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Shock progression and survival after use of a condom uterine balloon tamponade package in women with uncontrolled postpartum hemorrhage

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Abstract

Objective: To examine the outcomes of women in advanced shock from uncontrolled postpartum hemorrhage (PPH) who underwent placement of an Every Second Matters for Mothers and Babies Uterine Balloon Tamponade (ESM-UBT) device.

Methods: In a prospective case series, data were collected for women who received an ESM-UBT device at healthcare facilities in Kenya, Senegal, Sierra Leone, and Tanzania between September 1, 2012, and September 30, 2016. Shock class was assigned on the basis of recorded blood pressures and mental status at the time of UBT placement.

Results: Data for 306 women with uncontrolled PPH from uterine atony across 117 facilities were analyzed. Normal vital signs or class I/II shock were reported for 166 (54.2%). In this group, one death occurred and was attributed to PPH (survival rate 99.4%). There were no cases of shock progression. One hundred and eleven (36.3%) were in class III shock and 29 (9.5%) in class IV shock; the respective survival rates were 97.3% (n=108) and 86.2% (n=25).

Conclusion: The ESM-UBT device arrests hemorrhage, prevents shock progression, and is associated with high survival rates among women with uncontrolled PPH from uterine atony.

KEYWORDS

Low-income countries; Maternal mortality; Postpartum hemorrhage; Shock; Uterine balloon tamponade

1 | INTRODUCTION

Advanced shock from uncontrolled postpartum hemorrhage (PPH) is the leading cause of maternal mortality worldwide, causing an estimated 115 000 deaths and many times that number of near misses and injuries each year.[1,2] The overwhelming majority of these deaths occur in low- and middle-income countries.[1]

The absolute priority when managing actively hemorrhaging patients is to gain control of and arrest ongoing blood loss.[3] In fact, measures to increase the blood pressure in actively hemorrhaging patients—e.g. fluid or vasopressor administration, or use of pneumatic antishock trousers—will do harm if enacted before gaining control of active hemorrhage.[4] In circumstances when blood loss continues unabated, the human body engages compensatory mechanisms that aim to preserve the most vital functions required for life.[5] When hemorrhage persists, the body passes through a continuum of worsening clinical states (stages of shock) as a result of progressive hypoxia at the cellular level, protecting cerebral and cardiovascular function as long as possible, yet ultimately arriving at an advanced stage of shock just before death.[6,7] In well-resourced settings, once shock

has developed, the expected mortality rate is more than 30% among women with maternal hemorrhage.[3,5] The mortality rates of women in advanced shock from uncontrolled PPH in resource-limited settings are unknown but will undoubtedly be considerably greater.

The first-line management of PPH includes uterine massage, identification and attempted repair of traumatic causes, evacuation of retained products of conception, and treatment doses of uterotonic agents.[8] When hemorrhage persists, alternative methods are often used, including aortic compression, uterine balloon tamponade (UBT), non-pneumatic antishock trousers, and surgical interventions such as uterine artery embolization, B-Lynch compression suturing, and ultimately hysterectomy.[6] In low-resource settings, access to surgical services is limited or nonexistent; thus, women with uncontrolled hemorrhage often die or become disabled.[9,10]

During the past 8 years, an evidence-based PPH package using an ultra-low-cost condom-based uterine balloon called Every Second Matters for Mothers and Babies UBT (ESM-UBT; Massachusetts General Hospital, Boston, MA, USA) has been designed, developed, implemented, and refined.[9–12] The ESM-UBT package—which consists of the UBT device, a PPH clinical management checklist, and a training module—has been successfully implemented across all levels of the health systems in Ghana, Kenya, Nepal, Senegal, Sierra Leone, South Sudan, Tanzania, and Zambia. Although the data available to date have suggested a very high survival rate (98%) in women overall,[9,10] a critical and incomplete part of the equation defining overall impact—to better understand the relationship between ESM-UBT device placement and maternal survival—remains.

The objective of the present study was to better define the true impact of the ESM-UBT package by specifically analyzing the outcomes of women in advanced stages of hemorrhagic shock—i.e. women who would typically be expected to have a high mortality rate.[5,7,13–17]

2 | MATERIALS AND METHODS

In a prospective case series, data were obtained for women who had an ESM-UBT device placed as a result of uncontrolled PPH originating from an atonic uterus. Health facilities representing all levels of the health systems in Kenya, Sierra Leone, Senegal, and Tanzania were recruited to participate in data collection subsequent to ESM-UBT implementation as directed by each in-country Ministry of Health between September 1, 2012, and September 30, 2016. In the course of the 4 years, facilities were defined as "online" once ESM-UBT wall charts were posted in each delivery area, 85% or more of the skilled birth attendants were trained on ESM-UBT and ESM-UBT manuals, and the devices were readily available.

Implementation of the ESM-UBT training package and subsequent use of the UBT device were considered part of standard practice at the participating health facilities and, as such, further consent was not sought from patients beyond that which they gave by electing to receive care at the health facility. De-identified quality assurance data were used for research purposes. Ethical approval for the current study was obtained from the Partners Human Research Committee (Massachusetts General Hospital, Boston, MA, USA), the Maseno University Ethics Review Committee (Maseno, Kenya), the Ministry of Health in Kenya, the Office of the Sierra Leone Ethics and Scientific Review Committee (Ministry of Health and Sanitation of Sierra Leone), the Conseil National de Recherche en Santé in Senegal, and the Ministry of Health Safe Motherhood Initiative and the National Institute for Medical Research in Tanzania.

Data were collected prospectively between delivery and facility discharge, and information on additional events/complications was collected via follow-up at 2 and 6 weeks after facility discharge. Data were obtained for patient demographics, pregnancy and relevant medical history, clinical course during the labor and delivery period, PPH interventions performed, and clinical outcomes. Because of the limitations of pre-existing health facility records in resource-limited settings, data collection for the study was via a multipronged approach: examination of the data cards included in each ESM-UBT device kit; telephone and in-person interviews with patients, village chiefs, and community health workers; and review of available health facility records to include postmortem findings. Facilities were called weekly, and institution and village site visits were conducted quarterly. In any instances of conflict among data sources, the researchers assessed the respective data quality and typically prioritized data recorded on the ESM-UBT data cards.

A woman was said to be in advanced shock if she met the criteria for either class III or class IV shock. Class III shock was defined as uncontrolled ongoing hemorrhage and a systolic blood pressure of less than or equal to 90 mm Hg but more than 70 mm Hg and/or an altered mental status without unconsciousness. Class IV shock was defined as ongoing uncontrolled hemorrhage and a systolic blood pressure of less than or equal to 70 mm Hg and/or unconsciousness. To give the most conservative assessment of the impact of ESM-UBT placement, PPH was categorized as resulting from uterine atony unless anatomical evidence directed otherwise. Women who had alternate causes of PPH such as cervical tear, uterine rupture, or disseminated intravascular coagulation owing to sepsis were excluded.

The data analysis was performed using Excel 2015 (Microsoft Corporation, Redmond, WA, USA) and SPSS version 23.0 (IBM, Armonk, NY, USA). $P<0.05$ was considered statistically significant.

3 | RESULTS

In total, 339 women with uncontrolled PPH from all causes had ESM-UBT devices placed at 117 study facilities in Kenya, Sierra Leone, Senegal, and Tanzania (Fig. 1). The study cohort included 306 women with uncontrolled PPH originating from an atonic uterus. Overall, 8 (2.6%) of the 306 women died from uncontrolled PPH. Two (0.7%) women with an atonic uterus survived PPH but then died from other causes (a pulmonary embolism and an "unknown" cause among a mother who died several days after discharge home in a "healthy state").

Table 1 shows characteristics of the study cohort, providers, and facilities. Almost all women delivered in a facility; those who had delivered at home were transferred to a facility because of their PPH.

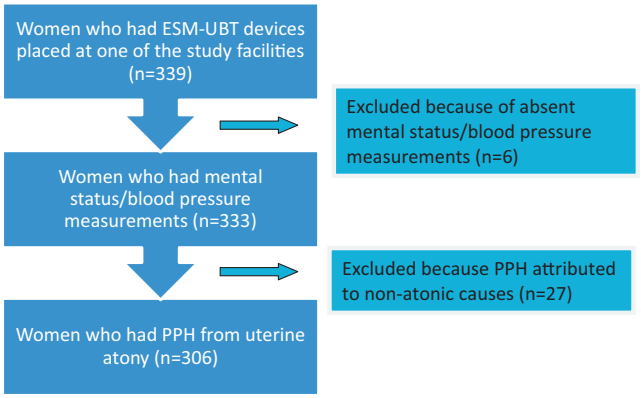

FIGURE 1 Flowchart of study participants. Abbreviations: ESM-UBT, Every Second Matters for Mothers and Babies Uterine Balloon Tamponade; PPH, postpartum hemorrhage.

Most women had their UBTs placed by nurses or midwives, or doctors. Slightly more than one-third of devices were placed at community health centers and lower-level facilities. The composition of the 117 study facilities varied. For example, in the first year (September 1, 2012 to August 31, 2013) of ESM-UBT implementation, only 12 facilities were on-line and all were rural nurse-midwifery centers in Kenya. Additionally, soon after the onset of the Ebola epidemic (June 2014), the facilities in Freetown, Sierra Leone, ceased reporting data and were subsequently replaced by facilities in Kenya over the ensuing 18 months. Four facilities in Tanzania joined the study in April 2016. All levels of facilities were represented, from tertiary care to very rural health facilities.

Overall, 166 (54.2%) of the 306 women with an atonic uterus had normal vital signs or were in class I or class II hemorrhagic shock at the time of UBT placement. Within this no-to-mild shock category, one woman died as a result of uncontrolled PPH (survival rate 99.4%). None of the remaining 165 women progressed to class III or class IV shock. Overall, 111 (36.3%) of the 306 women were in class III shock and 29 (9.5%) were in class IV shock. Among the 140 women in advanced shock (class III and class IV), 133 (95.0%) survived, with 108 (97.3%) of 111 and 25 (86.2%) of 29 women surviving after class III and class IV shock, respectively.

No significant differences between shock categories were seen for maternal age, parity, uterotonic dose, or location of delivery. However, the frequencies of blood transfusion and hysterectomy or other emergency surgical procedures were significantly increased among women with class IV shock (Table 2).

4 | DISCUSSION

The present study—which to our knowledge represents the largest cohort of PPH cases managed with UBT described to date—provides critical evidence on the effectiveness of UBT among women in advanced hemorrhagic shock. Use of the ESM-UBT device was associated with high patient survival, even among women in advanced shock.

TABLE 1 Patient, provider, and facility characteristics for the study cohort (n=306).

Characteristic	Value[a]
Age, y (n=299)	26.9 ± 6.4 (16–45)
Parity (n=300)	2.5 ± 2.5 (0–13)
Primiparous	75 (25.0)
Multiparous	169 (56.3)
Grand multiparous[b]	51 (17.0)
Great-grand multiparous[c]	5 (1.7)
Country (n=306)	
Kenya	189 (61.8)
Tanzania	45 (14.7)
Senegal	42 (13.7)
Sierra Leone	30 (9.8)
Location of delivery (n=302)	
Facility	286 (94.7)
Home	16 (5.3)
Location of UBT placement (facility level; n=302)[d]	
Community health center or another lower-level facility	111 (36.8)
District hospital or another higher-level facility	192 (63.6)
Healthcare provider cadre(s) who participated in placing the UBT device (n=296)[d]	
Nurse/midwife	143 (48.3)
Doctor	131 (44.3)
Lower-level cadre	29 (9.8)
Doses of uterotonics (n=305)	2.10 ± 0.88 (0–4)
Received at least one dose of uterotonics (n=306)	293 (95.8)
Blood transfusion (n=306)	135 (44.1)
Hysterectomy or another emergency surgical procedure (n=306)	8 (2.6)
PPH-related deaths (n=306)	8 (2.6)

Abbreviations: UBT, uterine balloon tamponade; PPH, postpartum hemorrhage.
[a]Values are given as mean ± SD (range) or number (percentage).
[b]≥5 births.
[c]≥10 births.
[d]In some cases, more than 1 facility type or cadre was indicated.

Among the present cohort of 306 women with uncontrolled PPH from an atonic uterus, the ESM-UBT device was highly effective, supporting an overall survival rate of 97.4% from the hemorrhage event. The device was particularly effective in the 166 women with uncontrolled PPH who had a uterine balloon placed before the onset of advanced shock, as evidenced by both arrest of progression along the continuum of shock and a survival rate of 99.4%. Although the expected mortality rate in these women is unknown, these findings of arrest of shock progression and high survival are compelling given that all other available measures had failed. Currently, WHO guidelines[18] recommend use of the uterine balloon as a rescue measure to

TABLE 2 Patient, provider, and facility characteristics by shock class (n=306).[a]

Characteristic	Normal vitals or mild shock (n=166)	Class III shock (n=111)	Class IV shock (n=29)	*P* value
Dose of uterotonics (n=305)	2.08 ± 0.89 (0–3)	2.05 ± 0.88 (0–4)	2.38 ± 0.78 (1–3)	0.178[b]
Received at least one dose of uterotonics (n=306)	157 (94.6)	107 (96.4)	29 (100.0)	0.375[c]
Blood transfusion (n=306)	60 (36.1)	55 (49.5)	20 (69.0)	0.002[c]
Hysterectomy or another emergency surgical procedure (n=306)	3 (1.8)	2 (1.8)	3 (10.3)	0.023[c]
Healthcare provider cadre(s) who participated in placing the UBT device (n=296)				0.112[c]
Doctor	71 (42.8)	40 (36.0)	20 (69.0)[d]	
Nurse/midwife	78 (47.0)	56 (50.5)	9 (31.0)[d]	
Lower-level cadre	15 (9.0)	12 (10.8)	2 (6.9)[d]	
Location of UBT placement (n=302)				0.233[c]
Lower-level facility	60 (36.1)	44 (39.6)	7 (24.1)	
Higher-level facility	104 (62.7)	65 (58.6)	22 (75.9)	
PPH-related deaths	1 (0.6)	3 (2.7)	4 (13.8)	–
Survival rate, %	99.4	97.3	86.2	0.306[c,e] 0.002[c,f] 0.035[c,g]

Abbreviations: UBT, uterine balloon tamponade; PPH, postpartum hemorrhage.
[a]Values are given as mean ± SD (range) or number (percentage), unless indicated otherwise.
[b]Three-way analysis of variance.
[c]χ^2 test.
[d]In 2 cases, 2 providers were credited with the placement of the balloon.
[e]Class III compared with normal vitals or no shock.
[f]Class IV compared with normal vitals or no shock.
[g]Class III compared with class IV.

be deployed at the end of the PPH clinical pathway, only when all else has failed. The present outcomes among the 166 women with no-to-mild shock yet with ongoing uncontrolled hemorrhage indicate that PPH clinical pathway guidelines should be revised and support early use of UBT, before the onset of advanced shock.

Among the 140 women in advanced shock (class III and class IV), the survival rate of 95.0% from uncontrolled hemorrhage was considerably higher than expected. Although the present study did not include a control group and there are no PPH animal models in the literature from which to draw, estimates based on hemorrhagic shock outcomes from the surgical, obstetrics, and gynecology literature place the minimum mortality rate at more than 30% in high-resource settings.[8] Given that 51 (36.4%) of these 140 women had their ESM-UBT devices placed at lower-level facilities in resource-scarce settings, logic tells us that the expected mortality rate, without an ESM-UBT device, would have been markedly greater than the 5.0% observed. Additionally, even though the survival rate in the present cohort decreased the later the ESM-UBT device was placed along the timeline of ongoing uncontrolled hemorrhage, the finding of an 86.2% survival rate even among the 29 women who had hard evidence of severe cardiovascular and/or central nervous system dysfunction (class IV shock) is reason for enthusiasm. The arrest of progression along the continuum of shock and the high overall survival rates strongly support early use in women who demonstrate findings of uncontrolled PPH from an atonic uterus.

The most important strengths of the present study are the size of the cohort overall and the number of women in advanced stages of shock. The most important limitation arose from the investigators' decision that a randomized control trial was not appropriate on ethical grounds. The authors also attempted but were unable to identify sufficiently reliable historical PPH control data in these settings; this was particularly difficult when considering how reliable the historical control data needed to be to accurately detect statistically significant rate changes among relatively infrequent PPH-related deaths. Therefore, the present study did not have a control group, limiting somewhat the claims regarding causation. Additionally, although all ESM-UBT devices were numbered and the research teams were quite vigilant, it is possible that not all cases of UBT use were reported. Because the online status and the make-up of the 117 study facilities were dynamic, defining an overall denominator of deliveries and PPH prevalence was not possible. Nevertheless, close follow-up with facilities and the use of both passive and active surveillance methods helped mitigate these limitations.

Most of the current published reports on UBT for PPH[9,10,19,20] are descriptive and based on series of women in whom UBTs were placed. Although each case of uncontrolled PPH with UBT placement is compelling to the individual maternal health provider who placed the UBT, it is challenging to quantify the true impact and, thus, responsibly advocate for policy change without a higher standard of evidence. Even though the present study was not a randomized controlled trial, we believe that the data are stronger than any other data reported

to date and should help to inform clinical decision making and policy toward the effort of reducing maternal mortality.

In conclusion, the ESM-UBT package arrests hemorrhage, prevents shock progression, and is associated with a high rate of survival in women with uncontrolled PPH from an atonic uterus. WHO and other maternal health leaders should advocate for the global implementation of ESM-UBT and other regionally approved UBT packages. Further research on the ESM-UBT package should seek to devise optimal models for scale, implement the package in settings with reliable historical data (to serve as historical controls), understand the opportunities to avert deaths by early UBT placement, and gain user feedback to optimize UBT devices and training.

AUTHOR CONTRIBUTIONS

TFB and MG conceived and designed the study, and obtained research funding. MO and VT recruited participating centers and patients, and managed the data, including quality control. TFB, SDB, and BDN provided statistical advice on the study design, analyzed the data, and drafted the article. All authors reviewed and contributed to its final version.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest.

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