Blood volume determination in obese and normal-weight gravidas: the hydroxyethyl starch method

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OBJECTIVE: The impact of obesity on maternal blood volume in pregnancy has not been reported. We compared the blood volumes of obese and normal-weight gravidas using a validated hydroxyethyl starch (HES) dilution technique for blood volume estimation.

STUDY DESIGN: Blood volumes were estimated in 30 normal-weight (pregravid body mass index [BMI] <25 kg/m^2) and 30 obese (pregravid BMI >35 kg/m^2) gravidas >34 weeks' gestation using a modified HES dilution technique. Blood samples obtained before and 10 minutes after HES injection were analyzed for plasma glucose concentrations after acid hydrolysis of HES. Blood volume was calculated from the difference between glucose concentrations measured in hydrolyzed plasma.

RESULTS: Obese gravidas had higher pregravid and visit BMI (mean [SD]): pregravid (41 [4] vs 22 [2] kg/m^2, $P = .001$); visit (42 [4] vs 27 [2] kg/m^2, $P = .001$), but lower weight gain (5 [7] vs 12 [4] kg, $P = .001$) than normal-weight women. Obese gravidas had similar estimated total blood volume to normal-weight women (8103 $\pm$ 2452 vs 6944 $\pm$ 2830 mL, $P = .1$), but lower blood volume per kilogram weight (73 $\pm$ 22 vs 95 $\pm$ 30 mL/kg, $P = .007$).

CONCLUSION: Obese gravidas have similar circulating blood volume, but lower blood volume per kilogram body weight, than normal-weight gravidas near term.

Key words: blood volume, hydroxyethyl starch, obesity, obstetric anesthesia

Cite this article as: Vricella LK, Louis JM, Chien E, et al. Blood volume determination in obese and normal-weight gravidas: the hydroxyethyl starch method. Am J Obstet Gynecol 2015;213:408.e1-6.

Blood volume expansion in pregnancy is believed to be important for supporting normal obstetric outcomes.[1] Obese individuals, despite having increased total blood volume, are known to have lower unit blood volume than lean individuals because fat mass is underperfused when compared to lean body mass.[2,3] The prevalence of obesity among pregnant women continues to rise.[4-6] The impact of obesity on circulating blood volume in pregnancy has not been well studied. In lean women, unit blood volume is 65 mL/kg in the nonpregnant state and increases to a mean of 100 mL/kg (range, 90–200 mL/kg) near term pregnancy.[2,7,8] Unit blood volume has been shown to decrease asymptotically with increasing body mass, to a nadir of 45 mL/kg in nonpregnant class III obese women.[7,9] A decrease in unit blood volume could contribute to the increased frequency of obstetric complications in obese gravidas including anesthesia-related adverse events.[10-13]

Hypotension is a common complication of obstetric regional anesthesia placement and can result in category 2 and 3 fetal heart rate tracings and emergent delivery.[14-18] Regional anesthesia induces sympathetic blockade, leading to decreased venous return that is mediated by blood volume.[19] The resulting hypotension is commonly treated with additional intravenous volume and vasopressor administration.[20-23] Prophylactic intravenous volume and/or vasopressor administration is commonly used prior to regional anesthesia to minimize the occurrence of hypotension.[16,22,24] In our previously published studies, we have observed that class III obese women (body mass index [BMI] $\geq$40 kg/m^2) undergoing regional anesthesia for childbirth have more anesthesia-related

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Received March 6, 2015; revised April 21, 2015; accepted May 10, 2015.

Supported by grants from the Clinical Research Unit, Case Western Reserve University–MetroHealth Medical Center; the National Center for Research Resources; and the Clinical and Translational Science Award program through the National Institutes of Health National Center for Advancing Translational Sciences (UL1 RR024989).

The authors report no conflict of interest.

The information presented is solely the responsibility of the authors and does not necessarily represent the official views of the National Institutes of Health.

Presented in poster format at the 35th annual meeting of the Society for Maternal-Fetal Medicine, San Diego, CA, Feb. 2-7, 2015.

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0002-9378/$36.00 • • http://dx.doi.org/10.1016/j.ajog.2015.05.021

TABLE 1
Baseline characteristics, lean vs obese gravidas

Characteristic	Lean	Obese	*P* value
n	29	30	
Weight			
Pregravid BMI, kg/m^2	22 ± 2	41 ± 4	.001
Study visit BMI, kg/m^2	27 ± 2	42 ± 4	.001
Weight gain, kg	12 ± 4	5 ± 7	.001
Body composition			
Percent lean, %	72 ± 5	57 ± 5	.001
Percent fat, %	28 ± 5	43 ± 5	

Presented as mean ± SD.

BMI, body mass index.

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hypotension and fetal heart rate abnormalities than lean gravidas.[25,26] These factors may contribute to the increased cesarean delivery rate and associated perioperative morbidity among class III obese women, such as hemorrhage, endometritis, wound infection, venous thromboembolism, and respiratory depression.[27-31]

We hypothesize that the obese gravida requires a larger volume infusion prior to sympathetic blockade and resulting peripheral venodilation than the normal-weight gravida.[3] Fluid volumes that are sufficient to expand intravascular volumes and avert hypotension in normal-weight women may be inadequate to prevent hypotension in obese women who have greater circulatory volume capacity. A better understanding of the blood volume of obese gravidas at term may contribute to alterations in intrapartum hemodynamic management. We sought to compare the total and relative blood volume of obese and lean gravidas near term using a dilution technique based on the colloid volume expander, hydroxyethyl starch (HES).[32] We also sought to compare these calculations to blood volume estimates based on weight alone.[7]

Materials and Methods

This study was performed in the Clinical Research Unit of the Case Western Reserve University Clinical Translational Research Collaborative (UL1 RR024989) at MetroHealth Medical Center, with institutional review board approval, and with written consent of each participant. All studies were performed on otherwise healthy women who were at least 18 years of age and at least 34 weeks' gestation. Women were recruited into 2 groups: lean (pregravid BMI <25 kg/m^2) and obese (pregravid BMI >35 kg/m^2). Women with preeclampsia, chronic hypertension requiring medication, insulin-dependent diabetes mellitus, renal or autoimmune diseases, bleeding disorders, congestive heart failure, and known allergy to corn or HES were excluded.

HES method

The HES method has been found to be highly accurate and precise and has been validated against the carbon-monoxide method in anesthetized neurosurgical patients in the intensive care unit.[32] HES is used clinically for plasma volume expansion in obstetric patients, and has been administered in various clinical trials for this purpose in the obstetric and anesthesia literature.[21,33-36] The HES method for blood volume estimation is a rapid, safe, and acceptable technique for use in pregnant patients, and does not cross the placenta.[32,33,37,38]

Proposed by Tschaikowsky et al[32] in 1997, the HES method uses HES as a dilution marker and calculates blood volume from the difference of glucose concentration obtained by acid hydrolysis of plasma before and after injection of HES.[39,40] Blood samples are collected before and after intravenous injection of HES. Derived plasma samples then undergo acid hydrolysis to disrupt the alpha glycosidic bonds and produce constant proportions of glucose and hydroxyethyl glucose. Comparison of hydroxyethyl glucose concentrations in the 2 samples yields a reproducible calculated total blood volume.[32]

Baseline measurements

Height, weight, blood pressure, pulse, and fetal heart tones were obtained on arrival at the medical center and used to calculate BMI and body surface area. Pregravid weights were obtained from direct measurements in the 3 months

TABLE 2
Blood volume estimation in lean and obese gravidas

Variable	Lean	Obese	*P* value
n	29	30	
Blood volume, mL			
BV-HES	6944 ± 2830	8103 ± 2452	.1
BV-FE	4417 ± 436	5568 ± 602	< .001
Blood volume, mL/kg			
BV-HES	95 ± 30	73 ± 22	.007
BV-FE	63 ± 4	50 ± 2	< .001

Presented as mean ± SD.

BV-HES, blood volume by hydroxyethyl starch method; *BV-FE*, blood volume by Feldschuh and Enson[7] equation based on sex, height, weight, and deviation from desired weight.

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