

OBSTETRICS

Impact of the Non-pneumatic Antishock Garment on pelvic blood flow in healthy postpartum women

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OBJECTIVE: The Non-pneumatic Antishock Garment (NASG) is a compression device that has shown significantly decreased blood loss in cases of obstetric hemorrhage. However, there are no physiologic studies of the NASG in postpartum women. This study used Doppler ultrasound to measure the resistive index (RI) in the internal iliac artery, thus approximating blood flow to the pelvis with and without the garment applied.

STUDY DESIGN: In this study, RI of the internal iliac artery was measured in a sample of 10 postpartum volunteers with and without the

NASG applied. Median RI was calculated and compared between baseline and full application.

RESULTS: Internal iliac artery median RI was 0.83 (SD 0.11) at baseline and increased to 1.05 (SD 0.15) with full NASG application ($P = .02$).

CONCLUSION: This study suggests a significant increase in internal iliac artery RI with NASG application and provides a physiological explanation of how the NASG might reduce postpartum hemorrhage.

Key words: Doppler ultrasound, internal iliac artery, Non-pneumatic Antishock Garment, postpartum hemorrhage, resistive index

Cite this article as: Lester F, Stenson A, Meyer C, et al. Impact of the Non-pneumatic Antishock Garment on pelvic blood flow in healthy postpartum women. *Am J Obstet Gynecol* 2011;204:409.e1-5.

Postpartum hemorrhage remains the leading cause of maternal death worldwide, particularly in developing countries where access to definitive treatment is often delayed and difficult to access. Thousands of women die of this preventable complication of childbirth each year. The Non-pneumatic Antishock Garment (NASG; ZOEX Corporation, Ashland, OR) is a neoprene and velcro device designed to reverse the effects of shock by shunting blood from the lower extremities and pelvis to the vital organs.¹ The NASG is composed of

lower extremity segments, a pelvic segment, and an abdominal segment, which includes an abdominal compression ball to provide increased pressure specifically to the lower abdomen and pelvis. This device has been shown in preliminary trials in Egypt and Nigeria to not only reverse shock and improve maternal outcomes, but also to significantly decrease blood loss by 33-78%.^{2,3} This finding suggests that in addition to shunting blood from the lower extremities and providing autotransfusion, the NASG may have a direct effect on the pelvic vascu-

ture, inhibiting blood flow to the pelvic organs and decreasing blood loss.

The Pneumatic Antishock Garment (PASG) predated the NASG and although it initially showed promise for use in general trauma, several studies including a Cochrane Database Review raised concerns about the safety and efficacy of the PASG in these patients.⁴ Despite these findings in general trauma, the PASG gained recognition as a possible first-aid device for obstetric hemorrhage based on several case reports that documented favorable outcomes in cases of severe hemorrhage and shock.⁵ These findings are consistent with the thinking that the PASG has differential effectiveness depending on whether blood loss is from injuries below the waist vs above the waist.⁵ The favorable case reports in obstetrics were further supported by studies of the hemodynamic impact of the PASG showing a significant decrease in aortic blood flow below the level of the renal arteries, suggesting that the device would be useful for stemming blood loss from the uterus that is supplied by a branch of the internal iliac artery, a branch of the distal aorta below the renal arteries.^{6,7}

The presumed mechanisms of action underlying the utility of the antishock

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Presented, in part, at the XIX World Congress of Gynecology and Obstetrics of the International Federation of Gynecology and Obstetrics, Cape Town, South Africa, Oct. 4-9, 2009.

Received Oct. 27, 2010; revised Dec. 22, 2010; accepted Dec. 27, 2010.

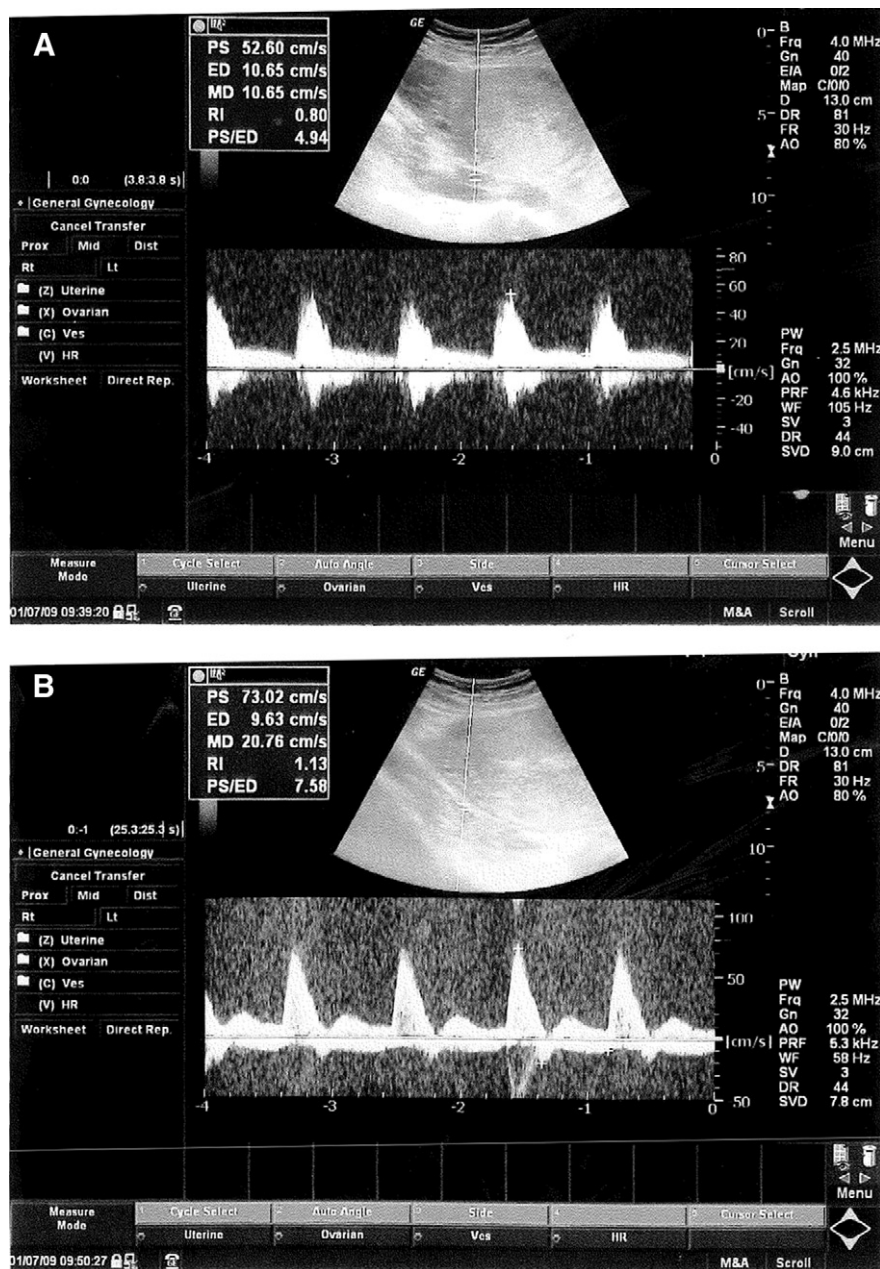
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The study was funded by the Program for Appropriate Technology in Health and a grant from the Clinical and Translational Science Institute, University of California, San Francisco, CA.

0002-9378/\$36.00 • © 2011 Mosby, Inc. All rights reserved. • doi: 10.1016/j.ajog.2010.12.054

FIGURE 1

Doppler images of internal iliac artery with and without NASG applied



A, NASG not applied, resistive index (RI) = 0.80 indicating forward flow. **B**, NASG fully applied, RI = 1.13 indicating absent or reverse flow.

NASG, Non-pneumatic Antishock Garment (ZOEX Corporation, Portland, OR).

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garment are based on 3 laws of physics.^{1,8} Poiseuille law states that the flow rate through a vessel is exponentially related to the radius of the vessel. Laplace law describes how tension is related to transmural pressure and the radius of a vessel. Bernoulli principle describes how the rate of bleeding depends on the size of

the opening of the vessel and the transmural pressure. The circumferential pressure provided by the antishock garment compresses the radius of blood vessels and decreases the transmural pressure, which, according to these laws, should have important physiologic effects. First, the compression of the ves-

sels should cause increased systemic vascular resistance, which decreases blood flow peripherally. Thus, if the blood cannot flow forward, it will back up and increase the blood flow through the non-compressed vessels, which should lead to increased preload and cardiac output, effectively providing autotransfusion. Second, it should lessen blood flow through the compressed vessels and if blood is being lost through these open vessels, this should result in a decrease or cessation of bleeding due to tamponade.

Like the PASG, the NASG applies circumferential counterpressure, but uses neoprene, a foam compression ball, and velcro rather than inflatable segments to do so.¹ It is thought that the NASG is particularly well designed for treatment of obstetric hemorrhage because it can be rapidly applied, has a compression ball over the abdomen, and avoids the risk of overinflation that can lead to side effects.⁵ Although there is evidence from nonrandomized clinical trials that the NASG can decrease blood loss and reverse shock associated with obstetric hemorrhage, and a recent study has demonstrated decreased blood flow in the distal aorta with application of the NASG, there are no published studies of the impact of the NASG on pelvic blood flow in postpartum patients.⁹

The objective of this study was to use a noninvasive method to estimate blood flow to the pelvis in nonhemorrhaging postpartum patients with the NASG applied. Delineating the physiologic mechanism of action of the NASG on pelvic blood flow is important for understanding how the NASG can impact blood loss due to obstetric hemorrhage.

MATERIALS AND METHODS

Approval for this study was obtained from the University of California, San Francisco, Institutional Review Board and from the Program for Appropriate Technology in Health Institutional Review Board. Participation was voluntary and all study subjects gave written informed consent.

This study was conducted at San Francisco General Hospital on the labor and delivery ward from June 2008 through

FIGURE 2

Photographs of Non-pneumatic Antishock Garment at different phases of application



A, Not applied. B, Leg segments applied. C, Full application.

NASG; ZOEX Corporation, Portland, OR.

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January 2009. Healthy female postpartum volunteers were recruited within 24 hours of a vaginal delivery. They were excluded if they had any underlying health problems, a cesarean section, an operative delivery, blood loss >500 mL postpartum, delivered >24 hours ago, a nonsingleton pregnancy, preeclampsia, an unstable hematocrit, pulmonary or cardiac problems, an unhealthy newborn, did not speak English or Spanish, or were <18 years of age. Demographic data were collected including patient age, gravidity, parity, and body mass index. The type of delivery, time since delivery, and uterotonic administration were noted. The objective of this study was to estimate the change in blood flow to the pelvis with application of the NASG. To use the least invasive form of evaluation possible, the blood flow was

measured using transabdominal ultrasonography of the internal iliac artery. The internal iliac artery provides the blood supply to the pelvis and was able to be visualized using transabdominal ultrasound even with the NASG in place.

The resistive index (RI) of the internal iliac artery was measured as an approximation of pelvic blood flow. RI measurement is noninvasive and can be easily obtained using standard equipment available in the obstetrics department and provides information on the distal vessels of interest.¹⁰ The RI is defined as the peak of systole divided by the sum of systole and diastole [$RI = S/(S + D)$]. A higher RI is correlated with decreased blood flow to a given vessel. A value <1.0 indicates forward flow; whereas a value of ≥ 1.0 indicates absent or reverse flow (Figure 1).

An ultrasonographer used portable Doppler ultrasound to measure the RI in the internal iliac artery with incremental application of the NASG. Figure 2 shows the NASG at 3 different stages of application. We sequentially measured the vital signs and internal iliac artery RI at the following 9 time points:

1. Baseline.
2. Immediately after application of the leg segments.
3. Ten minutes after application of the leg segments.
4. Immediately after full application of the NASG.
5. Ten minutes after full application.
6. Immediately after removal of the abdominal segment.
7. Ten minutes after removal of the abdominal segment.
8. Immediately after removal of all segments.
9. Ten minutes after removal of all segments.

Patients were asked to report any side effects they experienced during the monitoring period and this information was recorded.

Data were entered into Microsoft Excel for Mac 2008 (Microsoft Corp, Redmond, WA) and analyzed using JMP, version 8, SAS software package (SAS Institute, Cary, NC). Comparative statistics were reported using Wilcoxon matched-pairs signed-rank tests.

TABLE 1

Participant demographics

Participant demographics	Mean (range) n = 10
Age, y	25 (18–37)
BMI	27.8 (21–33)
Gravidity	2.7 (1–7)
Parity	2.4 (1–6)
Gestational age, wk	40 (39–41)
Time since delivery, h	12 (2–18)

BMI, body mass index.

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RESULTS

All 10 patients in this study delivered by normal spontaneous vaginal delivery. The majority (9/10) had received prophylactic intravenous oxytocin after delivery, while 1 had not received any uterotonics. The mean time from delivery to study inclusion was 12 hours (range, 2–18 hours). Mean age, gravidity, parity, and gestational age at time of delivery are described in Table 1. The majority of patients were normal weight, none were underweight, and 4 were overweight.

The median internal iliac RI at the 9 time points is shown in Table 2 and depicted graphically in Figure 3. There was little change in RI from baseline (0.83, SD 0.11) with application of the leg panels (0.84, SD 0.12). When the abdominal panel was applied, the median value in-

TABLE 2

Median resistive index (n = 10)

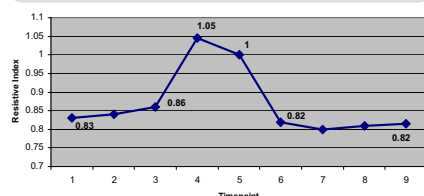
Time point	Median RI	SD
1	0.83	0.11
2	0.84	0.12
3	0.86	0.14
4	1.05	0.15
5	1.0	0.15
6	0.82	0.04
7	0.80	0.13
8	0.81	0.11
9	0.82	0.08

RI, resistive index.

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FIGURE 3

Median resistive index with application of Non-pneumatic Antishock Garment at 9 time points (n = 10)



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creased significantly (1.05, SD 0.15) and stayed high after full application for 10 minutes (1.00, SD 0.15). The RI rapidly returned to baseline with removal of the abdominal segment (0.82, SD 0.04), and remained low and near baseline after the removal of the entire garment (0.81, SD 0.11). There was a significant change in RI from baseline to full application (Wilcoxon matched-pairs signed-rank test; $P = .02$), as depicted in Figure 4. Vital signs remained stable throughout the application with little change noted in any of the parameters.

COMMENT

This study demonstrates a significant increase in the RI of the internal iliac artery with application of the NASG in healthy postpartum women. The internal iliac artery supplies the majority of blood flow to the uterus via the uterine arteries and thus this finding is consistent with the decrease in blood loss from postpartum hemorrhage that has been reported in published studies of the NASG.^{2,3,11} The observed increase in the RI of the internal iliac artery with NASG application provides a physiologically plausible mechanism to explain how hemorrhage is reduced by NASG application.

There are several methods for analyzing Doppler blood flow including flow volume or velocity measurement, resistance indices, and waveform analysis.¹⁰ Flow volume analysis most closely approximates true blood flow; however, it is difficult to perform and prone to error, as accurate measurement is dependent on the angle of insonation, vessel diam-

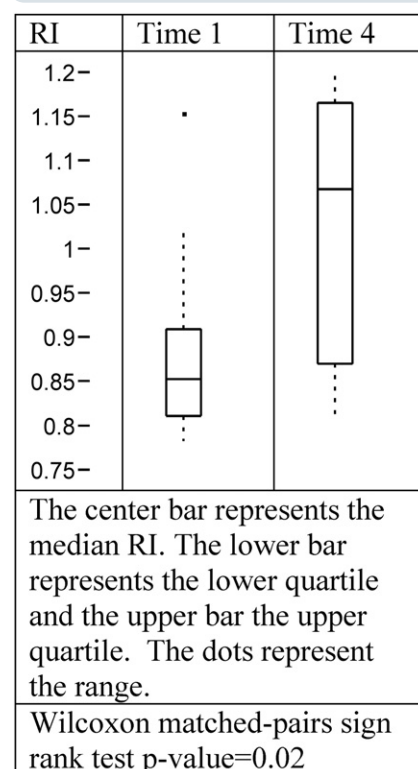
eter measurement, and the tortuosity of the vessels. Most ultrasounds used in routine obstetrics are not able to calculate flow volume due to the high analytic requirements of these calculations. Resistance indices are indirect measures of flow volume; however, they are angle independent and are considered to be useful for estimating blood flow in vessels distal to the point of the examination. One drawback of RI calculation is that it may not be as accurate in cases when blood flow is not continuous throughout the cardiac cycle. Waveform analysis is more complicated; however, it may provide a more accurate estimate of blood flow in conditions of noncontinuous blood flow during the cardiac cycle.¹⁰

In this study, the blood flow to the pelvis was measured transabdominally using Doppler ultrasound. Due to the location of the NASG's abdominal/pelvic segment and uterine compression ball in relationship to where the transabdominal ultrasound probe should be placed to image the uterine artery, an accurate measurement of the RI in these vessels was not possible. However, we were able to measure the RI in the internal iliac arteries with a transabdominal approach, which approximates blood flow to the pelvis and is an indirect measure of blood flow to the uterus. Future studies might consider transvaginal imaging to attempt to directly capture blood flow through the uterine arteries.

This study was conducted in euvolemic volunteers who were not suffering from hemorrhage or shock. Vital signs remained stable in the volunteers in this study; however, we know from NASG studies conducted with patients suffering from hypovolemic shock that there is a rapid and significant improvement in vital sign parameters (blood pressure, pulse, and shock index) with NASG placement.¹¹ It is likely that the cardiovascular profile would differ significantly between euvolemic volunteers and women with hemorrhagic shock. Moreover, the mean time from delivery was 12 hours in this study thus the findings do not represent the immediate postpartum physiology when most hemorrhagic shock occurs. Investigation of the hemodynamics and cardiovascular

FIGURE 4

Comparison of median resistive index (RI) at baseline and full application



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physiology in patients with active hemorrhage and shock would better characterize the true effect of the NASG on obstetric hemorrhage in the immediate postpartum period.

This study was limited by a small sample size, the use of an indirect measure (RI) of blood flow, the use of the internal iliac artery instead of the uterine artery, the use of transabdominal rather than transvaginal ultrasound, and by the use of healthy non-hemorrhaging volunteers who were studied a mean of 12 hours after delivery. Future studies should focus on understanding how the NASG works in patients who are in hypovolemic shock immediately following delivery, should use more direct measures of uterine blood flow with transvaginal ultrasound and potentially the use of flow volume measurements, and should endeavor to more fully characterize the cardiovascular effects of the NASG, including measurement of venous return,

cardiac output, central venous pressure, and systemic vascular resistance.

Despite these limitations, application of the NASG appears to significantly increase the RI of the internal iliac artery, providing a plausible physiologic explanation for decreased blood flow to the pelvis and the finding of decreased blood loss in patients with obstetric hemorrhage who are treated with the NASG. This study is an initial step toward explaining one of the NASG's mechanisms of action. Further investigation is merited to more fully understand the physiologic impact of the NASG in obstetric patients with hemorrhagic shock. ■

ACKNOWLEDGMENTS

The following individuals contributed to the study professionally: Jennifer Clark, Hilarie Martin, Elizabeth Butrick, Sheri Lippman.

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