Usefulness of Shock Index and Delta Shock Index for Management of Postpartum Hemorrhage in Hypertensive Disorder in Pregnancy Cases

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Abstract

Background : Although the SI (Shock index; heart rate / systolic blood pressure) is a useful indicator in the management of PPH (postpartum hemorrhage), there are few reports of SI in pregnant women with complicated with HDP (hypertensive disorder in pregnancy) cases. HDP patients have a high systolic blood pressure and the bleeding volume may not be reflected in SI. The purpose of this study was to examine whether SI and Δ SI (peak SI–baseline SI) would be clinically useful indicators, and to detect the cut-off value for judging abnormal obstetric bleeding.

Methods: Retrospective case-control study in 107 patients with HDP in an single perinatal medical center. The values of prepartum SI, postpartum highest SI (peak SI), and the amount of bleeding until peak SI were retrospectively examined. The Kruskal-Wallis test was used to determine the relationship between peak SI, Δ SI and the amount of bleeding until peak SI. ROC(receiver operatorating characteristic) analysis was performed to determine the cut-off value.

Results: Both peak SI and Δ SI were significantly related to the amount of bleeding up to peak SI ($p < 0.001$). ROC analysis showed a cut-off values of peak SI where the amount of bleeding exceeded 500ml, 1,000ml, and 1,500ml. The values are 0.77 (sensitivity 64%, specificity 84%; AUC 0.81), 0.76 (sensitivity 87%, specificity 69%; AUC 0.86), 0.99 (sensitivity 100%, specificity 91%; AUC 0.97). And Δ SI, respectively, were 0.25 (sensitivity 66.6%, specificity 88.7%; AUC 0.84), 0.31 (sensitivity 81%, specificity 87.9%; AUC 0.91), and 0.43 (sensitivity 100%, specificity 93.1%; AUC 0.98).

Conclusion: In HDP cases, if the peak SI is greater than 0.99, similar to non-HDP pregnancies, or if the Δ SI is greater than 0.43, we need to recognize it as bleeding of 1,500ml or more. In addition, Δ SI may be a more sensitive and specific indicator than conventional peak SI in HDP cases.

Background

It has long been pointed out that the maternal mortality rate in Japan is high among the developed countries. The Japanese Association of Obstetricians and Gynecologists has started reporting maternal deaths nationwide from 2010. The purpose is to survey the actual maternal mortality situations and to identify problems of them.

These reports had shown that maternal mortality is most commonly caused by obstetrical critical bleeding, and is more common than in other countries. The first cardiac arrest due to obstetrical critical bleeding is often about two hours after the appearance of the first symptoms, and it is clear that there is no cardiac arrest within 30 minutes, and early intervention based on early recognition of the first symptoms may reduce maternal death [1]. Against this background, simulation training courses have been conducted nationwide to respond to sudden changes in maternity women. Early warning signs for pregnant women are important, and SI (Shock index; heart rates / systolic blood pressure) is one of them.

SI is emphasized in the Guideline for Critical Bleeding in Obstetrics 2017, which was prepared and revised by a committee consisting of five organizations, such as the Japan Society of Perinatal and Neonatal Medicine and the Japanese Society of Obstetrics and Gynecology. It is presumed that SI = 1.0 of pregnant women has a bleeding volume of about 1,500 ml, and SI = 1.5 has a bleeding volume of 2,500 ml. If SI is 1.0 or more, it is judged as critical bleeding. In the case of a primary facility, transport to medical center are considered [2]. In delivery, even small amounts of external bleeding can be life-threatening. It is necessary to pay attention to changes in SI. Thus, SI is an important indicator for management of PPH (postpartum hemorrhage). Traditionally, PPH has been defined as greater than 500 ml estimated blood loss in vaginal delivery.

However, there are few reports of SI in pregnant women complicated with HDP (hypertensive disorder in pregnancy) cases. HDP cases have a high systolic blood pressure and the bleeding volume may not be reflected in SI. In HDP cases, assessment that rely on SI may underestimate the severity of the disease.

Thus, we retrospectively evaluated whether conventional SI and Δ SI could be a clinically useful indicator in HDP cases.

Methods

Enrollment of participants

Of the 2117 cases (excluding miscarriages) delivered by our department (perinatal maternal and child medical center) from April 2013 to October 2019, 231 were HDP cases, of which 107 were HDP cases that were managed by vaginal delivery. In this study, we retrospectively examined these 107 cases. This study was approved by the University of occupational and Environmental health, Japan ethical committee (approval number; UOEHCRB20-033).

Data Collection

Maternal background and amount of bleeding immediately after delivery to 30 minutes, one hour postpartum bleeding, two hours postpartum bleeding, pre-partum SI (baseline SI), post-partum SI (highest values: peak SI) and the amount of bleeding up to peak SI after delivery were retrospectively examined from medical records and midwifery records. The timing of vital sign measurement and blood loss measurement was always measured immediately after delivery, after the inspection of the birth canal, after suturing, one hour after delivery, two hours after delivery. The amount of bleeding was calculated by subtracting the amount of amniotic fluid from the amount of blood collected in the clean drape laid on the buttocks of the pregnant woman and the amount of blood contained in the gauze used (both after subtracting the dry weight). Blood volume was assumed to be 1 ml / g. Immediately after delivery, all pregnant women were given an infusion of 5 units of oxytocin in 5% of glucose or 500 ml of extracellular fluid.

Statistical analysis

The peak SI was defined as the highest SI within two hours after delivery. When peak SI was observed from immediately after delivery to 30 minutes, the amount of bleeding up to peak SI was the amount of bleeding immediately after delivery to 30 minutes. When peak SI was observed one hour after delivery and two hours after delivery, the amount of bleeding up to peak SI was defined as the sum of one hour postpartum bleeding and two hours postpartum bleeding. The prepartum SI (baseline SI) was calculated from the resting heart rate and systolic blood pressure before the start of delivery. In the case of induced delivery, it was calculated from vital signs before induction of labor. If multiple blood pressure measurements were recorded, the average value was taken as the pre-partum SI (baseline SI). In the case of natural labor pain, it was calculated from vital signs at the latest medical checkup for pregnant women.

Δ SI was the value obtained by taking the difference between peak SI and prepartum SI (baseline SI) (Δ SI; peak SI-baseline SI).

Kruskal-Wallis equality-of-populations rank test was used for relationship analysis. A p-value less than 0.05 was judged to be significant.

ROC (receiver operating characteristic) analysis was performed to determine the cutoff values and sensitivity, specificity, and AUC (area under the curve) for bleeding volume of 500 ml, 1,000 ml, and 1,500 ml for each of peak SI and Δ SI, respectively.

Statistical analyses were completed using STATA version 14.0 (Texas, USA).

Results

107 (5.1%) HDP cases had vaginal delivery in our department during the study period. We summarize the obstetrical and maternal background and the types of medical intervention during labor (Table 1). The median maternal age was 32 years (19-44 years), the median number of weeks of delivery was 38 weeks 2 days (30 weeks 2 days-41 weeks 2 days), and 85 (79%) were term deliveries of these, 22 (21%) were preterm deliveries. The median BMI (Body-mass index) at delivery was 25.9 kg / m². 33 cases (30.8%) were performed vacuum extraction delivery, 15 cases (14%) were performed painless delivery using epidural anesthesia. Delivery management with administering magnesium sulfate and antihypertensive agents was in 46 cases (42.9%) and 36 cases (33.6%), respectively. Three cases (2.8%) required blood transfusion, all of which were transfused with 4 units of concentrated red blood cell transfusion, and used intrauterine balloon tamponade. The median bleeding volume was 481 ml (77-2474 ml). (Table 1).

50 cases with abnormal postpartum bleeding (bleeding volume 500 ml or more) and 57 cases with less than 500 ml bleeding volume. 78 cases (72.8%) had peak SI from immediately after delivery to 30 minutes, 17 cases (15.8%) from 30 minutes to one hour after delivery, and 12 cases (11.2%) from one hour to two hours after delivery.

Figure 1 shows the relationship between the peak SI, Δ SI (change in SI; peak SI-baseline SI), and the amount of bleeding up to peak SI. The distribution of peak SI and bleeding up to peak SI, the distribution of Δ SI and bleeding up to peak SI are not normal distributions, so we performed a test for the difference between the three groups (Kruskal-Wallis test). Both of peak SI and Δ SI showed significant difference between the 3 groups ($P < 0.001$), and the bleeding volume increased as the SI value increased (Table 2).

ROC (receiver operating characteristic) analysis was performed for each of peak SI and Δ SI, and cutoff values and sensitivity, specificity, and AUC (area under the curve) for bleeding volume of 500 ml, 1,000 ml, and 1,500 ml were determined, respectively (Table 3).

The cut-off values of peak SI with bleeding volume of 500 ml, 1,000 ml, and 1,500 ml or more are 0.77 (sensitivity 64%, specificity 84%; AUC 0.81), 0.76 (sensitivity 87%, specificity 69%; AUC 0.86) and 0.99 (sensitivity 100%, specificity 91%; AUC 0.97), respectively. Δ SI were 0.25 (sensitivity 66.6%, specificity 88.7%; AUC 0.84), 0.31 (sensitivity 81%, specificity 87.9%; AUC 0.91) and 0.43 (Sensitivity 100%, specificity 93.1%; AUC 0.98), respectively.

At any given bleeding volume, Δ SI was greater than peak SI in AUC, indicating superior sensitivity and specificity.

Discussion

The definition of PPH, which means massive bleeding at birth, is defined as the bleeding volume within 24 hours after delivery is 500 ml or more for vaginal delivery and 1,000 ml or more for cesarean section [3]. According to the 2019 report of the Perinatal Committee of the Japan Society of Obstetrics and Gynecology, analysis of a database of 236,475 Japanese pregnant women revealed that 52.4% of all cases had bleeding volume less than 500 g and 47.6% of all had bleeding 500 g or more. Bleeding of 1,000 g or more accounted for 16.4% of the total, and bleeding of 1,500 g or more accounted for 6.1% of the total. 90%tile of total bleeding is 800 ml for single vaginal delivery, 1,500 ml for cesarean delivery, 1,600 ml for multiple vaginal delivery, and 2,300 ml for cesarean delivery. In our study, the median total bleeding volume was 481 ml (77-2474 ml), close to the standard 500 ml for massive bleeding, and the 90% tile was 1,536 ml. It is considered that our center mainly handles high-risk delivery and that HDP itself is a high risk of abnormal postpartum bleeding. In this study, the amount of bleeding was assumed to be the weight of blood (assumed to be 1 ml/g) collected in a clean drape or gauze laid on the buttocks of pregnant women, but it was difficult to measure the actual amount of bleeding. Although the visual estimation of bleeding has been conventionally performed for postpartum management, it has been reported that the amount of bleeding may be underestimated by 33–50%, especially in cases of heavy bleeding [4]. It is necessary to recognize that the estimated value of the amount of hemorrhage at delivery may be inaccurate. The amount of amniotic fluid excreted with blood at the time of delivery is subtracted from the drape weight is subjective to the doctor or midwife, and may not reflect the actual amount of bleeding. Due to this background and the fact that the cause of obstetric shock is not only due to external bleeding, only measuring external blood loss as an indicator of PPH may not reduce the maternal

mortality. An obstetrical early warning system that emphasizes vital signs is now being introduced around the world, including Japan [5]. One of these is MEOWS (modified early obstetric warning system), which has been introduced at many facilities in the United Kingdom (UK). In the UK, maternal deaths have been registered for more than 50 years, and based on this, CEMACH (Confidential Inquiry into Maternal and Child Health) reported that there were some cases in which the prognosis was thought to have improved if treatment or transportation to a advanced medical facility was taken after noticing an early abnormality. Based on this report, MEOWS has been widely used and its validity has been verified [6]. MEOWS defines red and yellow trigger criteria for eight vital signs and clinical findings: body temperature, systolic blood pressure, diastolic blood pressure, Heart rate, respiratory rate, oxygen saturation, pain score, and neurological response. These items do not include the amount of external bleeding, nor do blood tests that take time to determine the results. It was reported that the sensitivity was 89%, specificity was 79%, the positive predictive value was 39%, and the negative predictive value was 98% in the prediction of obstetric complications including bleeding of 1,500 ml or more [7]. ACOG (American College of Obstetricians and Gynecologists) recommends that continuous bleeding, heart rate of 110 / min or higher, blood pressure of less than 85/45 mmHg, and blood oxygen saturation of less than 95% as triggers for suspected PPH [3] [8]. In Japan, the " Guideline for Obstetric Critical Bleeding 2017 " prepared and revised by a committee composed of five organizations, such as the Japanese Society of Perinatal and Neonatal Medicine and the Japanese Society of Obstetrics and Gynecology provide guidelines for dealing with PPH. In this guideline, a visual estimate of the amount of bleeding is one of the judgment indexes, but SI, vital sign abnormalities (oliguria, peripheral circulatory insufficiency), and obstetrical DIC score are also listed as indicators. It is characteristic that SI is a important indicator [2]. One of the reasons is considered to be the large number of deliveries at primary facilities in Japan. When PPH is observed at the primary facilities, transportation of a patient to a advanced medical facilities should be considered. Using SI as the indicator of PPH, the decision to transport a patient is simplified and clinical usefulness can be expected.

In recent years, many reports have been made on the normal range of SI in the delivery of so-called "low risk" pregnant women without complications. Borovac-Pinheiro A, et al. reported SI of uncomplicated pregnant women with less than 500 ml of bleeding two hours after delivery. According to their report, SI was highest within 20 minutes after delivery and tended to decrease with time. And the average SI values was 0.82 ± 0.14 and 0.79 ± 0.13 in the preterm birth range from 33 to 36 weeks and after 37 weeks, respectively [9]. Similarly, HL. Nathan, et al. reported blood pressure and SI of 316 pregnant women with less than 500 ml of bleeding up to one hour after delivery. The median SI was 0.66 (0.52–0.89), indicating that the normal SI value up to one hour after delivery was less than 0.9 (the risk of serious consequences increases with SI value of 0.9 or higher) [10]. HL.Nathan, et al. also conducted a retrospective study of 233 patients with postpartum bleeding of 1,500 ml or more. They evaluated vital signs up to one hour after diagnosing PPH. Among the various vital signs, SI was the most sensitive vital sign for predicting serious consequences (ICU; Intensive Care Unit admission, blood transfusion of 4 units or more, surgical intervention, Hb < 7 g / dl), and SI less than 0.9 was a reassuring state. They concluded that SI 0.9 or higer required caution, and 1.7 or higer was urgent state [11]. Thus, evidence has been

accumulated on the management of PPH in normal pregnancy, but there are few reports on the management of PPH in cases of complications or abnormal pregnancy, and this is the research task from now on [9].

We retrospectively examined whether SI and delta SI (Δ SI) were useful for estimating the amount of bleeding in HDP cases (50 cases with PPH). In this study, we used the conventional measurement of blood loss up to two hours after delivery. Borovac-Pinheiro A, et al. reported the amount of postpartum bleeding and vital signs in normal pregnancy over twenty-four hours. 73% of the amount of twenty-four hours bleeding was lost in the first 40 minutes after delivery, and 91% of participants had 90% of the amount of twenty-four hours bleeding within two hours after delivery [12]. It is considered that the evaluation of the amount of bleeding up to two hours after delivery is a valid evaluation method in a study examining the management of PPH.

The concept of the delta shock index (Δ SI) has been reported for its usefulness in the field of emergency department. The SI at the trauma site where the ambulance arrives is the baseline SI, and the change from the SI when the patient arrives at the Emergency room (Δ SI) is more sensitive than the conventional SI, resulting in an increase in mortality due to trauma, necessity of blood transfusion, and staying at the ICU [13]. In recent years, in the obstetrics field, Kohn JR et al. had been retrospectively examining vital signs in 41 cases of PPH in normal pregnancy and 41 cases in the control group. SI and Δ SI (peak SI-baseline SI) was a useful indicator, and Δ SI was reported to be the most sensitive indicator for predicting the necessity of treatment intervention [14].

In our study, SI and Δ SI are considered to be both useful and related to the amount of bleeding in the management of PPH in HDP, and Δ SI is more useful as an early warning system for obstetrics.

Consider the actual clinical response based on the results of this study. In HDP cases, at the time of SI is greater than 0.77, it is necessary to recognize that the bleeding volume is 500 ml, which is the definition of massive bleeding at delivery. When the SI reaches 0.99, a bleeding volume of 1,500 ml is expected. As with non-HDP pregnancies, it is required to treat PPH at the SI reaches 1.0 according to the flowchart of "Guideline for Critical Bleeding in Obstetrics 2017".

As an actual clinical response using Δ SI, at the time of Δ SI is 0.25, it is necessary to recognize that the volume of bleeding is 500 ml, which is the first definition of massive bleeding at delivery. Bleeding volume of 1,500 ml is expected at SI reaches 0.43, and it is necessary to respond as PPH. Management using Δ SI can be more sensitive to recognition of massive bleeding and abnormal bleeding than SI evaluation in the results of ROC analysis, Δ SI was excellent in sensitivity, specificity, and AUC at any of the 500 ml, 1,000 ml, and 1,500 ml bleeding volumes.

The limitation of this study is that it is a short-term retrospective case-control study in a singleton perinatal maternal and child medical center.

Also, as shown at the beginning of this discussion, the bleeding volume may be inaccurate. This is always a problem in the study of bleeding disorders such as bleeding due to trauma as well as postpartum hemorrhage. Especially with regard to postpartum hemorrhage the amount of amniotic fluid contained in the clean drape laid in the delivery field is determined by the medical staff.

Conclusions

In this study, we should recognize as an early warning of abnormal bleeding(bleeding 500 ml or more) when SI is greater than 0.77 or Δ SI is greater than 0.25 in HDP cases. If the SI is greater than 1.0, similar to non-HDP pregnancies, or if the Δ SI is greater than 0.43, we should recognize it as bleeding of 1,500 ml or more. In addition, Δ SI may be a more sensitive and specific indicator than conventional peak SI. Since Δ SI can be easily obtained, it may be more useful indicator for PPH management in HDP cases.

Abbreviations

ACOG American College of Obstetricians and Gynecologists

AUC Area under the curve

BMI Body-mass index

HDP Hypertensive disorder in pregnancy

ICU Intensive care unit

PPH Postpartum hemorrhage

ROC Receiver operating characteristic

SI Shock index

UK United Kingdom

Declarations

Ethics approval and consent to participate

This study was approved by the University of occupational health, Japan ethical committee (approval number; UOEHCRB20-033). According to Japanese ethical guideline of Ministry of Health, Labor and Welfare, opt-out was done for informed consent to participate.

Consent for publication

Not applicable

Availability of data and materials

The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Author's contributions

HM and ES designed the study. HM collected and assembly of data. TK conducted the statistical analyses.

HM drafted of the article and conducted critical revision of the article for important intellectuall content.

All the other co-authors (EK, UT, KY) made substantive contribution to the conception of the study.

All authors approved the final draft of the manuscript.

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Tables

Table 1. Obstetric maternal background and medical interventions during labor (n=107).

characteristics	n=107
age(year)	32(19-44)
gestational age	38w2d(30w2d-41w2d)
BMI (kg/m ²)	25.9(19.0-47.5)
parity (primi/para)	50/57
preterm/term	22/85
Blood loss (ml)	481(77-2474)
mode of delivery (vaginal/ vacuum extraction)	74/33
epidural anaesthesia	15 (14.0%)
use of magnesium sulfate	46 (42.9%)
use of antihypertensive agent	36 (33.6%)
blood transfusion therapy	3(2.8%)

Table 2. Correlation between blood loss volume up to peak SI and peak SI, blood loss volume up to Δ SI and Δ SI (Kruskal-Wallis test). P value was determined using the Kruskal-Wallis test. * Significant $p \leq 0.05$.

peak SI	Number	Blood loss (ml) 50%tile(25-75%tile)
<0.673	35	333(230-482)
0.674-0.78	36	373(212-531)
0.785<	36	729(475-1071)
p < 0.001*		
Δ SI	Number	Blood loss (ml) 50%tile(25-75%tile)
<0.138	35	273(188-422)
0.139-0.253	36	394(313-521)
0.254<	36	758(579-1098)
p < 0.001*		

Table 3. Cut-off value, sensitivity, specificity, AUC of peak SI and Δ SI at blood loss of 500ml, 1,000ml, 1,500ml

Blood loss		cut-off value	sensitivity	specificity	AUC
500ml	peak SI	0.77	64.4	83.9	0.85
	Δ SI	0.25	66.7	88.7	0.85
1000ml	peak SI	0.76	87.5	69.2	0.86
	Δ SI	0.31	81.3	87.9	0.91
1500ml	peak SI	0.99	100.0	91.2	0.97
	Δ SI	0.43	100.0	93.1	0.98

Figures

Figure 1

Correlation between blood loss volume up to peak SI and peak SI (above chart), blood loss volume up to peak SI and ΔSI (below chart).

Figure 1

Correlation between blood loss volume up to peak SI and peak SI (above chart), blood loss volume up to peak SI and ΔSI (below chart).