 (84.0%)	186 (84.5%)	
501–1000 mL	18 (14.4%)	32 (14.5%)	
1001–1500 mL	1 (0.8%)	2 (0.9%)	
1501–2000 mL	1 (0.8%)	0	
Neonatal weight (g)	3215 ± 465	3307 ± 607	0.142[$$]

ΔBP_{mean} drop of systolic blood pressure, *BMI* body mass index, *L* lumbar vertebrae, *T* thoracic vertebrae

[$]Mann–Whitney *U* test

[$$]Student's *t* test

[$$$]χ^2 test

Table 5 Risk factors for bradycardia

Risk factors for bradycardia	Bradycardia ($n = 53$)	No bradycardia ($n = 292$)	*p* value
Sensory block %, (*n*)			< 0.001[$$$]
T2–4	32 (60.4%)	100 (34.2%)	
T5–6	21 (39.6%)	192 (65.8%)	
Age	33 (28;37)	32 (28;36)	0.351[$]
Administration interspace, *n* (%)			0.941[$$$]
L2–3	5 (9.4%)	29 (9.9%)	
L3–4	45 (84.9%)	243 (83,2%)	
L4–5	3 (5.7%)	20 (6.8%)	

T thoracic vertebrae, *L* lumbar vertebrae

[$]Mann–Whitney *U* test

[$$$]χ^2 test

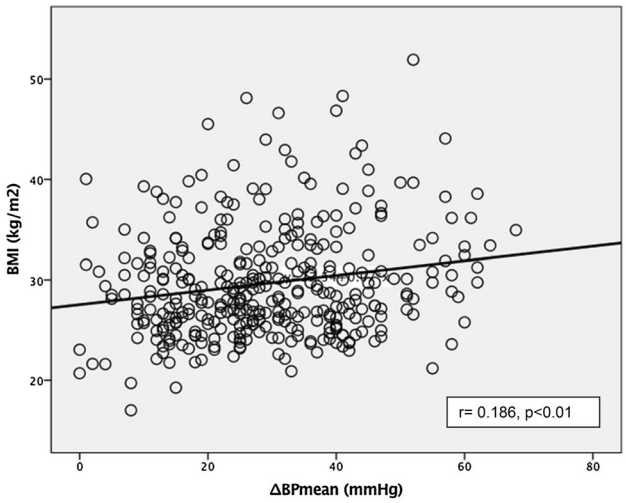

Fig. 4 Pearson correlation between ΔBP_{mean} and BMI. *ΔBP*$_{mean}$ Drop of mean blood pressure, *BMI* Body Mass Index

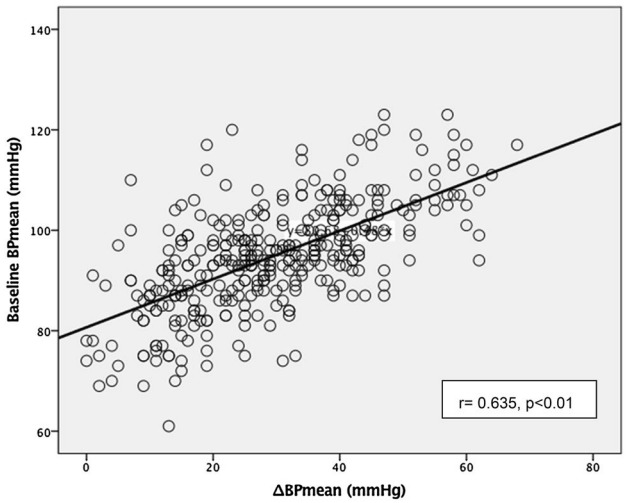

Fig. 5 Pearson correlation between ΔBP_{mean} and baseline BP_{mean}. *ΔBP*$_{mean}$ drop of mean blood pressure, *baseline BP*$_{mean}$ baseline mean blood pressure

sensory block spread may be a risk factor for bradycardia. It seems that patients with a sympathetic block spread up to T2–4 had a higher incidence of bradycardia than patients with a block up to T5–6.

Regarding potential risk factors for SAIH, BMI was related to a pronounced drop of $BP_{mean} > 25\%$ in our study, which confirms previous findings [40]. Esposito et al. observed that obese women have a higher sympathetic activity with a higher 24-h BP profile [41]. It may be hypothesized that patients with a higher sympathetic activity are susceptible to a more pronounced drop in BP due to SpA-induced sympatholysis.

Our findings of an association of higher baseline BP_{mean} with a drop of $BP_{mean} > 25\%$ was supported by a retrospective analysis of 919 patient data receiving epidural or SpA for elective C/S [42]. The authors identified the higher baseline BP_{mean} and maternal hypertension to be among other maternal risk factors that could influence a greater drop of BP_{mean} after induction of neuraxial anaesthesia.

Limitations

Our study used a historic control group that prospectively collected data, but nevertheless carried the risk of investigator and selection bias. Furthermore, a blinding of the study personnel was not feasible in the setting of a historic control group comparison. Another limitation is the significant difference in baseline BP_{mean} of the crystalloid and colloid groups. Interestingly, the seemingly clinically negligible difference of only 3 mmHg BP_{mean} may have had an impact on the significant correlation between baseline BP_{mean} and ΔBP_{mean}. To be sure of the impact of this difference, a prospective randomized and blinded trial accounting for these confounders would be needed to confirm our results.

Conclusion

From our findings we conclude that despite the greater incidence of SAIH and a greater drop in BP_{mean} in patients receiving a coload of crystalloid vs. colloid in conjunction with vasopressors, coloading with a crystalloid is a safe strategy for the management of SAIH. This strategy was associated with no difference in outcome for the mother or newborn as measured by umbilical pH and APGAR scores.

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Compliance with ethical standards

Conflict of interest The authors declare no competing financial interest.

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Affiliations

Lutz Kaufner[1] · A. Karekla[2] · A. Henkelmann[1] · S. Welfle[2] · K. von Weizsäcker[3] · L. Hellmeyer[4] · C. von Heymann[1,2]

[1] Department of Anaesthesiology and Intensive Care Medicine, Charité-Universitätsmedizin Berlin, Campus Virchow-Klinikum, Augustenburger Platz 1, 13353 Berlin, Germany

[2] Department of Anaesthesiology, Intensive Care Medicine, Emergency Medicine and Pain Therapy, Vivantes Klinikum im Friedrichshain, Berlin, Germany

[3] Department of Obstetrics, Charité-Universitätsmedizin Berlin, Berlin, Germany

[4] Department of Obstetrics and Gynaecology, Vivantes Klinikum im Friedrichshain, Berlin, Germany