Anti-shock garment in postpartum haemorrhage

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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...
horrific because it is preventable. Long delays in reaching emergency obstetric care are at the root of many maternal deaths. 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).

One recently recommended first-aid device for obstetric haemorrhage is the non-pneumatic anti-shock garment (NASG). 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.

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. 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. The G-suit was later modified from a full-body suit to a half-suit, called Military/Medical Anti-Shock Trouser (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%). Garment application results in increased preload, peripheral resistance and cardiac output. Tamponade of vessels, particularly the splanchnic plexus, can diminish further bleeding. The physiological basis for these benefits - Poiseuille’s law, Laplace’s law and the Bernoulli principle - have been described in detail elsewhere and are outlined in Table 1.

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 introduction initiated a wave of acceptance. PASGs were used for shock and trauma, including pelvic and lower-limb fractures, and hypovolaemic and septic shock. Despite the lack of positive RCTs in 1977 the American College of Surgeons’ Committee on Trauma included PASGs as essential equipment for ambulances.

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

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Table 1. Laws of physics underlying the mechanisms of action of anti-shock garments.

<table>
<thead>
<tr>
<th>Law</th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poiseuille’s law</td>
<td>( F = (P_1 - P_2) \frac{R^4}{8N}\cdot L )</td>
</tr>
<tr>
<td></td>
<td>( F ), flow; ( P_1 ), entrance pressure;</td>
</tr>
<tr>
<td></td>
<td>( P_2 ), exit pressure; ( R ), radius; ( N</td>
</tr>
<tr>
<td></td>
<td>, viscosity; ( L ), length</td>
</tr>
<tr>
<td>Laplace’s law</td>
<td>( T = P \cdot R )</td>
</tr>
<tr>
<td></td>
<td>( T ), tension inside blood vessel; ( P</td>
</tr>
<tr>
<td></td>
<td>, transmural pressure; ( R ), vessel radius</td>
</tr>
<tr>
<td>Bernoulli’s principle</td>
<td>( Q = (A \cdot P + 2V)/E )</td>
</tr>
<tr>
<td></td>
<td>( Q ), rate of leakage; ( A ), area of laceration/tear/opening; ( P</td>
</tr>
<tr>
<td></td>
<td>, transmural pressure; ( E ), density of blood; ( V</td>
</tr>
<tr>
<td></td>
<td>, speed or velocity of blood flow</td>
</tr>
</tbody>
</table>

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Anti-shock garment in PPH 1059
ischaemia, dyspnoea or other forms of respiratory distress, increased acidosis and the development of compartment syndrome.

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 published²⁶,³², 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>
<thead>
<tr>
<th>Author, year [ref. no.]</th>
<th>Study design</th>
<th>Outcomes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gardner and Storer, 1966¹⁵</td>
<td>Case series of 8 dogs with transected intra-abdominal aortas treated with pneumatic abdominal sleeve</td>
<td>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</td>
</tr>
<tr>
<td>Gardner, 1969¹⁶</td>
<td>Comparative study of 16 dogs with wounds to the iliac artery (8 PASG, 8 control)</td>
<td>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</td>
</tr>
<tr>
<td>Aberg et al., 1986¹⁷</td>
<td>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</td>
<td>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</td>
</tr>
<tr>
<td>Ali and Duke, 1991¹⁸</td>
<td>Comparative study of 12 anaesthetized dogs with splenic crush injuries (6 control, 6 PASG)</td>
<td>PASG-treated group survived twice as long as control group (2 hours vs. &lt;1 hour); blood loss in PASG-treated group significantly decreased (1.6 ± 0.9 mL/minute vs. 9.4 ± 1.4 mL/minute, p &lt; 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</td>
</tr>
</tbody>
</table>
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. Additionally, these RCTs did not control for confounders such as age, haemorrhage severity or time to garment application.

**Current status in emergency medicine**

After publication of these RCTs, PASG use became controversial. In 1997, the PASG was deemed ‘effective’ by the National Association of EMS Physicians for ruptured abdominal aneurysms only, and ‘potentially beneficial’ for pelvic fracture or lower-extremity haemorrhages. Some emergency medical practitioners still recommend the PASG for pre-hospital care, and it remains in emergency medicine curricula and textbooks.

**PNEUMATIC ANTI-SHOCK GARMENTS (PASG) FOR OBSTETRIC HAEMORRHAGE**

Although there are no PASG RCTs for obstetric haemorrhage, case studies are described elsewhere 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>
<thead>
<tr>
<th>Author, year [ref. no.]</th>
<th>Number, aetiologies</th>
<th>Interventions before PASG</th>
<th>Outcomes after PASG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gardner et al., 195840</td>
<td>1 woman with placenta percreta and uncontrollable haemorrhage</td>
<td>Patient received &gt;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</td>
<td>After PASG only one additional unit of blood was required; patient stabilized with BP 104/72</td>
</tr>
<tr>
<td>Hall and Marshall, 197941</td>
<td>4 women with ruptured ectopic pregnancies for pre-surgical treatment</td>
<td>None reported; IV fluid replacement began at same time as PASG application</td>
<td>All had decreased blood loss, improved vital signs and improved organ perfusion</td>
</tr>
<tr>
<td>Pelligra and Sandberg, 197930</td>
<td>Three women with obstetric haemorrhage: 1. Intra-abdominal bleeding post caesarean section</td>
<td>1. 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</td>
<td>1. Condition stabilized within 1 hour of PASG placement</td>
</tr>
<tr>
<td></td>
<td>2. Placenta praevia, caesarean section, disseminated intravascular coagulopathy (DIC)</td>
<td>2. 8 units packed RBCs, 6 units platelets and 4 units FFP</td>
<td>2. Transferred 56 km to fully equipped facility where patient received additional blood products and remained stable</td>
</tr>
<tr>
<td></td>
<td>3. Post-hysterectomy, placenta accreta</td>
<td>3. 63 units blood, 25 units FFP, 18 units cryoprecipitate and 132 platelet packs</td>
<td>3. Responded quickly when PASG placed</td>
</tr>
<tr>
<td>Sandberg and Pelligra, 198342</td>
<td>3 women with obstetric haemorrhage (one was previously reported in Pelligra &amp; Sandberg 1979) described above</td>
<td>1. Intrauterine gestation treated by laparotomy after &gt;5000 mL of blood loss 2. Hysterectomy following spontaneous foetal death</td>
<td>Application of PASG led to increased blood pressure and decreased blood loss for both women</td>
</tr>
<tr>
<td>Andrae, 199943</td>
<td>2 women with hypovolaemic shock due to uterine bleeding: Both received uterotonics, pressors, IV fluids, blood and blood components</td>
<td>PASG provided temporizing stabilization; bleeding ceased while PASG was in place, but</td>
<td></td>
</tr>
</tbody>
</table>
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. PASG inflation resulted in decreased aortic blood flow from the superior mesenteric to immediately below the renal arteries. In France, the ‘pantaloon antichoc’ is endorsed for postpartum haemorrhage, disseminated intravascular coagulations of pregnancy, and other obstetric and gynaecological bleeding.

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.

**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. 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.

The garment was developed in 1971 by Dr Ralph Pelligra of the National Aeronautics and Space Administration/Ames Research Centre (NASA/Ames). 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.

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**Table 4 (continued)**

<table>
<thead>
<tr>
<th>Author, year [ref. no.]</th>
<th>Number, aetiologies</th>
<th>Interventions before PASG</th>
<th>Interventions after PASG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ramachandran and Kirk, 2004</td>
<td>1 woman post-caesarean section for abdominal pregnancy</td>
<td>IV infusions, two surgeries to remove the infant and placenta, blood and blood products, abdominal packing; patient remained hypotensive, continued bleeding and developed DIC</td>
<td>PASG effected decreased bleeding, increased blood pressure; coagulation profile improved rapidly</td>
</tr>
</tbody>
</table>

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Anti-shock garment in PPH 1063
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.

Figure 1. Patient wearing non-pneumatic anti-shock garment (NASG).
| **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) | 1 person, no medical background required |
| **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 | Low; easy to apply, may be worn over clothing, no inflation required |
| **Training necessary for application**          | Depending on regional protocols >10 hours, regular practice and periodic re-training and exam | <1 hour basic training with practice |
| **Management during transport**                | Complex; may require reading manometers, re/deflating, monitoring vital signs | Simple; at most requires monitoring vital signs and observation for dyspnoea |
| **Management during and after resuscitation**  | 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 | 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 |
| **Cost**                                       | Up to $725.00 plus pressure-reading equipment and pressure infuser, if required, and replacement parts | $160.00 (Zoex Company) |
| **Maintenance**                                | Machine wash/hand wash/wipe clean depending on type. Repair as necessary; monthly inspections recommended | Simple cleaning required after each use; disinfect with bleach, launder, hang dry |
| **Adverse outcomes**                           | Possible compartment syndrome, ischaemia and acidosis | None known |
| **Other potential risks**                      | Risk of pump failure, leaks, cuts or tears, may not stay closed | None reported |

* May vary by PASG type and regional protocols.
Brees et al.\textsuperscript{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 Hensleigh\textsuperscript{12} nor Brees\textsuperscript{49} 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.\textsuperscript{6} All 364 women (158 pre-intervention phase, 206 post-intervention/NASG phase) had $\geq 750$ mL estimated blood loss (EBL) with signs of shock [pulse $\geq 100$ beats per minute (BPM), SBP $< 100$ mm Hg] at study entry. All were treated with a standardized protocol including IV fluids, uterotonic, 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 $200, 95\% \text{ CI } 250$ 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 ($n = 249$)\textsuperscript{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.\textsuperscript{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.\textsuperscript{67,68} These hospitals are often understaffed, ill-equipped and lack blood transfusions. Turan et al.\textsuperscript{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.\textsuperscript{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
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**

Hensleigh\(^{12}\) recommended the NASG for obstetric haemorrhage with Class II\(^{24}\) or moderate\(^{69}\) shock, defined as \(\geq 750\) mL blood loss, pulse \(\geq 100\) 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

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

* Only for those with external blood loss at study admission.
** 94 pre-NASG cases and 70 NASG cases.
has relative contraindications for women with mitral stenosis, congestive heart failure or pulmonary hypertension. 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 Ramana than and Arulkumaran\(^{72}\) 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
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 \( \leq 50 \text{ mL/hour} \), pulse \( \leq 100 \text{ BPM} \) and SBP \( \geq 100 \text{ mm Hg} \). 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.

### 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.

### 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 \(\geq 2\) hours.
- To avoid adverse events, always monitor removal; start at the ankles and never open the abdominal section first, unless prepared to operate.
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.

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