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The Role of the Nonpneumatic Antishock Garment in Reducing Blood Loss and Mortality Associated with Post-Abortion Hemorrhage

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Abstract

Maternal mortality attributable to post-abortion hemorrhage is often associated with delays in reaching or receiving definitive care. The nonpneumatic antishock garment (NASG), a low-technology first-aid device, has been shown to decrease blood loss and mortality among women experiencing hypovolemic shock secondary to obstetric hemorrhage etiologies. Women experiencing post-abortion hemorrhage face longer delays in receiving definitive treatment as a result of abortion-related stigma and lack of access to quality abortion care; thus the NASG has the potential to make an even greater impact within this population. We conducted a secondary analysis of data collected in Egypt, Nigeria, Zambia, and Zimbabwe in NASG trials, limiting our analytic sample to women who experienced post-abortion hemorrhage (n = 953). Blood loss significantly decreased when the NASG was added to standard hemorrhage management during the intervention phase, and there was a large, although not statistically significant, 52 percent decrease in mortality during the NASG phase. The results indicate that adding the NASG to post-abortion care among women experiencing severe hemorrhage and hypovolemic shock would decrease blood loss and mortality.

According to the World Health Organization (WHO), in developing countries one woman dies of complications of an unsafe abortion every eight minutes (Haddad and Nour 2009). Abortion accounts for an estimated 8 percent of maternal deaths worldwide (Say et al. 2014). In 2008, WHO reported approximately 21.6 million unsafe abortions globally, with an estimated unsafe abortion mortality ratio of 30 per 100,000 live births (Ahman and Shah 2011). Sub-Saharan Africa has the highest ratio of unsafe-abortion-related mortality at 90 per 100,000 live births (Ahman and Shah 2011). Although data on complications associated with spontaneous abortion are more limited, 12–15 percent of pregnancies end in spontaneous abortion (Regan and Rai 2000). Reducing abortion-related mortality and morbidity in high-risk regions is thus crucial to improving maternal health and lowering maternal mortality (Sedgh et al. 2012). Long-term morbidities associated with complications of abortion include chronic pelvic pain, secondary infertility, ectopic pregnancy, recurrent pregnancy loss, and consequences of internal organ injury (Okonofua 2006; Haddad and Nour 2009). It is estimated that nearly 40 percent of the more than 7 million women who experience complications of abortion do not receive adequate care (Culwell et al. 2010).

The most common direct cause of death associated with both spontaneous and induced abortion is hemorrhage (Haddad and Nour 2009). However, as for most other causes of maternal death in low-resource settings, delays in receiving quality definitive care are responsible for higher rates of abortion-related mortality. The three-delays model provides a framework for identifying barriers to adequate health-care use. These barriers include: (1) delays in the decision to seek care; (2) delays in reaching a health facility; and (3) delays in receiving adequate care at that facility (Thaddeus and Maine 1994; Pacagnella et al. 2012).

A number of sociocultural factors may cause women who are having post-abortion complications to delay seeking and/or receiving health care, thereby increasing the risk of abortion-related mortality. The stigma associated with abortion in many countries combined with the restrictive legal environment or criminalization of the woman and/or health-care workers often leads to a lack of compassionate, appropriate post-abortion care (Culwell et al. 2010). A study in Zambia reported that hemorrhaging women with pregnancies of less than 24 weeks—mainly from complications of abortion—were less likely to be transported by ambulance than women nearer term, regardless of the severity of bleeding or degree of shock (Butrick et al. 2014). Women may delay seeking health care because of the anticipated stigma, or they may face delays in receiving treatment at health-care facilities because of limited access to quality post-abortion care. In Gabon, women who died from post-abortion complications experienced delays that were 24 times greater than those of women with postpartum hemorrhage or eclampsia (Mayi-Tsonga et al. 2009).

One device that has the potential to help women who are in hypovolemic shock secondary to post-abortion hemorrhage survive delays in receiving emergency obstetric care is the nonpneumatic antishock garment (NASG). The NASG is a first-aid, lower-body compression device composed of neoprene and Velcro. When the device is tightly wrapped around the lower body of a hemorrhaging woman, it applies circumferential counter-pressure to the compressed areas, stabilizing women who are suffering from hypovolemic shock from all etiologies of obstetric hemorrhage. This device reverses shock by decreasing blood flow to the abdomen and lower body and maintaining circulating blood to core organs

of the upper body (Miller et al. 2006a; Miller et al. 2010a; Stenson, Miller, and Lester 2012). For a woman experiencing hypovolemic shock secondary to obstetric hemorrhage, this device can restore consciousness, pulse, and blood pressure, and it can buy her the time needed to receive definitive treatment (Fathalla et al. 2011). The device is simple to use and easy for anyone who has been trained to rapidly apply to a hemorrhaging woman. Prior studies of women with severe obstetric hemorrhage and hypovolemic shock of all etiologies conducted in tertiary-care facilities in Egypt, Nigeria, Zambia, and Zimbabwe have shown significant reductions in measured blood loss, more rapid recovery from shock, and decreased mortality when the NASG is added to standard hemorrhage- and shock-treatment protocols (Miller et al. 2007; Miller et al. 2009; Miller et al. 2013). However, the NASG's effect on blood loss solely for women with post-abortion hemorrhage and shock (defined as hemorrhage associated with pregnancy termination at less than 24 weeks gestation) has not been evaluated. Given the greater delays in receiving care experienced by women following abortions, the NASG has the potential to have an even greater effect among this population.

We examined the effect of the NASG on a primary outcome, measured blood loss, and a secondary outcome, mortality, for women with abortion-related hemorrhage and hypovolemic shock treated at tertiary facilities in Egypt, Nigeria, Zambia, and Zimbabwe. Since mortality is a rare event, blood loss is a proximate indicator of morbidity or mortality that may overcome the statistical power challenges to rare events analysis. On the basis of published results of NASG trials, we hypothesized that women with abortion-related hypovolemia secondary to hemorrhage receiving NASG intervention would have significantly reduced blood loss and decreased odds of mortality compared with women who did not receive the intervention.

METHODS

Data for this analysis were collected by the Safe Motherhood Program at the University of California, San Francisco, from referral hospitals in Egypt, Nigeria, Zambia, and Zimbabwe as part of three quasi-experimental trials (Miller et al. 2006b; Miller et al. 2010a; Miller et al. 2010b) and one cluster-randomized control trial (Miller et al. 2013) of the NASG among women with hypovolemic shock secondary to obstetric hemorrhage. The methodology of these studies is described in more detail elsewhere (Miller et al. 2006b; Miller et al. 2010a; Miller et al. 2010b; Miller et al. 2013). Briefly, the three quasi-experimental trials included a pre-intervention period that was followed by an intervention period based at the tertiary facility level, and the cluster-randomized control trial (CRCT) evaluated NASG application at the primary health clinic (PHC) level, prior to transport to a tertiary facility for definitive treatment concurrently in intervention and control clinics. The control participants in all studies received standard evidence-based hemorrhage and shock management (WHO 2003). Women in all trials were eligible for study participation if they reached a threshold estimated blood loss (EBL) and one or more of the following signs of hypovolemia: systolic blood pressure (SBP) < 100 mmHg and/or pulse > 100 beats per minute (BPM). In the tertiary facility studies in Egypt and Nigeria, the threshold estimated blood loss was > 750 mL, whereas in the Zambia and Zimbabwe PHC-enrolled study the threshold EBL was > 500 mL. Staff in the intervention facilities were trained in standardized protocol, blood collection and measurement, NASG use, and data collection and recording. Upon enrollment, patients'

vital signs, level of consciousness, IV fluids, blood products transfused and uterotonics administered, urine output, and blood loss were monitored and recorded every 15 minutes until the cause of bleeding was identified and treated, vital signs were stable (SBP > 100 mmHg, pulse < 100 BPM) for at least two hours, and blood loss had decreased to approximately 25–50 mL^3 per hour. Study personnel trained the facility-based clinicians in WHO-recommended evidence-based protocols for obstetric hemorrhage and shock, and in NASG use and application (WHO 2003). After the pre-intervention phase, the clinician data collectors at the referral hospitals were trained to use the NASG.

Our primary outcomes included mortality from hypovolemic shock secondary to obstetric hemorrhage and survival with severe morbidity. Mortality was defined as death before hospital discharge, because women were not followed up after they left the hospital. We also recorded measured blood loss in a calibrated blood measurement drape (Brass V Drape, Excellent Fixable Drapes, Madurai, India) from study entry to exit. Clinician data collectors (physicians, nurses, and midwives) were all trained to complete the data-collection forms. All data were recorded by the clinicians during or immediately after they cared for the patient in shock. All data forms were reviewed for completeness by on-site data supervisors and the site project coordinator. Data were double entered into OpenClinica (Akaza Research, Waltham, MA), a web-based, open-source clinical trials software program that included range and consistency checks; data were also checked for errors and inconsistencies, which were resolved prior to analysis.

The majority of facilities were understaffed, underresourced, and characterized by long delays in obtaining definitive care. All women provided informed consent, and ethics committees provided a waiver of consent from women who were unconscious or confused at the time of admission until they recovered or consent was obtained from a relative as proxy. Study protocols were approved by institutional review boards at the University of California, San Francisco, and for each study, respectively, by the following institutions: University of Zambia, Lusaka Research Ethics Committee; Medical Research Council of Zimbabwe; Department of Reproductive Health and Research of the World Health Organization Ethics Review Committee; National Reproductive Health Research Committee of the Nigerian Federal Ministry of Health, El Galaa Maternity Teaching Hospital; Assiut University Women's Health Center; Alexandria University Teaching Hospital; and Al Minya University Teaching Hospital. Data collection forms were completed during or immediately after caring for the patient.

Eligibility criteria were similar across trials: women with hypovolemic shock secondary to obstetric hemorrhage, an estimated blood loss of ≥ 500 mL, and one or more clinical signs of hypovolemic shock (systolic blood pressure ≤ 100 mmHg and/or pulse ≥ 100 BPM). Standard protocols for hemorrhage and shock were followed in both phases, which, for women with post-abortion hemorrhage, included administration of crystalloid intravenous fluids, use of uterotonics, blood transfusion, vaginal procedures (manual vacuum aspiration [MVA], curettage for retained tissue), and, rarely, surgery (laparotomy, hysterectomy) (Mourad-Youssif et al. 2010; El Ayadi et al. 2013; Miller et al. 2013). All treatments occurred during the study or immediately prior to study entry (15 minutes); treatments received outside of this time frame were not included within the analysis. Blood loss after

study entry was measured by a closed-end calibrated plastic drape—a validated and accurate method—that was placed under women for direct measurement of blood loss (Patel et al. 2006; Schorn 2010; Miller et al. 2012).

Exclusions

Across the four studies, 1,637 women were diagnosed with complications of abortion at a gestational age of less than 24 weeks. Within the study sites, the threshold of 24 weeks gestational age guided selection of the ward to which the patient was admitted (gynecology versus labor and delivery); thus our protocol followed this distinction. We excluded 684 women because data were missing on one or more key variables: gestational age (n = 202), severity of shock (n = 8), or blood loss (n = 564). The final analytic sample included 953 women who presented with abortion-related hemorrhage—181 women in the pre-intervention phase and 772 women in the NASG phase. We compared patient characteristics between those participants who were included and those who were excluded and found that these groups differed significantly only in distribution of country and proportion receiving MVA ($p < 0.05$, not shown). After applying our exclusion criteria, no participants from our Nigeria study remained in the analytic sample.

Key Variables

We evaluated the effect of NASG intervention on our primary outcome, measured blood loss after study entry. The closed-end, calibrated, plastic blood collection drape was placed under the women at study admission to accurately measure all vaginal blood loss. We considered blood loss to be an intermediate variable between NASG intervention and mortality; thus, despite the statistical power challenges to rare events analysis, we assessed mortality as a secondary outcome.

Participant characteristics collected included age and parity. Other covariates, selected on the basis of their prior significance in the literature on NASG and blood loss or abortion (Miller et al. 2007; Miller, Martin, and Morris 2008; Miller et al. 2010a, 2010b; Miller et al. 2013), included pregnancy trimester, severity of shock, and receipt of hemostatic procedures (uterotonics administered and/or MVA). We specified trimester as first (<12 weeks gestation) or second (13–24 weeks gestation) based on medical record or patient report to account for differences in uterine size, uterine blood flow, and placental development between the first and second trimester that could affect amount of blood loss (Dundas 2003; Chestnut et al. 2009). Severity of shock at study entry was categorized using mean arterial pressure (MAP)[1] as mild or moderate (MAP ≥ 60 mmHg) versus severe (MAP < 60 mmHg). Hemostatic treatments that could modify blood loss included administration of uterotonics and MVA. Uterotonic agents such as oxytocin, methergine, and ergometrine improve uterine tone and increase uterine smooth muscle contractility, which helps to reduce blood loss (Khan and El-Refaey 2006; El Ayadi et al. 2013c). We defined receipt of uterotonics as having received any uterotonic medication during the study as treatment for hemorrhage, irrespective of type, mode of administration, or dose. Uterotonics administered to this population included ergometrine, misoprostol, oxytocin, or synometrine. Receipt of

[1]MAP = (2 * diastolic blood pressure + systolic blood pressure) / 3.

MVA procedure, which empties the uterus of any retained products of conception, thereby minimizing bleeding, was also noted (Dao et al. 2007). Because receiving MVA had an effect on the amount of bleeding, controlling for this procedure minimized the possible confounding it may have on the NASG's effect on blood loss. Finally, we specified a country-level indicator variable to control for any unmeasured systematic differences in the characteristics of the populations within each country or in the quality of care provided.

Analysis

We assessed the bivariate relationships between participant characteristics and covariates and NASG intervention and measured blood loss using chi-square and Wilcoxon-Mann-Whitney tests using a p-value criterion of <0.05 for statistical significance.

Quantile regression models were estimated to assess the relationship between NASG intervention and median total blood loss while controlling for selected covariates due to the distribution of our blood-loss outcome. This analytic strategy is more robust than OLS regression to outliers and non-normal error terms (Beyerlein 2014). We prespecified the inclusion of pregnancy trimester, severity of shock, and receipt of hemostatic procedure into our models. An initial unadjusted model that examined only the relationship between NASG intervention and measured blood loss was created. Model 1 controlled for severity of condition (MAP < 60 mmHg) and trimester. Model 2 controlled for hemostatic treatments given (uterotonics and/ or MVA). Model 3 controlled for all covariates included in Models 1 and 2. Finally, we evaluated the possibility of an interaction effect between MAP and pregnancy trimester in Model 4, building off of Model 3. All regression models included country-level indicator variables to account for any broad differences in care-provision environment across sites.

To examine differences in maternal mortality between intervention groups, we estimated logistic regression models, again including a country-level indicator to account for any differences across countries. Mortality models were estimated both for our analytic sample (n = 953) and for the full sample of women, with diagnosis of complications of abortion at gestational age of less than 24 weeks prior to exclusions for missing data (n = 1,637) as a sensitivity analysis.

Because of the differences in number of study participants between the pre-intervention phase and the intervention phase and in the length of study time between the two phases, we further evaluated the characteristics of intervention participants across intervention years 1–4 using chi-square tests, and conducted sensitivity analyses replicating our quantile regression models with intervention year in place of intervention phase, with the pre-intervention phase as our reference group.

RESULTS

Of the 953 women included in the analysis, 181 (19 percent) were in the pre-intervention phase and 772 (81 percent) were in the NASG intervention phase (Table 1). Participants in the two phases were similar in age and parity. There were significant differences between intervention groups in pregnancy trimester, MAP < 60 mmHg at study entry, and receipt of

uterotonics and MVA procedure. Compared with women in the pre-intervention phase, women who received the NASG intervention were significantly less likely to be in their second trimester of pregnancy (37 percent versus 49 percent) and more likely to be in severe shock (51 percent versus 33 percent). The intervention groups also differed significantly in receipt of hemostatic procedures—the proportion of women who received uterotonics—with only 40 percent of women in the NASG phase receiving uterotonics compared with 73 percent in the pre-intervention phase.

Similarly, a significantly higher proportion of women in the pre-intervention phase received MVA (74 percent versus 42 percent). In the bivariate analyses, our primary outcome, blood loss, was significantly lower among women in the NASG intervention phase compared with the pre-intervention phase. As shown in Table 2, women in the NASG phase experienced a median blood loss of 70 mL compared with 560 mL for women in the pre-intervention group. Our secondary outcome, mortality, was rare for both intervention groups, with three deaths occurring in the pre-intervention group (1.7 percent) and six in the NASG intervention group (0.8 percent). The 52 percent lower mortality rate among women in the NASG phase was not statistically significant ($p = 0.27$).

In the quantile regression model examining the relationship between NASG intervention and blood loss without controlling for covariates, but adjusting for country, there was a median decrease of 490 mL blood loss in the NASG phase compared with the pre-intervention phase (Table 3). After controlling for severity of shock (MAP < 60 mmHg) and pregnancy trimester (Model 1), median blood loss for the NASG intervention group was 490 mL less than in the pre-intervention group and remained statistically significant. Controlling for hemostatic treatments given (uterotonics and MVA, Model 2), median blood loss for the NASG intervention group was 460 mL less than in the pre-intervention phase. In Model 3, where we included severity of shock, pregnancy trimester, and hemostatic treatments, median blood loss was 470 mL less for the NASG intervention phase and remained statistically significant. Finally, we evaluated the potential for an interaction between severity of shock and pregnancy trimester (Model 4), but our results did not support such a relationship.

Our sensitivity analyses modeling NASG intervention year supported a consistent statistically significantly reduced blood loss across all intervention years compared with the preintervention phase, ranging from a median reduction of 340 mL for intervention year 1 to 560 mL for intervention year 4 (Table 4, unadjusted models). The pattern of results by intervention year was similar across Models 1–4, which sequentially controlled for severity of shock, pregnancy trimester, and hemostatic treatments, described above.

For advanced analysis on mortality (Table 5) using our analytic sample and adjusting for country, we found that the NASG intervention was associated with a 52 percent reduction in maternal death, but this finding was not statistically significant (AOR: 0.48; $p = 0.313$). As a sensitivity analysis, we estimated this same model within our sample prior to implementing exclusions for missing covariate data and found a slightly smaller (49 percent) and similarly nonsignificant effect (AOR: 0.61; $p = 0.334$).

In our assessment of intervention participants by intervention year (Table 6), we found significant differences across intervention year in severity of shock at study entry, in the proportion of participants undergoing MVA and receiving uterotonics, and by country. Across intervention years 1–4, the proportion of study participants in severe shock (MAP < 60 mmHg) showed an increasing trend from 42 percent in year 1 to 58 percent in year 4, with the exception of year 3. Conversely, the proportion of participants undergoing MVA or receiving uterotonic medication decreased over intervention years: 46 percent of study participants underwent MVA in year 1 compared with 14 percent in year 4, and 72 percent of study participants in intervention year 1 received uterotonic medications compared with 16 percent in year 4. By country, Zambia contributed the greatest number of study participants across all study years, with fewer participants from Zimbabwe across all years, and Egypt represented only in intervention year 1.

DISCUSSION

Findings from this analysis suggest that use of the NASG significantly reduces blood loss in women experiencing post-abortion hemorrhage. After adjusting for pregnancy trimester, MAP < 60 mmHg, uterotonic administration, and MVA, median blood loss was 470 mL less for women in the NASG intervention phase compared with women in the pre-intervention phase. The blood-loss results in this secondary subanalysis of post-abortion hemorrhage cases are consistent with previous findings that the NASG reduces blood loss from all obstetric hemorrhage etiologies as well as when limited only to postpartum hemorrhage etiologies (Mourad-Youssif et al. 2010; Morris et al. 2011; Ojengbede et al. 2011). Studies of the NASG in Egypt and Nigeria examining blood loss from postpartum hemorrhage found that measured blood loss decreased by 50 percent with NASG intervention; women experienced a median blood loss of 400 mL in the pre-intervention compared with 200 mL in the NASG phase (Mourad-Youssif et al. 2010). Within the Egypt site alone, NASG intervention among women with obstetric hemorrhage resulting from uterine atony was associated with a significantly reduced blood loss of 409 mL among the pre-intervention group compared with 236 mL among the NASG intervention group (Morris et al. 2011). A similar subanalysis of this obstetric-hemorrhage trial in Nigeria also found that mean measured blood loss was significantly lower for women in the NASG intervention phase compared with women in the pre-intervention phase (73.5 mL versus 340.4 mL) (Miller et al. 2009). The statistically significant difference in blood loss in our analysis differs only from a recent finding in the Zambia and Zimbabwe cluster randomized trial, which found no difference in measured blood loss in transit from primary health care centers to referral hospitals among 880 women (205 mL NASG versus 218 mL control); however, these results were severely compromised by missing data. In that study, 62 percent of data were missing on blood loss in transit, and 72 percent of women had no total blood loss recorded (Miller et al. 2013).

Our sensitivity analysis, which evaluated the effect of NASG intervention year on blood loss, supported a consistent and statistically significant reduction in blood loss across all NASG intervention years when compared with the pre-intervention phase. However, it is important to note that the reduction seen in blood loss for NASG intervention year 1 was smaller than for NASG intervention years 2–4. There are several possibilities for this

finding. First, over time clinicians may have improved their use of the NASG and associated interventions, which resulted in the improved outcome. Second, it is also possible that as the NASG intervention became more ingrained in the clinical study sites, the distribution of study participants was altered. When reviewing patient characteristics at study entry across NASG intervention years, we noted that there were statistically significant increases in the proportion of women who entered the study in severe shock (MAP < 60 mmHg). We also found that the proportion of women receiving uterotonics or MVA decreased and the distribution by country also varied. We included in our multivariable analyses all variables that differed significantly across NASG intervention years.

In our subanalysis of women with post-abortion hemorrhage, we found NASG intervention to be associated with a 52 percent reduction in maternal death, although this reduction was not statistically significant. We estimated this same model with all women experiencing post-abortion hemorrhage, including those we had excluded from our analytic sample because of missing data on severity of shock at study entry, trimester of pregnancy, and blood loss, and found a slightly attenuated 49 percent reduction, also not statistically significant. These findings are consistent with other reports of the effect of the NASG on maternal mortality. Previous analyses have consistently shown decreased odds of mortality with NASG intervention ranging from 46 to 70 percent, with some variation in significance levels given that mortality was a rare outcome (Ojengbede et al. 2011). A systematic review of five studies (n = 3,563) of NASG at the tertiary-facility level found a statistically significant reduction in maternal mortality: 39 percent among all women in shock and 58 percent when the analysis was restricted only to women with the most severe shock (El Ayadi et al. 2013a). Individual study results, including a subanalysis of the Egypt trial that examined only atonic hemorrhage, also found decreasing trends of similar magnitude for mortality (Morris et al. 2011). Among women with postpartum hemorrhage etiologies in Nigeria, NASG was associated with a statistically significant 70 percent reduction in mortality (Ojengbede et al. 2011). Furthermore, in the recent Zambia and Zimbabwe cluster randomized trial, NASG intervention was associated with a nonsignificant 46 percent reduced odds of mortality (Miller et al. 2013)

The consistency in reduced blood loss associated with the NASG intervention found in our analysis as well as in previous work on different subsets of hemorrhage etiologies further strengthens the evidence supporting the effectiveness of the NASG in reducing blood loss for women with all obstetric hemorrhage. Because only women with post-abortion hemorrhage were examined in the present study, these findings contribute to the knowledge base that NASG use among this specific patient population may also contribute to reduced blood loss and better maternal outcomes. Our mortality results are also very similar in effect size to what has been reported for obstetric hemorrhage more broadly, despite a lack of statistical significance for this small sample.

It is important to consider how the statistically significant differences in demographic characteristics between phases may have affected our results. The proportion of women entering the study with MAP < 60 mmHg was significantly higher in the NASG intervention phase (51 percent) than in the pre-intervention phase (33 percent). Thus, more women in the NASG intervention phase were in severe shock and may have been more likely to experience

adverse outcomes, even when treatments were administered. Women in the NASG phase also were less likely to receive any hemostatic treatments. A smaller proportion of women in the NASG phase received uterotonics (40 percent versus 73 percent) or MVA (42 percent versus 74 percent). Despite being in worse condition and receiving fewer hemostatic treatments, the women in the NASG phase still had significantly lower blood loss and decreased mortality; controlling for these factors did not modify the magnitude of difference observed.

In contrast, there was a significantly higher proportion of second-trimester pregnancies in the pre-intervention phase (49 percent) than in the NASG phase (37 percent). Pregnancies in the second trimester have more-developed placental circulation with increased diameter of spinal arteries and larger blood sinuses, which could lead to more blood loss when compared with first-trimester pregnancies. We controlled for this difference in pregnancy trimesters in our multivariable regression models.

Study Strengths

Strengths of this analysis include the large sample of women pooled from four low-resource countries with similar care contexts who received NASG for treatment of hypovolemic shock secondary to post-abortion hemorrhage and the use of the NASG in real-world situations (El Ayadi et al. 2013c). The analysis used data from settings where NASG is more likely to have a large impact because of longer delays in getting treatment, which is more relevant for women experiencing post-abortion hemorrhages. In low-resource settings that have high maternal mortality rates, health-care facilities are busy, understaffed, and experience delays in transport and time to receive definitive therapies. These delays are often even greater for women who experience post-abortion hemorrhage. Conducting trials in these real-world settings means results can be applied to similar settings where post-abortion care may be deficient (Miller et al. 2013).

Valid appraisal of blood loss is a common challenge for any study on obstetric hemorrhage; the studies included in this analysis used a closed-end calibrated plastic drape for blood-loss measurement. Measurement of blood loss with this drape has been found to be comparable to spectrophotometry, which is the gold standard for measuring blood loss but is often impractical in real-world settings. This outcome supports the validity of our blood-loss measures (Khan and El-Refaey 2006; Patel et al. 2006; Schorn 2010).

Limitations

There are several limitations to consider when interpreting these results. Most of the data come from quasi-experimental trials, with a nonrandomized, nonblinded, pre-intervention/intervention design (Miller et al. 2006b; Miller et al. 2010b). This study design is susceptible to selection bias. For example, some women who experience post-abortion obstetric hemorrhage never arrive at a facility. Further, providers may have chosen to use NASG only on more severe cases. In addition, the skill level of clinicians may have improved over the study periods, where the non-NASG phase occurred first, as a result of frequent trainings and more experience with using the evidence-based protocol.

In addition, there was a notable imbalance between phases: only 19 percent of women were in the pre-intervention phase, compared with 81 percent in the NASG intervention phase. This gap was slightly increased from the distribution before exclusions (26 percent pre-intervention versus 74 percent NASG intervention). This is likely because most of the sample (87 percent) came from the Zambia and Zimbabwe study. In that study the pre-intervention phase lasted one year, while the NASG phase lasted four years. This difference in length of phases is likely the reason for the higher number of women in the NASG intervention group, and the imbalance may have reduced our statistical power to detect the hypothesized effects (Whitley and Ball 2002). Our assessment of participant characteristics across intervention years indicated statistically significant differences in severity of shock at study entry, MVA procedure, uterotonic receipt, and country. These results reflect the greater severity of participant condition across the intervention phase and suggest that facilities were implementing protocol changes in both uterotonic administration and MVA over time—variables that were controlled for in our multivariable analysis. The observed discrepancies across country are consistent with study length across the sites, and country was also controlled for in our multivariable analysis. However, the high proportion of study participants from one country may influence the generalizability of results. Finally, our complete case analysis excluded a substantial proportion of individuals because of missing data on critical variables, which may have reduced the precision of our estimates.

The majority of women in this study were enrolled in the intervention when they arrived (often after being transported long distances) at tertiary-care facilities, where delays occurred in receiving treatment. Our results cannot be generalized to other care settings, such as community-level clinics.

Many post-abortion deaths in low-income countries result from septic shock from unsafe abortion (Haddad and Nour 2009). The NASG might have a first-aid benefit for such patients because of the circumferential pressure that shunts blood to the core organs and increases blood pressure; however, we are unable to investigate this possibility because our study focus was limited to hypovolemic shock. Finally, because our study did not systematically capture nonhemorrhage co-morbidities, we were unable to evaluate the extent to which co-morbidities combined with obstetric hemorrhage modified the risk of adverse outcome within this sample.

CONCLUSION

This study provides valuable information about management of women suffering from abortion-related hemorrhage and hypovolemic shock and adds to the limited information available about this patient population in Africa. The study highlights the effectiveness of the NASG in significantly decreasing blood loss among women experiencing hypovolemia secondary to post-abortion hemorrhage. Previous studies have demonstrated imbalances in time to treatment as well as time for transport to a health care facility among women suffering from post-abortion complications (Hynes et al. 2012). This extended time before receiving treatment puts women at greater risk of losing higher volumes of blood and therefore experiencing worse outcomes. Our analysis also suggests 52 percent lower odds of mortality among women treated with the NASG. While not statistically significant, this

represents a clinically important decrease in mortality with the use of a simple low-technology first-aid device.

The NASG plays an innovative role in all obstetric hemorrhage and hypovolemic shock management, and this analysis shows that it holds promise as a first-aid device that can significantly decrease blood loss and, perhaps, mortality among women experiencing abortion-related hemorrhage. It might therefore be beneficial to incorporate the NASG into regular practice by making it part of standard hemorrhage-treatment protocols, including for women with abortion-related hypovolemic shock secondary to hemorrhage. Using the NASG as part of standard clinical practice in low-resource settings where primary prevention has failed or is unavailable may lead to better health outcomes for women who do not have immediate access to definitive treatment for shock. Further research is needed to validate the NASG's effect of reducing blood loss and mortality in women with post-abortion hemorrhage when used prior to reaching referral hospitals. In low-resource settings where women with complications of abortion often die as a result of long delays in receiving definitive treatment, this low-technology, low-cost, novel approach for buying time may help more women survive.

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TABLE 1

Participant characteristics for analytic sample of abortion cases by study phase

	Pre-intervention phase (n = 181)		NASG intervention phase (n = 772)	
Characteristic	**n**	**%**	**n**	**%**
Age (years)	(n = 181)		(n = 769)	
<20	18	9.9	60	7.8
20–24	47	26.0	185	25.1
25–29	60	33.2	219	28.5
30–34	31	17.1	169	21.9
35+	25	13.8	136	17.7
Parity	(n = 181)		(n = 764)	
0	34	18.8	120	15.7
1	36	19.9	145	18.9
2–4	89	49.2	398	52.1
5+	22	12.1	101	13.2
Trimester of pregnancy**				
First ≤12 weeks	92	50.8	485	62.8
Second 13–24 weeks	89	49.2	278	37.2
Severity of shock at study entry***				
MAP ≥ 60 mmHg	122	67.4	376	48.7
MAP < 60 mmHg	59	32.6	396	51.3
Received uterotonics***				
Yes	132	72.9	306	39.6
No	49	27.1	466	60.4
MVA procedure***				
Yes	134	74.0	322	41.7
No	47	26.0	450	58.3
Country***[a]				
Egypt	24	13.3	34	4.4
Zambia	150	82.9	650	84.2
Zimbabwe	7	3.9	88	11.4

*Significant at $p < 0.05$

**$p < 0.01$

***$p < 0.001$

indicating categorical variable distribution differs across study phases.

MAP = Mean arterial pressure. MVA = Manual vacuum aspiration.

[a]No participants from Nigeria remained in our analytic sample after applying the exclusion criteria.

TABLE 2

Distribution of primary and secondary outcomes by NASG intervention phase

Outcome	Pre-intervention phase (n = 181)	NASG intervention phase (n = 772)
Median blood loss (IQR) ***[a]	560 (315–800)	70 (35–200)
Mortality, n (%)	3 (1.7%)	6 (0.8%)

*** Significant at $p < 0.001$.

[a] Wilcoxon Rank-Sum Test.

TABLE 3

Multivariable quantile regression results for effect of NASG intervention on mL blood loss, adjusted for country

	Unadjusted models	Model 1	Model 2	Model 3	Model 4
	β	*β*	*β*	*β*	*β*
NASG intervention	490***	490***	460***	470***	460***
MAP < 60 mmHg					
Yes	−30	−5		0	10
Trimester					
First (r)	(r)	(r)		(r)	(r)
Second	70***	35*		25	50**
MAP * trimester					−40
Uterotonic					
Yes	80***		10	15	10
MVA					
Yes	95***		40*	35*	35

*Significant at $p < 0.05$

**$p < 0.01$

***$p < 0.001$.

MAP = Mean arterial pressure. (r) = Reference category.

NOTE: N = 953.

TABLE 4

Multivariable quantile regression results for effect of NASG intervention on mL blood loss, by intervention year, adjusted for country

	Unadjusted models	Model 1	Model 2	Model 3	Model 4
	β	*β*	*β*	*β*	*β*
NASG intervention					
Pre-intervention (r)	(r)	(r)	(r)	(r)	(r)
Year 1	−340.0***	−325.0***	−335.0***	−327.5***	−326.3***
Year 2	−510.0***	−500.0***	−510.0***	−497.5***	−493.8***
Year 3	−515.0***	−505.0***	−510.0***	−501.3***	−498.8***
Year 4	−560.0***	−555.0***	−555.0***	−543.8***	−543.8***
MAP < 60 mmHg					
Yes	−30.0	0.0		−2.5	0
Trimester					
First (r)	(r)	(r)		(r)	(r)
Second	70.0***	25.0		23.8	26.3
MAP * trimester					−16.3
Uterotonic					
Yes	80.0***		15	6.3	7.5
MVA					
Yes	95.0***		−5	6.3	2.5

*Significant at $p < 0.05$

**$p < 0.01$

***$p < 0.001$.

(r) = Reference category.

NOTE: N = 953.

TABLE 5

Adjusted odds ratios for mortality by study phase for analytic sample and full sample, adjusted for country

	Pre-intervention		Intervention		
	n	%	n	%	Adjusted OR
Analytic sample (n = 953)	3	1.66	6	0.78	0.48
Full sample (n = 1,637)	6	1.41	11	0.91	0.61

NOTE: Pre-intervention n = 426; intervention n = 1,211; includes all women with abortion diagnosis even if missing gestational age, severity of shock, or blood loss.

TABLE 6

Participant characteristics for analytic sample of abortion cases by study year

	Pre-intervention (n = 181)		Intervention Year 1 (n = 118)		Intervention Year 2 (n = 244)		Intervention Year 3 (n = 285)		Intervention Year 4 (n = 125)	
Characteristic	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Age (years)										
<20	18	9.9	10	8.6	21	8.6	17	6.0	12	9.6
20–24	47	26.0	23	19.7	56	23.1	74	26.1	32	25.6
25–29	60	33.2	41	35.0	63	25.9	89	31.3	26	20.8
30–34	31	17.1	27	23.1	52	21.4	66	23.2	24	19.2
35+	25	13.8	16	13.7	51	21.0	38	13.4	31	24.8
Parity										
0	34	18.8	17	14.9	33	13.6	51	18.0	19	15.3
1	36	19.9	22	19.3	47	19.3	54	19.1	22	17.7
2–4	89	49.2	62	54.4	127	52.0	148	52.3	61	49.2
5+	22	12.1	13	11.4	36	14.8	30	10.6	22	17.7
Trimester of pregnancy										
First ≤12 weeks	92	50.8	63	53.4	156	63.9	190	66.7	76	60.8
Second 13–24 weeks	89	49.2	55	46.6	88	36.1	95	33.3	49	39.2
Severity of shock at study entry *										
MAP ≥ 60 mmHg	122	67.4	69	58.5	109	44.7	147	51.6	52	41.6
MAP < 60 mmHg	59	32.6	49	41.5	135	55.3	138	48.4	73	58.4
Received uterotonics ***										
Yes	132	72.9	85	72.0	146	59.8	55	19.3	20	16.0
No	49	27.1	33	28.0	98	40.2	230	80.7	105	84.0
MVA procedure ***										
Yes	134	74.0	54	45.8	178	73.0	73	25.6	17	13.6
No	47	26.0	64	54.2	66	27.1	212	74.4	108	86.4
Country ***[a]										
Egypt	24	13.3	34	28.1	0	0.0	0	0.0	0	0.0
Zambia	150	82.9	58	49.2	207	84.8	270	94.7	115	92.0
Zimbabwe	7	3.9	26	22.0	37	15.2	15	5.3	10	8.0

*Significant at $p < 0.05$

**$p < 0.01$

***$p < 0.001$

indicating categorical variable distribution differs across intervention years only (excluding pre-intervention).

[a]No participants from Nigeria remained in our analytic sample after applying the exclusion criteria.