



ELSEVIER

5

Anti-shock garment in postpartum haemorrhage

Suellen Miller* CNM, PhD

Director, Safe Motherhood Programs

Hilarie B. Martin BA

Data Analyst, Safe Motherhood Programs

Jessica L. Morris MA

Project Specialist, Safe Motherhood Programs

Department of Obstetrics, Gynecology and Reproductive Sciences, University of California, San Francisco, 50 Beale Street, San Francisco, CA 94105, USA

The non-pneumatic anti-shock garment (NASG) is a first-aid device that reverses hypovolaemic shock and decreases obstetric haemorrhage. It consists of articulated neoprene segments that close tightly with Velcro™, shunting blood from the lower body to the core organs, elevating blood pressure and increasing preload and cardiac output. This chapter describes the controversial history of the predecessors of NASG, pneumatic anti-shock garments (PASGs), relates case studies of PASG for obstetric haemorrhage, compares pneumatic and non-pneumatic devices and posits why the NASG is more appropriate for low-resource settings. This chapter discusses the only evidence available about NASGs for obstetric haemorrhage – two pre-post pilot trials and three case series – and describes recently initiated randomized cluster trials in Africa. Instructions and an algorithm for ASGs in haemorrhage and shock management are included. Much remains unknown about the NASG, a promising intervention for obstetric haemorrhage management.

Key words: anti-shock trousers; maternal mortality; postpartum haemorrhage.

INTRODUCTION

An estimated 150,000 women die from obstetric haemorrhage each year; most of these deaths occur in low-resource settings. Death from obstetric haemorrhage is particularly

* Corresponding author: Tel.: +415 597 9394; Fax: +415 597 9300.
E-mail address: suellenmiller@gmail.com (S. Miller).

horrific because it is preventable. Long delays in reaching emergency obstetric care are at the root of many maternal deaths.¹ Definitive haemorrhage therapies, blood transfusions and surgery are often hours or days away from the home or facility where many birthing women begin to haemorrhage. Obstetric haemorrhage can be fatal even in high-resource settings, such as the United Kingdom; 10 of the 17 maternal mortalities that occurred during 2003–2005 were from postpartum haemorrhage (PPH).^{2,3}

One recently recommended first-aid device for obstetric haemorrhage is the non-pneumatic anti-shock garment (NASG).^{4,5} The NASG, a lower body suit of articulated neoprene and Velcro™ segments, provides lower body circumferential counter-pressure that restores blood pressure to the core. In pilot studies of obstetric haemorrhage, the NASG significantly decreased bleeding by 50%, decreased morbidities and improved survival.^{6,7}

This chapter describes the NASG's predecessors – lower body counter-pressure devices known collectively as anti-shock garments (ASGs) – delineates differences between NASGs and other ASGs, explains why the NASG is relevant for low-resource settings, describes best practice use of NASGs, and discusses ongoing efficacy trials and other research necessary before the NASG is included in the routine management of obstetric haemorrhage and shock.

METHODS

A four-stage review of the literature included: (1) a search of electronic databases – PubMed, EMBASE, and the Cochrane Library – using the terms 'anti-shock garment', 'anti-shock trousers', 'G-suit', 'anti-gravity suit', 'pneumatic suit', 'PASG' and 'NASG' for articles, abstracts and reviews published from 1903 to January 2008; (2) a hand search of these articles, as well as other known articles and presentations, including the authors' own work and personal reference lists; (3) a review of references from all retrieved papers; and (4) personal communications with ASG experts.

This search yielded 556 articles, which were hand searched to eliminate those not related to hypovolaemic shock from trauma or obstetric/gynaecological aetiologies. Only 73 remained, 21 of which were evidence-based. These included four animal studies, four pre-hospital prospective randomized controlled trials (RCTs), one meta-analysis, six obstetric case series, one guideline for emergency medicine, two pre-post comparative studies and three case series of the NASG for obstetric haemorrhage. One of the authors (Miller) is conducting RCTs with the NASG; the best practice recommendations are adapted from the clinical trial protocols.

HISTORICAL DEVELOPMENT

In 1903, George Crile developed the first hypovolaemic compression suit. It increased peripheral resistance, reduced bleeding and sustained blood pressure. Crile's device was temporarily abandoned after the introduction of safe blood transfusion technology.⁸ The concept was re-introduced during World War II when the anti-gravity suit (G-suit) was developed to prevent syncope during rapid ascent. During the Vietnam War, G-suits were used to resuscitate and stabilize battlefield casualties.⁹ The G-suit was later modified from a full-body suit to a half-suit¹⁰, called Military/Medical® Anti-Shock Trousers (MASTs), or pneumatic anti-shock garments (PASGs).

MECHANISMS OF ACTION

All ASGs have the same mechanisms of action. Circumferential compression of the abdomen and legs reduces total vascular volume (container size) while expanding the central circulation. In animal studies, the translocation of blood has been estimated to be 750–1000 mL (up to 30%).¹¹ Garment application results in increased preload, peripheral resistance and cardiac output. Tamponade of vessels, particularly the splanchnic plexus, can diminish further bleeding.^{12,13} The physiological basis for these benefits - Poiseuille's law, Laplace's law and the Bernoulli principle - have been described in detail elsewhere^{11,14} and are outlined in Table I.

ANIMAL STUDIES

Much of the supportive data for the physiological effects of ASGs come from animal studies (Table 2) that have demonstrated decreased bleeding, increased systolic blood pressure (SBP) and increased survival.

PASG IN EMERGENCY MEDICINE

PASGs were introduced into civilian emergency medicine in 1973; the successful report of this introduction¹⁹ initiated a wave of acceptance.²⁰ PASGs were used for shock and trauma, including pelvic and lower-limb fractures, and hypovolaemic and septic shock.^{11,19,21–23} Despite the lack of positive RCTs in 1977 the American College of Surgeons' Committee on Trauma included PASGs as essential equipment for ambulances.²⁴

Contraindications included injuries above the diaphragm, congestive heart failure and pulmonary oedema.¹⁹ A variety of reported adverse effects of PASG use include: decreased urine output, increased intra-operative blood loss, hypoxia,

Table I. Laws of physics underlying the mechanisms of action of anti-shock garments.

Poiseuille's law: $F = (P_1 - P_2) R^4 / 8N \cdot L$

F, flow; P_1 , entrance pressure; P_2 , exit pressure; R, radius; N, viscosity; L, length

Flow rate through a blood vessel is related to the vessel's radius; rate per unit time is related to the fourth power of the radius^{11,14}

Laplace's law: $T = P \cdot R$

T, tension inside blood vessel; P, transmural pressure; R, vessel radius

External counter-pressure compresses lower body and splanchnic vessels, reduces transmural pressure and vessel radius. These synergistic effects reduce the difference in tension across the vessel, reducing blood loss¹⁴

Bernoulli's principle: $Q = (A \cdot P + 2V) / E$

Q, rate of leakage; A, area of laceration/tear/opening; P, transmural pressure; E, density of blood; V, speed or velocity of blood flow

Rate of leakage from open blood vessels depends on the size of the defect and the intraluminal pressure and the extraluminal pressure (together represented by transmural pressure). External pressure compresses torn vessel walls and reduces the area of the defect^{11,14}

Table 2. Pneumatic anti-shock garments (PASG) animal studies.

Author, year [ref. no.]	Study design	Outcomes
Gardner and Storer, 1966 ¹⁵	Case series of 8 dogs with transected intra-abdominal aortas treated with pneumatic abdominal sleeve	Sustained mean SBP 74 mm Hg (40–110 mm Hg); when sleeve deflated after 1 hour, 6 of 8 dogs lost blood pressure and died within 5 minutes; 2 dogs survived 30 and 40 minutes after deflation; both showed sealing at the aortic incision
Gardner, 1969 ¹⁶	Comparative study of 16 dogs with wounds to the iliac artery (8 PASG, 8 control)	All controls died within minutes of the surgical incision; 8 PASG-treated dogs survived until the PASG was deflated 60 minutes later; 75% of survivors died within 5 minutes of deflation
Aberg et al., 1986 ¹⁷	Comparative study of 30 rats (5 control, 5 PASG alone, 10 saline infusion alone, 10 PASG with saline infusion) subjected to lethal hepatic and retro-hepatic caval vein injury	PASG-alone group showed increase in median survival time: 120 minutes (114–120) vs. 10 minutes (9–26) in control group; 9 of 10 animals with combined PASG and infusion treatment developed pulmonary oedema
Ali and Duke, 1991 ¹⁸	Comparative study of 12 anaesthetized dogs with splenic crush injuries (6 control, 6 PASG).	PASG-treated group survived twice as long as control group (2 hours vs. <1 hour); blood loss in PASG-treated group significantly decreased (1.6 ± 0.9 mL/minute vs. 9.4 ± 1.4 mL/minute, $p < 0.05$); PASG effectively maintained blood pressures: PASG-treated groups' SBP 102 mm Hg after 1 hour, controls' SBP 0 mm Hg after 1 hour

ischaemia, dyspnoea or other forms of respiratory distress, increased acidosis and the development of compartment syndrome.^{8,11,21,25–32}

A team of researchers conducted a 2.5-year randomized, prospective study of PASG for pre-hospital treatment of hypotensive trauma patients in urban Houston, Texas, USA. Patients with entry SBP ≤ 90 mm Hg were randomized into control and PASG groups by alternate-day methodology. There were no significant differences in paramedic management, demographics or injury type. Two key analyses were published^{26,32}; a third analysis²⁸ included one additional year of enrolment. Chang et al.³³ later conducted a similar RCT. All four reports (Table 3) failed to demonstrate efficacy of PASG in reducing morbidity or mortality.

A Cochrane meta-analysis ($n = 1075$)³⁴ found the PASG group to have a non-statistically significant higher risk of death [relative risk (RR) 1.13, 95% confidence interval (CI) = 0.97 to 1.32], and longer stays in the ICU (RR 1.7 days, 95% CI = 0.33 to 2.98). The authors also noted the poor quality of the trials.

Table 3. Pneumatic anti-shock garment (PASG) randomized, controlled trials in human emergency medicine.

Author, year [ref. no.]	Number, type of trauma	Outcomes
Pepe et al., 1986 ³²	401 patients: 74 primary truncal injuries, 175 penetrating abdominal injuries, 152 penetrating thoracic injuries	No statistically significant differences in survival; compartment syndrome in three PASG patients
Bickell et al., 1987 ²⁶	201 patients (97 PASG, 104 control) all with gunshot or stab wounds to anterior abdomen	Survival rates higher in the non-PASG group (77.9% vs. 69.1% in PASG group, $p = 0.097$)
Mattox et al., 1989 ²⁸	784 patients (345 PASG, 439 control)	PASG required longer stays in intensive care unit (ICU) (3.7 ± 12.5 days vs. 1.9 ± 6.5 , $p < 0.05$) and had lower survival rates (69% survival rate for PASG patients vs. 75% for control, $p < 0.05$)
Chang et al., 1995 ³³	248 trauma patients (95 PASG, 153 control)	PASG group had longer hospitalizations (11.2 ± 34.3 days vs. 8.5 ± 17.0 days for control, ns) and lower survival rates (59.0% PASG vs. 62.1% control, ns)

All studies were prospective RCTs with alternate day randomization.

The results from these pre-hospital RCTs might be confounded by the inclusion of patients with upper-body injuries and by the urban setting, with rapid transport to trauma hospitals available; the time required for PASG application might have delayed such transport.²⁰ Additionally, these RCTs did not control for confounders such as age, haemorrhage severity or time to garment application.³⁵

Current status in emergency medicine

After publication of these RCTs, PASG use became controversial.^{31,34,36,37} In 1997, the PASG was deemed 'effective' by the National Association of EMS Physicians for ruptured abdominal aneurysms only²², and 'potentially beneficial' for pelvic fracture or lower-extremity haemorrhages.³⁸ Some emergency medical practitioners still recommend the PASG for pre-hospital care²⁰, and it remains in emergency medicine curricula and textbooks.^{36,39}

PNEUMATIC ANTI-SHOCK GARMENTS (PASG) FOR OBSTETRIC HAEMORRHAGE

Although there are no PASG RCTs for obstetric haemorrhage, case studies are described elsewhere¹⁴ and are summarized in Table 4.

These cases indicate that the PASG can be useful in managing obstetric haemorrhage, as a temporizing measure before definitive treatment or as a last resort

Table 4. Pneumatic anti-shock garment (PASG) case studies of obstetric haemorrhage.

Author, year [ref. no.]	Number, aetiologies	Interventions before PASG	Outcomes after PASG
Gardner et al., 1958 ⁴⁰	1 woman with placenta percreta and uncontrollable haemorrhage	Patient received >57 units of blood during failed surgery for adherent placenta, abdominal hysterectomy and ligation of internal iliac arteries; had uterine packing. BP 86/62, pulse 144, haemorrhage continued	After PASG only one additional unit of blood was required; patient stabilized with BP 104/72
Hall and Marshall, 1979 ⁴¹	4 women with ruptured ectopic pregnancies for pre-surgical treatment	None reported; IV fluid replacement began at same time as PASG application	All had decreased blood loss, improved vital signs and improved organ perfusion
Pelligra and Sandberg, 1979 ³⁰	Three women with obstetric haemorrhage: <ol style="list-style-type: none"> Intra-abdominal bleeding post caesarean section Placenta praevia, caesarean section, disseminated intravascular coagulopathy (DIC) Post-hysterectomy, placenta accreta 	<ol style="list-style-type: none"> 31 units whole blood, 8 units fresh frozen plasma (FFP), 4 units platelets, 7 units packed red blood cells (RBC) and cryoprecipitate over 30 hours 8 units packed RBCs, 6 units platelets and 4 units FFP 63 units blood, 25 units FFP, 18 units cryoprecipitate and 132 platelet packs 	<ol style="list-style-type: none"> Condition stabilized within 1 hour of PASG placement Transferred 56 km to fully equipped facility where patient received additional blood products and remained stable Responded quickly when PASG placed
Sandberg and Pelligra, 1983 ⁴²	3 women with obstetric haemorrhage (one was previously reported in Pelligra & Sandberg 1979) described above	<ol style="list-style-type: none"> Intrauterine gestation treated by laparotomy after >5000 mL of blood loss Hysterectomy following spontaneous foetal death 	Application of PASG led to increased blood pressure and decreased blood loss for both women
Andrae, 1999 ⁴³	2 women with hypovolaemic shock due to uterine bleeding:	Both received uterotonics, pressors, IV fluids, blood and blood components	PASG provided temporizing stabilization; bleeding ceased while PASG was in place, but

Table 4 (continued)

Author, year [ref. no.]	Number, aetiologies	Interventions before PASG	Outcomes after PASG
	1. Placenta accreta 2. Undiagnosed severe uterine bleeding		started again after PASG removal; radiological intervention by transcatheter embolization was needed for full recovery
Ramachandran and Kirk, 2004 ⁴⁴	1 woman post-caesarean section for abdominal pregnancy	IV infusions, two surgeries to remove the infant and placenta, blood and blood products, abdominal packing; patient remained hypotensive, continued bleeding and developed DIC	PASG effected decreased bleeding, increased blood pressure; coagulation profile improved rapidly

when other methods have failed. Further support for PASG use for obstetric haemorrhage is a Doppler study of regional blood flow in ten healthy adults.⁴⁵ PASG inflation resulted in decreased aortic blood flow from the superior mesenteric to immediately below the renal arteries. In France, the '*pantalon antichoc*' is endorsed for postpartum haemorrhage, disseminated intravascular coagulations of pregnancy, and other obstetric and gynaecological bleeding.⁴⁶

Currently, there is interest in treating women with hypovolaemic shock secondary to obstetric haemorrhage in low-resource settings with a lower-technology, easy-to-apply first-aid device such as the NASG.^{4,5,12,47}

NON-PNEUMATIC ANTI-SHOCK GARMENTS (NASG)

The NASG is a lightweight, relatively inexpensive, washable neoprene suit composed of articulated horizontal segments with three segments on each leg, one segment over the pelvis and another, over the abdomen, which includes a foam compression ball (Figure 1). Using the three-way elasticity of neoprene and the tight closure of the Velcro™, the garment applies 20–40 mm Hg circumferential counter-pressure to the lower body to reverse hypovolaemic shock by shunting blood to the vital core organs.¹⁴

The garment was developed in 1971 by Dr Ralph Pelligra of the National Aeronautics and Space Administration/Ames Research Centre (NASA/Ames).⁴⁸ In 1991, the NASG (Zoex Corporation, Ashland, OR, USA) received a US Food and Drug Administration 510(k) medical device regulations number. Based on the PASG's circumferential counter-pressure, but without air bladders, manometers, stop-cocks, foot pump and tubing, and the associated risks of over-inflation and subsequent ischemia, the NASG is a promising first-aid treatment for haemorrhagic shock.^{6,7,12,14,49–52}



Figure 1. Patient wearing non-pneumatic anti-shock garment (NASG).

ADVANTAGES OF NASG FOR OBSTETRIC HAEMORRHAGE

Despite the lack of RCTs, it is speculated that NASG use for obstetric haemorrhage in low-resource settings might yield better results than the PASG trauma RCTs.¹⁴ First, the NASG avoids some PASG-related adverse outcomes due to its design, being non-inflatable and applying a lower pressure to the body (20–40 mm Hg¹⁴ vs. PASG ≤ 104 mm Hg⁵³). Second, the NASG, used for obstetric haemorrhage, would be applied to reduce bleeding in the pelvic region, the region demonstrated to have the greatest effect from compression.⁴⁵ Third, the negative PASG RCTs might be associated with the studies' urban settings, where transport to specialized trauma units is quick. Non-PASG patients might have benefited from more rapid definitive treatment, as acknowledged by the studies' authors.^{26,28,33}

The majority of maternal mortalities occur far from healthcare facilities and/or at facilities unable to provide rapid definitive treatment.^{1,4,54} The NASG could be a first-aid temporizing device for women who face delays in obtaining emergency obstetric care. The simplicity of the NASG adds to its utility for use in community settings where healthcare providers might be alone or have minimal training. The differences between the PASG and NASG are summarized in [Table 5](#).

NASG STUDIES

NASG use for obstetric haemorrhage in low-resource settings was first explored in two case series at a tertiary-level maternity hospital in Sialkot, Pakistan, where there was no blood bank. Hensleigh¹² described six women with obstetric haemorrhage, in moderate to severe shock. All patients were managed with a protocol of immediate NASG application, fluid replacement, blood transfusions, uterotonics and procedures/operations as needed. Resuscitation was defined as restoration of mean arterial pressure (MAP) to ≥ 70 mm Hg and clearing of sensorium. All women experienced rapid resuscitation and remained stable while awaiting definitive treatment.

Table 5. Non-pneumatic anti-shock garments (NASG) vs. pneumatic anti-shock garments (PASG).

	PASG*	NASG
Personnel required	At least 2 authorized personnel (emergency medical technicians/ paramedics with PASG training and certification) ^{55,56}	1 person, no medical background required ^{6,7,12,14,49,51,52,57,58}
Complexity	High; may require removing patient's clothing or at least removing sharp objects from clothing, inflation at multiple points, may require binding in place with tape, possible pressure measuring with specialized equipment and re-inflation or deflation as necessary, managing PASG variations ^{53,55,59}	Low; easy to apply, may be worn over clothing, no inflation required ^{6,7,12,14,49,51,52,57,58}
Training necessary for application	Depending on regional protocols >10 hours, regular practice and periodic re-training and exam ^{56,59}	<1 hour basic training with practice ^{6,7,12,14,51,52,57,58}
Management during transport	Complex; may require reading manometers, re/deflating, monitoring vital signs ^{53,60}	Simple; at most requires monitoring vital signs and observation for dyspnoea ^{12,49}
Management during and after resuscitation	<ol style="list-style-type: none"> 1. Controlled fluid therapy by skilled attendant 2. PASG must be removed before diagnostic, vaginal and/or surgical procedures are performed 3. Physician must be present for deflation^{53,61} 	<ol style="list-style-type: none"> 1. Controlled fluid therapy by skilled attendant 2. Uterine massage (internal or external) and vaginal procedures can be conducted with NASG in place 3. Removal must be conducted in skilled facility^{6,7,12,14,49,51,52,57,58}
Cost	Up to \$725.00 plus pressure-reading equipment and pressure infuser, if required, and replacement parts ^{53,62,63}	\$160.00 (Zoex Company)
Maintenance	Machine wash/hand wash/wipe clean depending on type. Repair as necessary; monthly inspections recommended ⁵³	Simple cleaning required after each use; disinfect with bleach, launder, hang dry ^{14,58}
Adverse outcomes	Possible compartment syndrome, ischaemia and acidosis ^{8,11,21,25-32}	None known ^{6,7,12,14,49,51,52,57}
Other potential risks	Risk of pump failure, leaks, cuts or tears, may not stay closed ^{53,64}	None reported ^{6,7,12,14,49,51,52,57}

* May vary by PASG type and regional protocols.

Brees et al.⁴⁹ reported on 14 consecutive cases of obstetric haemorrhage in Sialkot; obstetric aetiologies and conditions upon NASG placement were similar to those reported by Hensleigh. Thirteen cases were resuscitated immediately after NASG placement; they then received standard haemorrhage treatment and all stabilized. There was one mortality, who died on post-operative day 19 she had suffered multiple organ failure and severe anaemia before NASG application. Neither Hensleigh¹² nor Brees⁴⁹ reported adverse effects.

Comparative NASG studies

The first comparative NASG study was a pre-post pilot of severe obstetric haemorrhage in four Egyptian tertiary hospitals.⁶ All 364 women (158 pre-intervention phase, 206 post-intervention/NASG phase) had ≥ 750 mL estimated blood loss (EBL) with signs of shock [pulse ≥ 100 beats per minute (BPM), SBP < 100 mm Hg] at study entry. All were treated with a standardized protocol including IV fluids, uterotonics, blood transfusions and vaginal procedures or abdominal surgeries as needed. Post-intervention women also received the NASG. Blood loss after study entry, the main outcome variable, was measured with a graduated, closed-end blood-collection device. NASG-phase women entered the study in worse condition with statistically significant greater EBL (975 mL vs. 750 mL, $p < 0.001$) and more severe signs of shock (SBP 97.5 mm Hg vs. 88.7 mm Hg, $p < 0.0005$). Despite this discrepancy at study entry, the NASG-treated women had better outcomes, with a statistically significant lower median measured blood loss (500 mL pre-intervention vs. 250 mL post-intervention, median difference -200 , 95% CI -250 to -120 , $p < 0.001$) and a non-statistically significant 69% decrease in extreme adverse outcomes (mortality and morbidity combined).

Further analysis of these data ($n = 249$)⁷ found that NASG-treated women experienced decreased shock recovery times, indicated by return to normal shock index (SI). SI is a reliable indicator of shock severity, especially in cases of concealed blood loss (e.g. ectopic, ruptured uterus). Higher SI values are associated with increased rates of mortality or morbidity.^{65,66} Median SI recovery was significantly shorter in the NASG group (75 vs. 120 minutes, $p = 0.003$). A log rank test adjusted for severity at admission showed that the NASG group had a statistically significant decrease in recovery time (90 vs. 45 minutes in the less severe at admission group; 240 minutes vs. 120 minutes in the more severe group; log rank test 15.15, $p = 0.000$). Recovery time was independent of standard treatments, such as volume of IV fluids and/or waiting time for blood transfusions.

Miller and colleagues are currently conducting a similar pre-post pilot trial in six tertiary hospitals in Nigeria.^{67,68} These hospitals are often understaffed, ill-equipped and lack blood transfusions. Turan et al.⁶⁸ reported an interim analysis of 260 women; the findings were similar to the Egypt study (shown in Table 6). Final results of this study, which involves 181 pre-intervention and 539 post-intervention women, are pending analysis.

CASE REPORT OF NASG FOR PPH IN HIGH-RESOURCE SETTINGS

The NASG is being studied for efficacy in reducing maternal mortality and morbidity in low-resource settings, but it also can be used in high-resource settings. El-Sayed et al.⁵⁰ reported on an 18-year-old woman with intractable PPH at the Lucile Packard Children's Hospital, Stanford University, California, USA. The woman, bleeding profusely after vaginal twin delivery, received multiple interventions, including Ringer's

Table 6. Results from pre-post pilot trial in six tertiary level hospitals in Nigeria ($n = 260$).

	Pre-NASG ($n = 99$)	NASG ($n = 161$)	Statistical test
<i>Condition on entry</i>			
Median estimated blood loss in mL* (range) ($n = 232$)	1000 (200–3000)	1600 (100–3000)	Median diff = -500, 95% CI: 250–500
Women with non-palpable pulses, n (%) ($n = 260$)	10 (10.1%)	60 (37.3%)	$\chi^2 = 22.99$, $p = 0.000$
<i>Outcomes</i>			
Median measured blood loss (mL, range) ($n = 164$)**	600 (0–2500)	230 (0–800)	Median diff = 400, 95% CI: 250–520
Mortality, n (%) ($n = 259$)	7 (7.1%)	10 (6.2%)	RR = 0.870, 95% CI: 0.342–2.210, ns
Morbidity, n (%) ($n = 242$ woman who survived)	3 (3.3%)	1 (0.7%)	Chi-square, ns

* Only for those with external blood loss at study admission.
 ** 94 pre-NASG cases and 70 NASG cases.

lactate infusions, each with 35 units of oxytocin per litre; two doses of 0.2 mg methergine IM; three doses of 250 mcg haemabate IM; 800 mcg misoprostol per rectum; along with transfusions of packed red blood cells, recombinant factor VII, uterine massage and uterine curettage. Having exhausted standard treatment measures, the surgeons packed the uterus and applied the NASG. Within minutes of NASG placement, bleeding subsided, pulse decreased and blood pressure rose. The patient remained haemodynamically stable with normal vaginal bleeding. The NASG was removed on postpartum day 1 without complications or recurrent bleeding.

ONGOING STUDIES

The NASG has not yet proven to significantly decrease morbidity or mortality. Further, NASG studies have been conducted only in tertiary care centres, albeit with delays in obtaining blood transfusions and surgery. A cluster RCT has been initiated in Zimbabwe and Zambia to examine whether early application of the NASG by midwives at the primary health-care level, prior to transfer to a referral hospital, will decrease mortality and morbidity. The study will also analyse potential side effects of NASG use.

NASG PROTOCOLS

Hensleigh¹² recommended the NASG for obstetric haemorrhage with Class II²⁴ or moderate⁶⁹ shock, defined as ≥ 750 mL blood loss, pulse ≥ 100 BPM and mild hypotension. The NASG is not recommended for use in patients with a viable fetus or with bleeding above the diaphragm. Based on contraindications to the PASG, the NASG

has relative contraindications for women with mitral stenosis, congestive heart failure or pulmonary hypertension.¹¹

Standard protocols for the prevention and management of obstetric haemorrhage must be followed. These includes active management of the third stage of labour (AMTSL) and administration of uterotonics, IV fluids and oxygen therapy.^{70,71}

When to apply

When to initiate NASG application is dependent upon where in the healthcare delivery system the haemorrhage occurs, the attendants' skills and capacity for blood transfusions and/or surgery. In lower-level facilities, or when women present in shock and with circulatory collapse, the NASG should be applied as the first step in resuscitation; application will fill blood vessels, enabling an IV to be started, or, if there is no capacity for IV infusions, enhanced core organ perfusion. If a woman begins to haemorrhage at any level of the healthcare system, the algorithm recommended by Ramathan and Arulkumaran⁷² and Lalonde et al.,⁴ under the acronym HAEMOSTATIS, should be implemented, with the NASG applied if the steps 'HAEMO' do not effect improvement and it is appropriate to 'Shift' to an operating theatre or refer to a higher-level facility. Further, if operative measures fail, the NASG can be applied as post-surgical resuscitation.⁵⁰ In obstetric units where there is access to arterial embolization, the NASG can be applied to stabilize the woman, maintain vital signs and decrease bleeding whilst the team assembles.^{43,73}

NASG application

1. Open the NASG and place under the woman with the top of the garment at her lowest rib. If the patient is unconscious, two people can roll her onto her side placing the garment underneath her, similar to making an occupied bed.
2. Stretch and fasten the garment tightly, starting with the ankle segments (#1) (Figure 2).
3. Continue with #2 segments below the knee and #3 segments around the thighs; for shorter women, fold segment #1 into segment #2 before starting.
4. Secure the pelvic segment (#4) tightly at the level of the symphysis pubis; only one person should secure the pelvic and abdominal segments.
5. Place segment #5 over the umbilicus, close by securing segment #6.

If the woman experiences difficulty breathing, slightly loosen – but do not remove – the abdominal segment. If NASG application does not result in prompt increased SBP and decreased pulse, check for adequate tightness and give additional IV fluids.

NASG patient management

If the NASG has been placed as a first resuscitative measure, institute the next steps in haemorrhage protocol: calling for help, assessing vital signs, finding source of bleeding, giving IV fluids, uterotonics, etc. The NASG permits complete perineal access, thus vaginal procedures can be conducted with the NASG in place. Uterine massage can also be performed with the NASG in place. If abdominal surgery is necessary, open only the abdominal/pelvic segments immediately prior to making the first incision; replace them rapidly as soon as surgery is complete. It is common for blood pressure

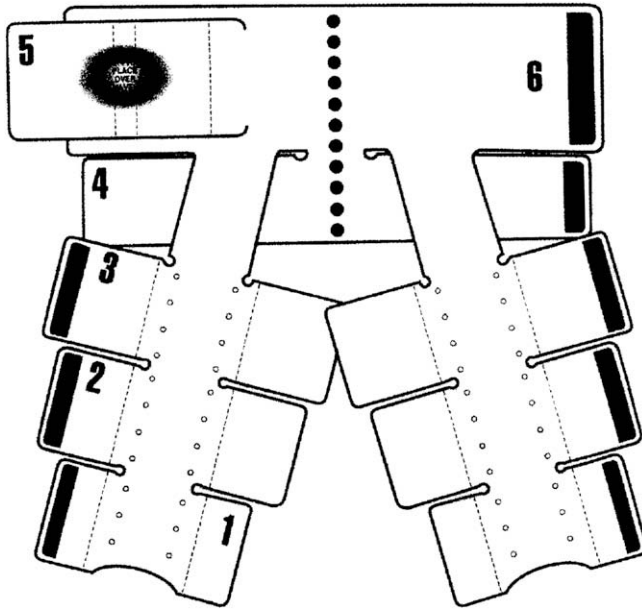


Figure 2. Schematic of non-pneumatic anti-shock garment (NASG).

to drop when the abdominal segment is opened; the anaesthesiologist should be prepared to manage the blood pressure with IV fluids.

NASG removal

The NASG must be removed only under skilled supervision in a setting where vital signs can be monitored and there are adequate IV fluids. The NASG should not be removed until the woman has been haemodynamically stable for at least 2 hours with blood loss ≤ 50 mL/hour, pulse ≤ 100 BPM and SBP ≥ 100 mm Hg. To safely remove the NASG, start with the ankle segments and proceed upwards. Allow 15 minutes between opening each segment for the redistribution of blood, then check vital signs. If SBP falls by 20 mm Hg or the pulse increases by 20 BPM, rapidly replace all segments and consider the need for more saline or blood transfusions. If there is recurrent bleeding, replace the NASG and determine the source of bleeding and further action for treatment.

If the NASG is removed incorrectly, by opening the abdominal section first (not in the surgical setting) or by prematurely removing the NASG before the woman has achieved haemodynamic stability, the woman will suffer immediate shock; it is therefore essential to follow the removal instructions exactly.

Possible side effects

To date, few negative side effects of the NASG have been noted. This might be due to limited research and publication of results. Potential side effects attributed to PASGs have been minimized or eliminated by the improved design of the NASG.

SUMMARY

All ASGs operate on the same principles: shunting blood from lower extremities to the core, reversing shock and decreasing blood loss. PASGs have had a controversial history, with negative or no-difference findings in RCTs for trauma patients. Only case studies have been published on the PASG use in obstetrics. The NASG might overcome some of the deficiencies of the PASG, but little research has been published on the NASG for obstetric haemorrhage: only three case reports^{12,49,50} and two reports from pilot comparative studies.^{6,7} There are theoretical reasons why the negative RCTs of the PASG might not be applicable to the NASG: its improved design overcomes the risks associated with inflation and its intended use specifically counters the delays in obtaining emergency obstetric care in low-resource settings. Currently, evidence suggests the NASG is a promising first-aid device for obstetric haemorrhage and shock that might help overcome delays in transport and in acquiring appropriate haemorrhage management at referral facilities. It could also play a role in sophisticated tertiary care units by keeping women stable whilst awaiting arterial embolization, or as a post-surgical or last-resort measure for intractable obstetric haemorrhage. Completion of the ongoing RCT and research on haemodynamics, effectiveness, logistics and acceptability will help determine the future of the NASG in obstetrics.

Practice points

- Timing of the application of the NASG in a haemorrhage and shock management algorithm depends on the patient's condition, staff capacity and facility level.
- Apply NASG as tightly as possible; two people can apply leg segments, only one person should apply the pelvic and abdominal sections.
- Do not remove until the woman has been haemodynamically stable for ≥ 2 hours.
- To avoid adverse events, always monitor removal; start at the ankles and never open the abdominal section first, unless prepared to operate.

Research agenda

- Efficacy trials for morbidity and mortality reduction (RCT currently ongoing).
- Haemodynamics.
- Training and supervision packages.
- Appropriate logistics, distribution and stocking NASGs in appropriate quantities to cover patient volume.
- Best methods of cleaning, reuse and storage.
- Diffusion of innovation.
- Overcoming challenges to prompt and correct application and removal.
- Acceptability: providers, patients, families.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no financial or personal relationships with any other people or organizations that could inappropriately influence the content of this article.

ACKNOWLEDGEMENTS

- Dr Ralph Pelligra, Chief Medical Officer, Health and Medical Technical Authority, NASA/Ames Research Centre.
- Dr Paul Hensleigh (posthumous), Professor Emeritus of Obstetrics and Gynecology at the Stanford University School of Medicine.
- The John D. and Catherine T. MacArthur Foundation.

Author contributions

- Development of search strategies: all authors.
- Performance of independent searches: all authors.
- Review of manuscripts: all authors.
- Data extraction: HM, JM.
- Analysis, interpretation and writing of manuscript: all authors.
- All have seen and approved the final version.

REFERENCES

1. Thaddeus S & Maine D. Too far to walk: maternal mortality in context. *Soc Sci Med* 1994; **38**(8): 1091–1110.
2. Doumouchtsis SK & Arulkumaran S. Postpartum haemorrhage: changing practices. In Ledger W & Dunlop W (eds.). *Recent advances in obstetrics & gynaecology 24*. London, UK: Royal Society of Medicine Press Ltd, 2008.
3. Liston W. *Saving mothers' lives: reviewing maternal deaths to make motherhood safer-2003–2005. Chapter 4: haemorrhage*. London: Confidential Enquiry into Maternal and Child Health (CEMACH), 2007. 78–85.
4. Lalonde A, Daviss BA, Acosta A et al. Postpartum hemorrhage today: ICM/FIGO initiative 2004–2006. *Int J Gynaecol Obstet* 2006; **94**(3): 243–253.
5. Tsu VD. New and underused technologies to reduce maternal mortality. *Lancet* 2004; **363**(9402): 75–76.
- *6. Miller S, Hamza S, Bray E et al. First aid for obstetrical hemorrhage: the pilot study of the Non-Pneumatic Anti-Shock Garment (NASG) in Egypt. *BJOG* 2006; **113**(4): 424–429.
- *7. Miller S, Turan J, Dau K et al. Use of the Non-Pneumatic Anti-Shock Garment (NASG) to reduce blood loss and time to recovery from shock for women with obstetric hemorrhage in Egypt. *Glob Pub Health* 2007; **2**(2): 110–124.
8. Vahedi M, Ayuyao A, Parsa M et al. Pneumatic antishock garment-associated compartment syndrome in uninjured lower extremities. *J Trauma* 1995; **384**(4): 616–618.
9. Cutler BS & Daggett WM. Application of the 'G-suit' to the control of hemorrhage in massive trauma. *Ann Surg* 1971; **173**(4): 511–514.
10. Kaplan B, Poole F & Flagg J. Medical pneumatic trouser for emergency autotransfusion. United States Patent 3933150, Available from: <http://www.freepatentsonline.com/3933150.html>.
- *11. McSwain Jr. NE. Pneumatic anti-shock garment: state of the art 1988. *Ann Emerg Med* 1988; **17**(5): 506–525.

12. Hensleigh PA. Anti-shock garment provides resuscitation and haemostasis for obstetric haemorrhage. *BJOG* 2002; **109**(12): 1377–1384.
13. Schou J, Ginz HF, Herion HP et al. Abdominal haemorrhage—a preventable cause of death after field stabilization? *Resuscitation* 2000; **43**(3): 185–193.
- *14. Miller S, Ojengbade A, Turan JM et al. Anti-shock garments for obstetric hemorrhage. *Current Women's Health Reviews* 2007; **3**(1): 3–11.
15. Gardner WJ & Storer J. The use of the G-Suit in control of intra-abdominal bleeding. *Surg Gynecol Obstet* 1966; **123**(4): 792–798.
16. Gardner WJ. Hemostasis by pneumatic compression. *Am Surg* 1969; **35**(9): 635–637.
17. Aberg T, Steen S, Othman K et al. The effect of pneumatic antishock garments in the treatment of lethal combined hepatic and caval injuries in rats. *J Trauma* 1986; **26**(8): 727–732.
- *18. Ali J & Duke K. Pneumatic antishock garment decreases hemorrhage and mortality from splenic injury. *Can J Surg* 1991; **34**(5): 496–501.
19. Kaplan BC, Civetta JM, Nagel EL et al. The military anti-shock trouser in civilian pre-hospital emergency care. *J Trauma* 1973; **13**(10): 843–848.
- *20. McSwain MJ & McSwain NE. Pneumatic antishock garment: state of the art at the turn of the century. *Trauma* 2000; **2**(1): 63–75.
21. Connolly B, Gerlinger T & Pitcher JD. Complete masking of a severe open-book pelvic fracture by a pneumatic antishock garment. *J Trauma* 1999; **46**(2): 340–342.
22. Domeier RM, O'Connor RE, Delbridge TR et al. Use of the pneumatic anti-shock garment (PASG). National association of EMS physicians. *Prehosp Emerg Care* 1997; **1**(1): 32–35.
23. Pearse CS, Magrina JF & Finley BE. Use of MAST suit in obstetrics and gynecology. *Obstet Gynecol Surv* 1984; **39**(7): 416–422.
24. ACOS, Advanced trauma support. *Estimated blood losses based on 70kg male on initial presentation*. Chicago: American College of Surgeons, 1993. p. 86.
25. Aprahamian C, Gessert G, Bandyk DF et al. MAST-associated compartment syndrome (MACS): a review. *J Trauma* 1989; **29**(5): 549–555.
26. Bickell WH, Pepe PE, Bailey ML et al. Randomized trial of pneumatic antishock garments in the prehospital management of penetrating abdominal injuries. *Ann Emerg Med* 1987; **16**(6): 653–658.
27. Brotman S, Browner BD & Cox EF. MAS trousers improperly applied causing a compartment syndrome in lower-extremity trauma. *J Trauma* 1982; **22**(7): 598–599.
- *28. Mattox KL, Bickell W, Pepe PE et al. Prospective MAST study in 911 patients. *J Trauma* 1989; **29**(8): 1104–1111. discussion: 1111–1112.
29. Maull KI, Capehart JE, Cardea JA et al. Limb loss following Military Anti-Shock Trousers (MAST) application. *J Trauma* 1981; **21**(1): 60–62.
30. Pelligra R & Sandberg EC. Control of intractable abdominal bleeding by external counterpressure. *J Am Med Assoc* 1979; **241**(7): 708–713.
31. Pepe P. Controversies in the prehospital management of major trauma. *Emerg Med* 2000; **12**(3): 180–189.
32. Pepe PE, Bass RR & Mattox KL. Clinical trials of the pneumatic antishock garment in the urban prehospital setting. *Ann Emerg Med* 1986; **15**(12): 1407–1410.
33. Chang FC, Harrison PB, Beech RR et al. PASG: does it help in the management of traumatic shock? *J Trauma* 1995; **39**(3): 453–456.
- *34. Dickinson K & Roberts I. Medical anti-shock trousers (pneumatic anti-shock garments) for circulatory support in patients with trauma. *Cochrane Database Syst Rev* 2000; (2). CD001856.
35. Miller S & Hensleigh P. *Non-pneumatic anti-shock garment for obstetric hemorrhage*. Chapter 14. In B-Lynch C, Keith L, LaLonde A et al (eds.). An international Federation of Obstetrics and Gynecology (FIGO) book. Postpartum hemorrhage: new thoughts, new approaches. London, UK: Sapiens Publications, 2006, pp. 136–146.
36. Chang K, Dunford J, Hoyt D et al. MAST 96. *J Emerg Med* 1996; **14**(4): 419–424.
37. Mackersie RC, Christensen JM & Lewis FR. The prehospital use of external counterpressure: does MAST make a difference? *J Trauma* 1984; **24**(10): 882–888.
38. Bledsoe B. EMS Myth #1: Medical Anti-Shock Trousers (MAST) autotransfuse a significant amount of blood and save lives, in EMS Magazine. posted Nov 17, 2005. Available from: <http://publicsafety.com/article/article.jsp?id=2024&sitesection=52003>.
39. Brennan V, Burba A, Gallagher J et al. *Paramedic certification exam*. 3rd ed. New York: Learning Express, 2006.

40. Gardner WJ, Taylor HP & Dohn DF. Acute blood loss requiring 58 transfusions. *J Am Med Assoc* 1958; **167**: 985–986.
41. Hall 3rd M & Marshall JR. The gravity suit: a major advance in management of gynecologic blood loss. *Obstet Gynecol* 1979; **53**(2): 247–250.
- *42. Sandberg EC & Pelligra R. The medical antigravity suit for management of surgically uncontrollable bleeding associated with abdominal pregnancy. *Am J Obstet Gynecol* 1983; **146**: 519–525.
43. Andrae B, Eriksson LG & Skoog G. Anti-shock trousers (MAST) and transcatheter embolization in the management of massive obstetrics hemorrhage. A report of two cases. *Acta Obstet Gynecol Scand* 1999; **78**(8): 740–741.
44. Ramachandran K & Kirk P. Massive hemorrhage in a previously undiagnosed abdominal pregnancy presenting for elective cesarean delivery. *Can J Anaesth* 2004; **51**(1): 57–61.
45. Hauswald M & Greene ER. Regional blood flow after pneumatic anti-shock garment inflation. *Prehosp Emerg Care* 2003; **7**(2): 225–228.
46. Quinot J, Cantais E & Kaiser E. Le pantalon antichoc: A-ti-il reelement une place dans le traitement du choc? *Medecine D'urgence* 2001; 119–126.
47. Tsu VD & Shane B. New and underutilized technologies to reduce maternal mortality: call to action from a Bellagio workshop. *Int J Gynaecol Obstet* 2004; **85**(Suppl. 1): S83–S93.
48. Haggerty J. Anti shock garment. Available from: <http://www.sti.nasa.gov/tto/spinoff1996/28.html>; 1996.
49. Brees C, Hensleigh PA, Miller S et al. A non-inflatable anti-shock garment for obstetric hemorrhage. *Int J Gynaecol Obstet* 2004; **87**(2): 119–124.
50. El-Sayed, Y., L. Brodzinsky, J. Collins, et al. Incorporation of the Non-Pneumatic Anti-Shock Garment (NASG) in the management of postpartum haemorrhage and shock at a tertiary level hospital. In: International Federation of Gynecology and Obstetrics (FIGO) World Congress. 2006. Kuala Lumpur.
51. Miller S, Lester F & Hensleigh P. Prevention and treatment of postpartum hemorrhage: new advances for low-resource settings. *J Midwifery Womens Health* 2004; **49**(4): 283–292.
52. Miller S, Turan JM, Ojengbode A et al. The pilot study of the Non-Pneumatic Anti-Shock Garment (NASG) in women with severe obstetric hemorrhage: combined results from Egypt and Nigeria. *Int J Gynaecol Obstet* 2006; **94**(Suppl. 2): S154–S156.
53. *Medical Anti-Shock Trousers (MAST), instruction manual*. David Clark Company, Inc., 1997.
54. ten Hoop-Bender P, Liljestrand J & MacDonagh S. Human resources and access to maternal health care. *Int J Gynaecol Obstet* 2006; **94**(3): 226–233.
55. Pneumatic Antishock Garment (PASG) & Training DVD. *Brookside associates, medical education division*. Winnetka, IL: United States Army, 1993.
56. *Guidelines for the use and application of pneumatic anti-shock garments (MAST)*. Fairfield, Connecticut: Southwestern Connecticut Emergency Medical Services Council, Inc., 1999. Available from: <http://www.jhpcems.com/downloads.htm>.
57. Miller S, Butrick E, Turan J et al. The anti-shock garment for post-partum and post-abortion hemorrhage in Nigeria. *J Midwifery Womens Health* 2007; **52**(5): 534.
58. Miller S. *Using the NASG as first aid in obstetric hemorrhage and hypovolemic shock: doctors' training DVD*. San Anselmo, CA, USA: Docfilms, Inc., 2007.
59. IAS, Immediate Action Services Newsletter. Section 5: PASG and IV (12–1) Clinics. 2005, Joint Hospital Planning Council. Volume 2, Edition 3.
60. Pelligra R. Non-pneumatic antishock garment use. *Emergency* 1994; (26): 53–56.
61. Gavrieli N. Is MAST a must?. Available from: http://www.ohkmed.com/Products_A-TT_ClinicalStud.html.
62. lifemedicalsupplier.com. M.A.S.T. anti shock trousers. Available from: <http://www.lifemedicalsupplier.com/mast-anti-shock-trousers-adult-ref-001mastiiam-p-1959.html>; 2008.
63. savelives.com. Life support products MAST trousers. Available from: <http://www.savelives.com/cgi-bin/instock.pl?group=10&subgroup=10>; 2008.
64. Miller, S., O. Ojengbode, J. Turan, et al. Non-pneumatic anti-shock garment decreases mortality form obstetric haemorrhage in Nigeria. In: British International Congress of Obstetrics and Gynaecology (BICOG). July 4–6. 2007. London, UK.
65. Birkhahn RH, Gaeta TJ, Terry D et al. Shock index in diagnosing early acute hypovolemia. *Am J Emerg Med* 2005; **23**(3): 323–326.

66. Birkhahn RH, Gaeta TJ, Van Deusen SK et al. The ability of traditional vital signs and shock index to identify ruptured ectopic pregnancy. *Am J Obstet Gynecol* 2003; **189**(5): 1293–1296.
67. Ojengbede, O., J. Turan, H. Galadanci, et al. Use of the non-pneumatic Anti-Shock Garment for treatment of obstetric haemorrhage. In: Society of Gynaecology and Obstetrics of Nigeria (SOGON) Annual Conference. 2007. Ibadan, Nigeria.
68. Turan, J., S. Miller, E. Butrick, et al. A new tool for saving women's lives in Nigeria: The potential of the Non-Pneumatic Anti-Shock Garment (NASG). In: American Public Health Association (APHA) 135th Annual Meeting and Exposition. November 3–7. 2007. Washington, DC.
69. Creasy R & Resnik R. *Maternal-fetal medicine: principles and practice*. 3rd ed. Philadelphia: WB Saunders Co, 1994. 880.
70. ICM/FIGO. Joint statement: management of the third stage of labour to prevent post-partum haemorrhage. Available from: http://www.internationalmidwives.org/modules/ContentExpress/img_repository/final%20joint%20statement%20active%20management-eng%20with%20logo.pdf; 2003.
71. ICM/FIGO, Joint statement: prevention and treatment of post-partum haemorrhage. New advances for low resource settings. 2006.
- *72. Ramanathan G & Arulkumaran S. Postpartum haemorrhage. *Curr Obstet Gynaecol* 2006; **16**(1): 6–13.
73. Choji K & Shimizu T. *Embolization*. Chapter 30. In B-Lynch C, Keith L, LaLonde A et al (eds.). An international Federation of Obstetrics and Gynecology (FIGO) Book. Postpartum Hemorrhage: new thoughts, new approaches. London: Sapiens Publications, 2006, pp. 277–286.