

Maternal Cardiac Output Changes After Crystalloid or Colloid Coload Following Spinal Anesthesia for Elective Cesarean Delivery: A Randomized Controlled Trial

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BACKGROUND: Minimizing hypotension associated with spinal anesthesia for cesarean delivery by administration of IV fluids and vasopressors reduces fetal and maternal morbidity. Most studies have concentrated on noninvasive systolic blood pressure (SBP) measurements to evaluate the effect of such regimens. We used a suprasternal Doppler flow technique to measure maternal cardiac output (CO) variables in parturients receiving a phenylephrine infusion combined with the rapid administration of crystalloid or colloid solution at the time of initiation of anesthesia (coload). We hypothesized that a colloid coload compared with a crystalloid coload would produce a larger sustained increase in CO and therefore reduce vasopressor requirements.

METHODS: We recruited 60 healthy term women scheduled for elective cesarean delivery under spinal anesthesia for this randomized double-blind study. Baseline heart rate, baseline SBP, and CO variables including stroke volume, corrected flow time, and contractility were recorded in the left lateral tilt position. At the time of spinal injection, subjects were allocated to receive a rapid 1-L coload of either 6% w/v hydroxyethyl starch solution (HES) or Hartmann (crystalloid) solution (HS). A phenylephrine infusion was titrated to maintain maternal baseline SBP. CO was measured at 5-minute intervals for 20 minutes after initiation of spinal anesthesia. The primary outcome, CO, was compared between groups, as were secondary outcomes: phenylephrine dose and maternal hemodynamic and fetal outcome data.

RESULTS: Maternal demographics, surgical times, and fetal outcome data were similar between groups. There were no significant differences between groups in any measured CO variable at any time point. CO was transiently higher than baseline at 5 minutes in the HS group and at 5 and 10 minutes in the HES group (range, 0.13–1.74 L/min); the overall mean difference in CO between crystalloid and colloid over the study period was 0.06 L/min (95% confidence interval: -0.46 to 0.58). Stroke volume was higher than baseline in both groups throughout; peak velocity was consistently higher than baseline only in the HES group; and corrected flow time increased in both groups; the effect was transient in the HS but sustained in the HES group. Heart rate was not different at any time point within or between groups but did decrease over time. The total phenylephrine dose from time of spinal anesthesia to delivery was similar between groups.

CONCLUSION: We found no difference in CO in women randomized to colloid or crystalloid coload. In addition, there were no differences in vasopressor requirements or hemodynamic stability. We conclude that there is no advantage in using colloid over crystalloid when used in combination with a phenylephrine infusion during spinal anesthesia for elective cesarean delivery. (*Anesth Analg* 2011;113:803–10)

The sympathectomy associated with spinal anesthesia for cesarean delivery reduces systemic vascular resistance (SVR) and produces relative hypovolemia secondary to increased venous capacitance. Therefore, to

preserve arterial blood pressure (BP), there must be an adequate compensatory increase in cardiac output (CO) or SVR. The optimal fluid/vasopressor regimen would achieve this by minimizing reductions in SVR and maximizing increases in CO. The search for this ideal combination has generated much research.

Phenylephrine is the preferred vasopressor over ephedrine.¹ The optimal fluid volume, type, and timing of administration, however, remain less clear cut. Fluid infused before or at the time of induction of spinal anesthesia is referred to as “preloading” and “coload,” respectively. Pharmacokinetic studies predict fluid administration to be more effective if delayed until induction of spinal anesthesia and rapidly infused thereafter.² Three possible fluid type/timing combinations have been compared: colloid versus crystalloid preloading,^{3–8} crystalloid preloading versus

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crystalloid coload,⁹ and colloid preloading versus colloid coload.^{10–13} To our knowledge, the current study is the first to examine the fourth possible combination, colloid versus crystalloid coload, and only 1 of several studies to measure CO variables despite the fact that CO has been shown to correlate better with uteroplacental blood flow than upper arm BP.¹⁴

Unfortunately, no fluid regimen alone has proven to be effective enough for preventing hypotension associated with spinal anesthesia for cesarean delivery. A randomized controlled study has shown that combining a phenylephrine infusion with a crystalloid coload during spinal anesthesia for elective cesarean delivery dramatically reduces hypotension compared with no coload.¹⁵ Therefore, we designed a double-blind randomized controlled study to test the hypothesis that a phenylephrine infusion combined with a coload consisting of 1 L of 6% w/v hydroxyethyl starch solution (HES) would result in higher maternal CO variables in parturients undergoing planned cesarean delivery than a coload of 1 L Hartmann (crystalloid) solution (HS). CO was measured using a handheld suprasternal ultrasound CO monitor device. This technique has been validated, providing linear measurements of CO consistent with volumetric measures derived from thermodilution.¹⁶

METHODS

After ethics committee approval (Royal Free Hampstead NHS Trust, London, UK) and written informed consent, we recruited 66 healthy parturients at term scheduled to receive spinal anesthesia for planned cesarean delivery. Exclusion criteria were multiple pregnancy, gestational age <37 weeks, cardiac disease, cardiac medications, pre-eclampsia, sepsis, weight <50 kg or >100 kg, and height <149 cm or >212 cm.

An investigator not connected with clinical care and data collection randomized subjects using a computer-generated random number table into 1 of 2 groups based on a coload protocol. Preprinted sheets within sealed sequentially numbered opaque envelopes contained information on group allocation. The crystalloid group received 1 L HS and the colloid group received 1 L of 6% w/v HES (average molecular weight of 70,000 Da; EloHAES 6% in 0.9% saline [Fresenius, Hamburg, Germany]). Each infusion was commenced at the time of spinal injection and completed within 5 minutes.

Baseline measures of heart rate (HR), systolic BP (bSBP), oxygen saturation, CO, corrected flow time (FTc), and other Doppler CO variables were taken in the 15° left lateral tilt position as measured using a protractor. bSBP and baseline HR were taken as the mean of 3 readings within 10% of each other with the BP recorded from the dependent arm. A 14-gauge (with the use of local anesthetic) and a 20-gauge IV cannula were sited in the arm without the BP cuff. Three anesthesiologists were involved in the study for each subject. The first anesthesiologist opened the sealed randomization envelope and placed the assigned study fluid (at room temperature) in a simple pressurized infusion system (Medex C-Fusor® 100; Medex, Dublin, OH) pressurized to 300 mm Hg, and attached this to the 14-gauge cannula; this anesthesiologist was solely responsible for its subsequent administration according to

the study protocol. Identity of the study fluid was disguised from the other anesthesiologists using an opaque cover. The second anesthesiologist prepared syringes of vasoactive drugs: phenylephrine 50 µg/mL (50-mL syringe for infusion), phenylephrine 100 µg/mL (“rescue syringe”), ephedrine 3 mg/mL, and glycopyrrolate 200 µg/mL. The same anesthesiologist attached an infusion device containing the phenylephrine infusion to the 20-gauge cannula and was solely responsible for adjusting the infusion rate according to the study protocol. The third anesthesiologist performed all Doppler measurements and the combined spinal-epidural technique in the sitting position at the estimated L3-4 interspace using a Portex CSEcure 27-gauge/16-gauge needle (Smiths Medical, Keene, NH). An intrathecal dose of hyperbaric bupivacaine 0.5% 12 mg with fentanyl 15 µg was injected over 30 seconds after which the subject was immediately returned to the 15° left lateral tilt position. The fluid coload was administered at the start of spinal injection and was completed within 5 minutes in all subjects. No further fluid was given until after delivery. The phenylephrine infusion was also started at the time of spinal injection at a rate of 100 µg/min and was either on or off according to BP measurements determined at 1-minute intervals. The infusion continued if the BP was at or below bSBP and turned off if above baseline. Two successive readings of hypotension (SBP <80% bSBP) were treated with phenylephrine 100 µg from the rescue syringe, and if there was no improvement after 2 further readings, ephedrine 6 mg was administered. The phenylephrine infusion was stopped for 2 consecutive readings of bradycardia (HR <50 bpm) with SBP at bSBP. Glycopyrrolate 200 µg was administered for 2 consecutive readings of bradycardia with SBP < bSBP.

The third anesthesiologist assessed motor block and the upper sensory level of anesthesia to light touch. This modality was chosen to assess dermatomal spread of spinal anesthesia, because tests for light touch have shown the least variability.¹⁷ CO studies were conducted before and at 5-minute intervals for 20 minutes after spinal anesthesia. Surgery was allowed to commence after completion of the CO studies if a sensory block to touch at the T5 dermatome was present. No further assessments of block height were recorded once surgery commenced.

Hypotensive episodes, defined as SBP <80% bSBP, and hypertensive episodes defined as SBP >120% bSBP, were recorded. The total dose of phenylephrine from the time of spinal injection to delivery was recorded. The presence of nausea and vomiting was measured on a 3-point scale of 1, 2, and 3 indicating no nausea and no vomiting, nausea only, and both nausea and vomiting, respectively. Assessments were done at 5-minute intervals, until 20 minutes after the spinal injection, and when the parturient complained of sickness. Obstetric data collected included gestational age, time interval from spinal injection to start of surgery, uterine incision to delivery time, neonatal outcome as assessed by Apgar scores at 1 and 5 minutes, and umbilical arterial and venous blood gases obtained from a double-clamped segment of umbilical cord.

CO was measured using the SupraQ® Cardiac Function Monitor (Deltex Medical Limited, Chichester, UK). Measurements were taken from the aortic arch and performed

by a single operator, trained over a 3-month period in suprasternal ultrasound techniques. The Doppler complexes were transferred, real-time, onto a remote storage disk. The stored complexes were played back for more detailed analysis of the velocity time profile by the anesthesiologist who was blinded to group allocation. Each CO variable used for statistical analysis represented the mean of 3 measures derived from 3 consecutive complexes at each measurement time. We also measured FTc and peak velocity (PV).

Fetal cardiocardiograph monitoring continued from spinal injection to the time of sterilization of skin for surgery. Oxygen was administered at 4 L/min via a Hudson face-mask if oxygen saturation decreased below 95%. The study ended with delivery.

Data are presented as mean (SD), median [IQR], and frequency and were analyzed using the 2-sided unpaired Student *t* test, Mann-Whitney *U* test, and Fisher exact test, respectively. Within- and between-group comparisons of hemodynamic variables from baseline to predefined time points (for 20 minutes after spinal injection) were performed using repeated-measures analysis of variance with Geisser-Greenhouse corrections within $P < 0.01$ to adjust for variance asymmetry (assessed using Box M and Mauchly tests), analysis of covariance (using baseline hemodynamic variables as covariates), and Tukey-Kramer multiple comparison tests. Analyses were performed using Number Cruncher Statistical Systems (NCSS) 2004 (NCSS Inc., Kaysville, UT).

The sample size calculation was based on detecting a 20% difference in CO in groups as the primary outcome variable in the first 20 minutes after spinal anesthesia. From previous data^a using a coefficient of variation of 24%, it was estimated that 25 and 32 patients per group would have 80% and 90% power, respectively, to identify this difference ($P < 0.05$). We planned to recruit 33 patients per group to allow for dropouts and exclusions. Secondary outcomes measures included other CO variables, phenylephrine dose, BP, HR, incidences of bradycardia, hypotension, and hypertension (SBP $>120\%$), block height, nausea and vomiting, umbilical cord blood gas values, and Apgar scores.

RESULTS

Data analysis was performed on 60 patients (Fig. 1) enrolled in the study from December 2005 until June 2006. Details of maternal characteristics are summarized in Table 1. HES group patients were taller; all other maternal characteristics were similar.

CO (Fig. 2A) was significantly higher compared with baseline at 5 minutes (0.78; 95% confidence interval [CI]: 0.26–1.31 L/min) in the HS, and at 5 minutes (1.21; 95% CI: 0.69–1.74 L/min) and 10 minutes (0.66; 95% CI: 0.13–1.18 L/min) in the HES group with no significant between-group differences. The overall mean difference in CO between crystalloid and colloid over the study period was 0.06 L/min (95% CI: –0.46 to 0.58). All other CO variables were similar between groups. Stroke volume (SV) was

significantly higher than baseline in both groups throughout the study period (mean difference 11.6 mL; 95% CI: 7.4–15.9 mL) with no between-group differences (Fig. 2B). There were no significant differences between groups in PV or FTc (Table 2). PV increased significantly at 5, 10, and 15 minutes compared with baseline in the HES group, but not in the HS group. FTc increased significantly above baseline in both groups, with the effect sustained in the HES group over 20 minutes but only over 10 minutes in the HS group.

Surgical times, block height 20 minutes after spinal injection, and maximal cephalad sensory level of anesthesia were not different between groups (Table 3). No subject required oxygen and there were no abnormal cardiocardiograph recordings. SBP was equally maintained in both groups (Fig. 3A) with no significant intergroup differences in the incidence of hypotensive or hypertensive episodes (Table 3). The lowest SBP measurement recorded in the HS and HES groups occurred at 4 minutes and 8 minutes, respectively. One subject required ephedrine in the HS group. One subject with hypotension was symptomatic with associated nausea and vomiting (HS group). Twelve subjects had episodes of nausea with no difference between groups. There were no significant differences in the incidence of hypertension or bradycardia. The highest recorded SBP measurement in the HS and HES groups occurred at 1 minute and 2 minutes, respectively. No episodes of hypertension were associated with bradycardia. There was no significant difference in HR at any time point within or between groups (Fig. 3B), although HR decreased over time ($P < 0.01$, linear trend). One patient per group received glycopyrrolate for bradycardia without hypertension, occurring at 13 minutes in the HS group with a SBP of 107 mm Hg and at 15 minutes in the HES group with a SBP of 114 mm Hg. One of these subjects had a baseline HR of 55 bpm.

There was no significant difference in total phenylephrine dose (0.38 mg; 95% CI: –0.13 to 0.88) (Table 3), or in the number of subjects requiring rescue bolus doses. In the HES group, all boluses were administered as a single intervention; in the HS group, 3 subjects received a single bolus and 5 received multiple boluses.

Fetal data are summarized in Table 4. There were no significant differences in umbilical cord gases or Apgar scores between groups. One neonate per group had a uterine artery pH <7.2 . In the HES group, the neonate with the lowest uterine artery pH (pH = 7.18) had a uterine incision–delivery time of 5 minutes and 1- and 5-minute Apgar scores of 9 and 10. In the HS group, the lowest uterine artery pH was 7.07 with a uterine incision–delivery time of 2 minutes and 1- and 5-minute Apgar scores of 9 and 9.

DISCUSSION

The current study is one of few studies investigating CO changes with spinal anesthesia in the obstetric population and one of several investigating the relatively new but promising technique of fluid coload. We showed no difference in CO variables, vasopressor requirement, or hemodynamic stability in women randomized to receive colloid versus crystalloid administered as a coload in

^aAshpole K, Fernando R, Tamilselvan P, Columb M. Maternal cardiac output changes with phenylephrine and ephedrine infusions after spinal anaesthesia for caesarean section. *Int J Obstet Anesth* 2005;14:55.

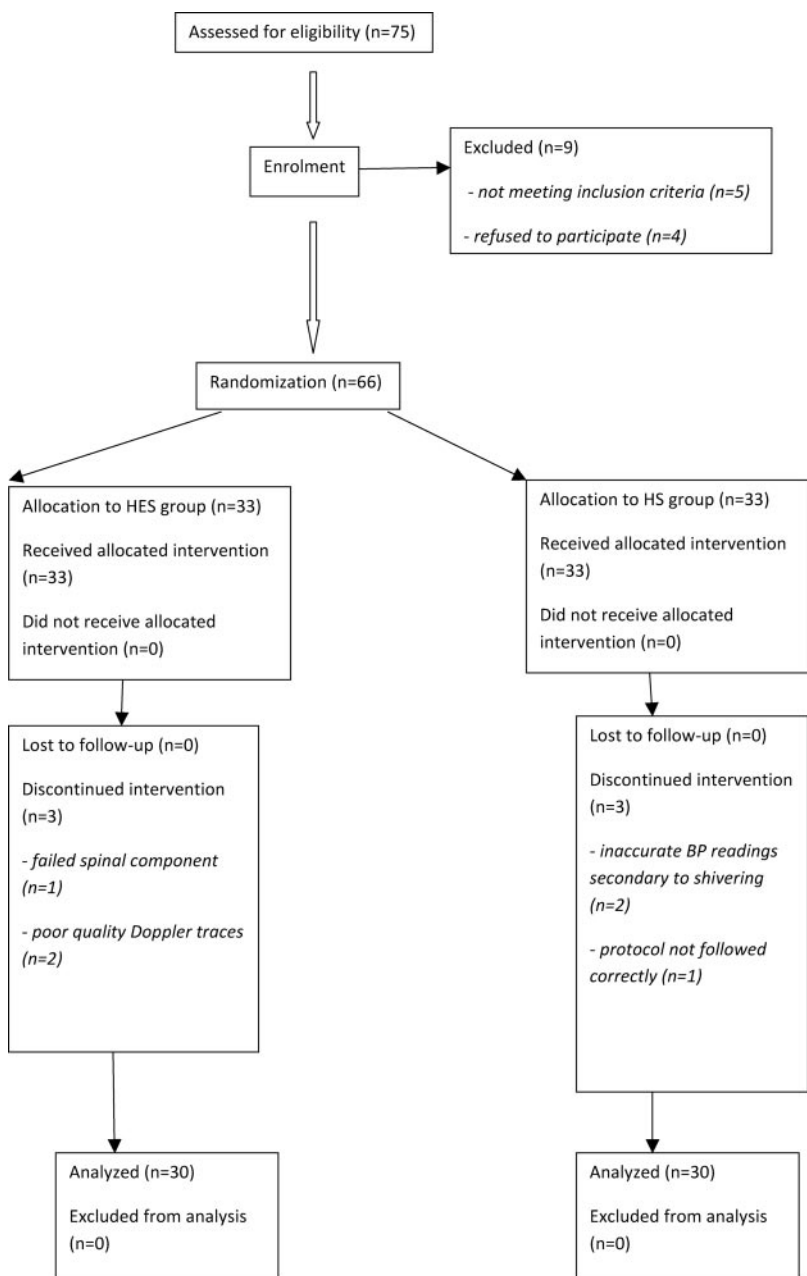


Figure 1. CONSORT (Consolidated Standards of Reporting Trials) flow diagram. BP = blood pressure; HES = hydroxyethyl starch; HS = Hartmann solution.

Table 1. Maternal Characteristics

	HES group (n = 30)	HS group (n = 30)	P value
Age (y)	34 ± 6	35 ± 5	0.56
Weight (kg)	76 ± 10	76 ± 12	0.99
Height (cm)	166 ± 5	162 ± 7	0.03

Data are mean ± SD.
HES = hydroxyethyl starch; HS = Hartmann solution.

combination with a phenylephrine infusion during spinal anesthesia for elective cesarean delivery.

The coload technique developed after the efficacy of preloading was questioned. Crystalloid preloading is relatively ineffective for preventing hypotension^{18,19} despite infusing volumes of up to 30 mL/kg.²⁰ Atrial natriuretic

peptide release with subsequent vasodilator and diuretic effects compounded with time-related fluid redistribution are suggested causes of its ineffectiveness. Subsequent research compared crystalloid with colloid. Ueyama et al.³ measured blood volume and CO before and after preloading with crystalloid 1.5 L, and colloid 0.5 L and 1 L. After 30 minutes, 28% of the crystalloid remained in the circulation compared with 100% of the colloid. The investigators concluded that preloading volume, regardless of type of fluid, must be large enough to result in a significant increase in CO for effective prevention of hypotension. Tamilselvan et al.⁴ compared preload volumes of colloid 0.5 L and 1 L, and crystalloid 1.5 L; CO and FTc significantly increased in all groups before the initiation of anesthesia. After spinal anesthesia, this effect was maintained in only the colloid 1-L group; however, the

incidence of hypotension was unchanged compared with the other groups. They concluded that the observed increase in CO could not compensate for reductions in SVR after spinal anesthesia. Even though the incidence of hypotension was not dramatically different among fluid

groups in either of these studies, the fact that the increase in CO with colloid lasted longer is still important because CO correlates better with uteroplacental perfusion than changes in maternal BP.¹⁴

Dyer et al.⁹ investigated whether a crystalloid coload would be more effective than a preload and showed that 20 mL/kg crystalloid coload reduced hypotension compared with the equivalent preload volume. Teoh and Sia¹⁰ found that 15 mL/kg colloid preload but not coload, significantly increased maternal CO within the first 5 minutes after spinal injection, with no difference in the incidence of hypotension. However, the mean volume and duration of coload infusion was 1.1 L over 9 minutes, so it is difficult to know how much had infused within 5 minutes of spinal injection. Additionally, as acknowledged by the authors, baseline CO and SV were significantly lower in the coload group. These results differ from the current study in which we found CO to be transiently higher after spinal injection compared with baseline in both colloid and crystalloid groups, despite the coadministration of a phenylephrine

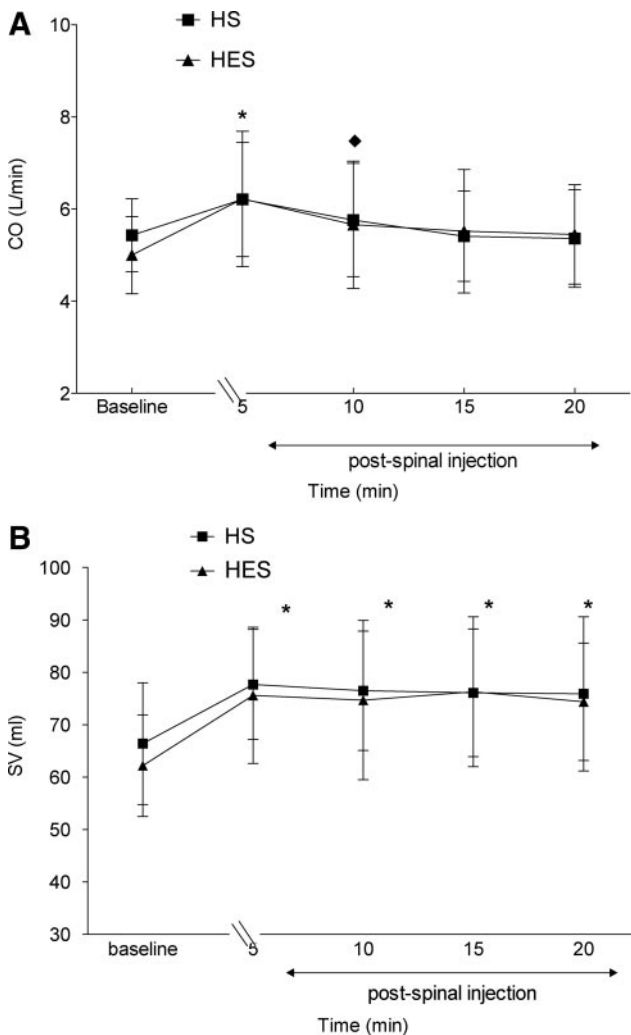


Figure 2. A, Cardiac output (CO) versus time. * $P = 0.002$ versus baseline, hydroxyethyl starch (HES) and Hartmann solution (HS); $\blacklozenge P = 0.003$ versus baseline, HES; Tukey-Kramer multiple comparison tests. Box M test $P = 0.69$; Mauchly test $P = 0.003$; Geisser-Greenhouse $P < 0.001$ value for effect of time. B, Stroke volume (SV) versus time. No significant group effect using repeated-measures analysis of variance. * $P = 0.002$ versus baseline, HES and HS; Tukey-Kramer test. Data are mean (\pm SD).

Table 3. Hemodynamic Data and Phenylephrine Requirements from Spinal Injection to Delivery

	HS group (n = 30)	HES group (n = 30)	P value
Total phenylephrine dose: spinal injection to delivery (mg)	2.59 (1.05)	2.21 (0.90)	0.14
≥ 1 boluses of phenylephrine, n (%)	8 (27%)	3 (10%)	0.18
Hypotension, ^a n (%)	18 (60%)	12 (40%)	0.20
1 episode of hypotension, n (%)	8 (27%)	2 (7%)	0.08
Bradycardia (<50 beats/min), n (%)	6 (20%)	4 (13%)	0.49
Hypertension, ^b n (%)	12 (40%)	9 (30%)	0.64
>1 episode of hypertension, n (%)	6 (20%)	2 (7%)	0.08
Maximal SBP (mm Hg)	147 (15)	144 (16)	0.50
Minimal recorded SBP (mm Hg)	94 (19)	100 (18)	0.23
Spinal injection to delivery interval (min)	42 [35–49]	42 [39–49]	0.82
Block height, dermatome at 20 min	T2 [T3–T2]	T2 [T3–T2]	0.64
Surgical incision to delivery interval (min)	8 [6–12]	8.5 [6–13]	0.7

Data are presented as mean (SD), median [IQR], or count (%) and were analyzed using the Student *t* test, Mann-Whitney *U* test, or Fisher exact test, respectively.

HES = hydroxyethyl starch; HS = Hartmann solution; SBP = systolic blood pressure.

^a Hypotension = SBP <80% baseline SBP.

^b Hypertension = SBP >120% baseline SBP.

Table 2. Corrected Flow Time and Peak Velocity Data

Group	Baseline	5 min	10 min	15 min	20 min
PV (cm/s)					
HS (n = 30)	97.7 \pm 9.8	103.3 \pm 10.2	98.8 \pm 9.6	99.3 \pm 10.8	99.2 \pm 9.3
HES (n = 30)	92.9 \pm 8.8	102.0 \pm 14.2*	100.3 \pm 12.6*	100.1 \pm 13.2*	98.9 \pm 9.4*
FTc (ms)					
HS (n = 30)	384.3 \pm 39.7	420.0 \pm 47.6*	421.4 \pm 35.0*	402.9 \pm 29.1	400.4 \pm 31.4
HES (n = 30)	380.3 \pm 18.4	416.0 \pm 26.4*	408.2 \pm 35.4*	402.9 \pm 33.4*	397.9 \pm 25.9*

Data are mean \pm SD.

FTc = corrected flow time; HES = hydroxyethyl starch; HS = Hartmann solution; PV = peak velocity.

* $P < 0.05$ compared with baseline (corrected for multiple comparisons/Tukey Kramer test).

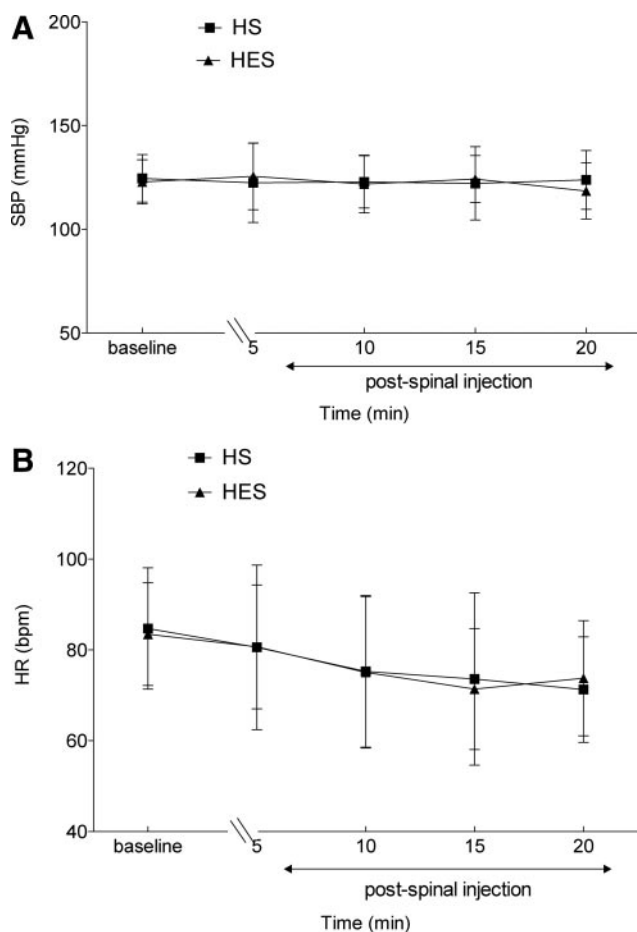


Figure 3. A, Systolic blood pressure (SBP) versus time. No significant differences within or between groups using repeated-measures analysis of variance. B, Heart rate (HR) versus time. HES = hydroxyethyl starch; HS = Hartmann solution. HR within both groups decreased over time using repeated-measures analysis of variance, linear trend ($P < 0.01$). No significant differences in HR between groups over time, using repeated-measures analysis of variance. Data are mean (\pm SD).

Table 4. Fetal Data

	HES group (n = 30)	HS group (n = 30)	P value
UA pH	7.29 \pm 0.04	7.29 \pm 0.06	0.74
UA BE (mEq/L)	-0.9 \pm 1.9	-1.1 \pm 4.0	0.73
UV pH	7.34 \pm 0.03	7.35 \pm 0.06	0.51
UV BE (mEq/L)	-1.9 \pm 2.6	-1.6 \pm 1.8	0.57
Apgar scores at 1 min <7 (n)	0	0	
Apgar scores at 5 min <7 (n)	0	0	

Data are mean \pm SD or number (n). Data presented as mean \pm SD were analyzed using the Student t test.

BE = base excess; HES = hydroxyethyl starch; HS = Hartmann solution; UA = umbilical artery; UV = umbilical vein.

infusion. Our increased rate of fluid administration (all subjects received 1 L of coload within 5 minutes) may account for this difference.

We compared crystalloid to colloid coload because this combination had not been investigated and we also chose to administer a phenylephrine infusion in both

groups to maintain bSBP following on work by Ngan Kee et al.²¹ Titrated phenylephrine infusions minimize maternal nausea, vomiting, and episodes of hypotension, and they result in higher neonatal pH and lower base deficits.¹ Additionally, Ngan Kee et al.¹⁵ demonstrated a dramatic decrease in the incidence of hypotension by combining a crystalloid coload with a high-dose phenylephrine infusion compared with no coload. Our incidence of hypotension from spinal injection to delivery was 60% in the HS group versus 40% in the HES group, which is considerably higher than 1.9% observed by Ngan Kee et al.¹⁵ The definition of hypotension was the same in both studies. However, the coload volume in the Ngan Kee et al. study was almost double the volume we infused, and was administered over a longer period of time. Additionally, the mean spinal injection to delivery interval was longer in the current study than in the Ngan Kee et al. study (42 vs 27 minutes). The number of subjects in our study having >1 episode of hypotension was low (7% vs 27% in the HES and HS groups, respectively), suggesting hemodynamic control is better than the overall incidence of hypotension of 50% suggests. Our incidence of reactive hypertensive episodes was 30% in the HES group versus 40% in the HS group. Because of intermittent CO measurements, it is impossible to determine whether these were associated with a reduction in CO, although none was associated with bradycardia. Dyer et al.²² have shown CO change to correlate with HR changes after vasopressor administration, emphasizing the importance of HR as a surrogate indicator of CO.

The number of subjects requiring rescue phenylephrine boluses was small suggesting good BP control with the phenylephrine infusion. All boluses administered in the HES group were as a single intervention, whereas most of the boluses in the HS group were repeated. This finding suggests that HES may have an advantage over HS, although a larger study is necessary to confirm this finding. We propose that phenylephrine requirements were similar because CO did not fall below baseline in both groups. PV and FTc were significantly higher than baseline in the colloid group throughout, but not the crystalloid group; this may indicate preservation of adequate intravascular expansion. SV was significantly higher than baseline at all time points in both groups but CO was only transiently significantly higher and this can be attributed to the observed reduction in HR. Stewart et al.²³ and Langesaeter et al.²⁴ found a dose-dependent reduction in HR with phenylephrine use that is associated with a decrease in maternal CO. This emphasizes the fine balance between the maintenance of BP with α agonists and a potential baroreceptor-mediated reduction in CO, the fetal effects of which have yet to be fully evaluated, particularly in the emergency cesarean setting. Maintaining intravascular volume by filling of the venous system provides energy in the form of elastic recoil to create the pressure gradient allowing blood from the capacitance vessels to empty into the right atrium.

Langesaeter et al.²⁴ compared CO and hemodynamic changes, using the LidCO[®] CO monitor, with different spinal anesthetic doses. All subjects received 0.75 L crystalloid coload over 20 minutes and half received a phenylephrine infusion. An initial decrease in SVR and increase in CO

occurred in all patients immediately after spinal injection and a significantly slower HR and decrease in CO occurred in the phenylephrine groups. Dyer et al.,²² using a LidCO monitor, also demonstrated reductions in CO with phenylephrine use but found that CO remained above baseline because CO values immediately before vasopressor administration were higher than baseline. In these 2 studies, similar to ours, all subjects received a coload. It would be interesting to compare CO immediately before and after vasopressor administration in subjects receiving different volumes of coload to determine whether the coload technique itself prevents CO from decreasing to below baseline after vasopressor administration.

More frequent CO measurements in the immediate postspinal period would have allowed us to compare our data with those of Langesaeter et al.²⁴ Unfortunately, we could not perform CO measurements more frequently than every 5 minutes without compromising maternal comfort. Our highest BP readings occurred within 2 minutes of spinal injection, suggesting that our vasopressor infusion could be reduced at this time. This view differs from that of Langesaeter et al.²⁴ who suggested an additional bolus of vasopressor at induction of spinal anesthesia. Of note, they used a much slower and smaller volume of coload as well as a lower phenylephrine infusion dose. Further work to investigate immediate CO changes after spinal injection with different combinations of fluids and vasopressors would be valuable because this is probably the time when the mother and fetus are at most risk.

Our finding that colloid offers no advantage over crystalloid in maintaining CO and reducing vasopressor requirement is important because colloid use is linked with pruritus, hypocoagulability, and allergic reactions, thus crystalloid is preferable to colloid if colloid offers no advantages. The risk of pulmonary edema and dilutional anemia with large volumes of crystalloid, however, should also be considered. It would be interesting to repeat our study using smaller coload volumes.

HES was our colloid of choice because the incidence of anaphylactoid reactions with starches is lower compared with gelatins,²⁵ the 2 most widely used colloids in our institution. We observed no adverse reactions to HES in this small study. The lower weight limit for inclusion criteria to our study was 50 kg; therefore, our coload volume of 1 L did not exceed the recommended daily dose of 20 mL/kg. We could have improved our study design by administering fluid on a volume/weight basis; however, from a practical point of view, we chose a fixed volume. We also chose not to include a control group, that is, a group receiving a phenylephrine infusion with no coload, because previous work by Ngan Kee et al.¹⁵ has shown that omitting a coload in this situation significantly increases the incidence of maternal hypotension.

In summary, we showed no difference in CO variables, vasopressor requirement, or hemodynamic stability between colloid and crystalloid and conclude no benefit in using colloid over crystalloid as a coload when used in combination with a phenylephrine infusion for spinal anesthesia for elective cesarean delivery. ■■

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DISCLOSURES

Name: Sarah McDonald, FRCA.

Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.

Attestation: Sarah McDonald has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.

Name: Roshan Fernando, FRCA.

Contribution: This author helped design the study, conduct the study, analyze the data, and write the manuscript.

Attestation: Roshan Fernando has seen the original study data, reviewed the analysis of the data, approved the final manuscript, and is the author responsible for archiving the study files.

Name: Keri Ashpole, FRCA.

Contribution: This author helped design the study.

Attestation: Keri Ashpole has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.

Name: Malachy Columb, FRCA.

Contribution: This author helped design the study, analyze the data, and write the manuscript.

Attestation: Malachy Columb has seen the original study data, reviewed the analysis of the data, and approved the final manuscript.

This manuscript was handled by: Cynthia A. Wong, MD.

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