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Full length article

## Improving obstetric hemorrhage morbidity by a checklist-based management protocol; a quality improvement initiative

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### ABSTRACT

**Objective:** Postpartum hemorrhage is a leading cause of maternal morbidity and mortality worldwide. Institutions are encouraged to have a standardized approach to the management of obstetric hemorrhage. The purpose of this quality improvement project was to investigate postpartum hemorrhage associated morbidity before and after implementing an obstetric hemorrhage checklist-based protocol.

**Study design:** In 2015, a resident-driven initiative for obstetric hemorrhage was initiated at a single institution using a checklist-based protocol for postpartum hemorrhage. The project included development of the obstetric hemorrhage checklist by a multidisciplinary team and implementation using low cost education and training strategies. Following implementation, a pre-and post-protocol retrospective analysis was performed measuring maternal morbidity surrogates and protocol compliance. During the 18 month study period, 422 women were identified for review and 147 met criteria in the pre-protocol group and 150 met criteria in the post-protocol group.

**Results:** There was a significant decrease in severe postpartum hemorrhage rates in the post-protocol group ( $p=0.04$ ) and all other surrogates for maternal morbidity decreased in the post-protocol group. Protocol compliance was 62.2% and compliance with screening using an assessment of hemorrhage risk was 75.7%.

**Conclusion:** The implementation of a checklist-based management protocol for postpartum hemorrhage has shown a promising trend in improving maternal morbidity, screening, early diagnosis, and healthcare delivery for obstetric hemorrhage at our institution and has been approved for larger scale implementation within our health system.

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### Introduction

Obstetric hemorrhage is a leading cause of maternal morbidity and mortality worldwide [1–3]. Of the multiple etiologies of postpartum hemorrhage (PPH), uterine atony is the most commonly occurring despite the widespread availability of potent uterotonic agents and effective surgical techniques for the treatment of uterine atony [2]. For many years, obstetric teams have used a general approach to the management of PPH, predominately relying on clinical judgment solely by the physician. Our medical critical care colleagues long ago abandoned the notion that physician judgment alone should guide the provision of basic

and advanced cardiac life support in favor of comprehensive protocols [4]. A similar standardized approach is recommended for the management of obstetric hemorrhage, as well as other leading causes of maternal morbidity and mortality such as hypertensive crisis and venous thromboembolism [5].

In 2014, the Council on Patient Safety in Women's Healthcare released their initial maternity patient safety bundle on obstetric hemorrhage with the goal that every maternity unit would implement a similar safety bundle [6]. To further encourage institutions to implement these critical clinical practices, they launched their first National Improvement Challenge on Obstetric Hemorrhage in 2015. The goal of this innovative program was to improve women's healthcare by residency level development of quality improvement (QI) programs. In addition, our institution launched a high-value initiative for house staff to develop projects aimed at improving quality and patient safety in a cost-effective manner. To this end, we developed a comprehensive,

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## POSTPARTUM HEMORRHAGE PROTOCOL

Scan into medical record upon completion

	Time	EBL (total)	BP	Pulse	Notes
<b>Atony diagnosed; EBL &lt; 500cc</b> <input type="checkbox"/> Physician in room, primary nurse in room <input type="checkbox"/> Bimanual compression <input type="checkbox"/> Oxytocin 30u in 500mL NS, wide open <input type="checkbox"/> Rule out other etiologies of PPH <input type="checkbox"/> Call for Uterotonic kit <input type="checkbox"/> Empty bladder <input type="checkbox"/> Second nurse to room with uterotonic kit	_____	_____	_____	_____	If at any time EBL>2000cc, SBP <80, DBP <40, and/or pulse >120, skip to last step and initiate MTP and proceed to OR  If on MgSO <sub>4</sub> , discontinue and give calcium gluconate 1gm IV
<b>5 MINUTE REEVALUATION</b> (continue bimanual compression, see additional interventions below if continued bleeding)					
<b>Stage 1 PPH; EBL &gt; 500cc *</b> <input type="checkbox"/> Activate Stage 1 PPH; Team Lead, third nurse, and PPH cart to room <input type="checkbox"/> Administer Tranexamic Acid 1 gram (100mg/ml) IV over 10 minutes (1ml/min) <input type="checkbox"/> Administer Methergine 0.2mg IM <input type="checkbox"/> Obtain labs and type/cross for 2u PRBC <input type="checkbox"/> Second IV access <input type="checkbox"/> Increase IVF (200cc/hr NS or LR) <input type="checkbox"/> Continuous pulse ox, q5min vital signs	_____	_____	_____	_____	*EBL >1000cc for Cesarean section  <b>Labs (CBC, CMP, Coags):</b> <input type="checkbox"/> Hgb _____ Hct _____ <input type="checkbox"/> Plt _____ Fib _____ <input type="checkbox"/> PT _____ PTT _____ <input type="checkbox"/> INR _____ Cr _____
<b>15 MINUTE REEVALUATION</b> (continue bimanual compression, see additional interventions below if continued bleeding)					
<b>Bleeding persists; EBL &gt; 1000cc</b> <input type="checkbox"/> Administer Misoprostol 1000mcg PR <input type="checkbox"/> Call for second physician <input type="checkbox"/> Call for anesthesia provider <input type="checkbox"/> Place foley (if not already in place)	_____	_____	_____	_____	If platelets <60K, give 1 single donor platelet pack If fibrinogen <100mg/dL, give FFP and/or cryoprecipitate to keep >100 mg dl
<b>30 MINUTE REEVALUATION</b> (continue bimanual compression, see additional interventions below if continued bleeding)					
<b>Stage 2 PPH; EBL &gt; 1500cc</b> <input type="checkbox"/> Activate Stage 2 PPH <input type="checkbox"/> Administer Hemabate 250mcg IM <input type="checkbox"/> Tamponade balloon / uterine packing <input type="checkbox"/> Transfuse 2u PRBCs, call for 2u more <input type="checkbox"/> Alert OR and/or IR <input type="checkbox"/> Apply SCDs and warming blanket <input type="checkbox"/> Obtain repeat labs <input type="checkbox"/> If bleeding continues after 30 minutes or stops and restarts within 24 hours of first dose, give 2nd dose of Tranexamic Acid 1 gram IV over 10 minutes (Max 2 doses of TXA)	_____	_____	_____	_____	<b>Repeat Labs:</b> <input type="checkbox"/> Hgb _____ Hct _____ <input type="checkbox"/> Plt _____ Fib _____ <input type="checkbox"/> PT _____ PTT _____ <input type="checkbox"/> INR _____ Cr _____ <input type="checkbox"/> Ca _____ Na _____ K _____ <input type="checkbox"/> ABG _____  <b>Bakri balloon:</b> <input type="checkbox"/> Inflated to _____ cc
<b>40 MINUTE REEVALUATION</b> (continue bimanual compression, see additional interventions below if continued bleeding)					
<b>Bleeding persists; EBL &gt; 2000cc</b> <input type="checkbox"/> Initiate massive transfusion protocol <input type="checkbox"/> Proceed to OR for laparotomy <input type="checkbox"/> Alert ICU of possible admission	_____	_____	_____	_____	<b>Blood product tally:</b> <input type="checkbox"/> PRBCs _____ <input type="checkbox"/> FFP _____ <input type="checkbox"/> Plts _____ <input type="checkbox"/> Cryo _____

Physician Signature: \_\_\_\_\_ Date/Time: \_\_\_\_\_ (sign at conclusion of PPH)



\*9074\* Physician Orders

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(08/2017)

Fig. 1. Checklist for patients with postpartum hemorrhage.

EBL, estimated blood loss; SBP, systolic blood pressure; DBP, diastolic blood pressure; NS, normal saline; MTP, massive transfusion protocol; PPH, postpartum hemorrhage; OR, operating room; MgSO<sub>4</sub>, magnesium sulfate; IV, intravenous; IM, intramuscular; CBC, complete blood count; CMP, comprehensive metabolic panel; PRBC, packed red blood cells; Hgb, hemoglobin; Hct, hematocrit; Plt, platelet; Fib, fibrinogen; IVF, intravenous fluids; LR, lactated ringer; PT, prothrombin time; PTT, partial thromboplastin time; q, every; INR, international normalized ratio; Cr, creatinine; PR, per rectum; FFP, fresh frozen plasma; IR, interventional radiology; Ca, calcium; Na, sodium; K, potassium; SCD, sequential compression device; ABG, arterial blood gas; ICU, intensive care unit; Cryo, cryoprecipitate.

multidisciplinary, checklist-based protocol for the management of PPH and implemented it at our institution. The aim of this QI

initiative was to determine if implementation of a checklist-based management protocol for PPH would improve maternal morbidity



## POSTPARTUM HEMORRHAGE PROTOCOL

Scan into medical record upon completion

### Uterotonic kit - Dosing and Contraindications:

- Methergine 0.2mg IM; q 2-4hrs
  - HTN/Pre-eclampsia/CAD
- Misoprostol 1000mcg PR; single dose
  - None
- Hemabate 250mcg IM; q 15-90min
  - Pulmonary/Cardiac/Renal disease
- Calcium gluconate 1gm IV (if on MgSO4)
- Tranexamic Acid 1 gram over 10 min (max 2 doses)
- If contraindication to uterotonic medication, then move to the next uterotonic in the protocol
- If alternate order of uterotonic medication used, continue with protocol and document the order

### Education/Explanations:

- Wide open = remove from pump
- Other etiologies of PPH = lacerations, retained products, invasive placentation, uterine inversion, uterine rupture, coagulopathy
- Obtain labs = CBC, CMP, PT (includes INR), PTT, Fibrinogen, Type and Screen
- Each unit of FFP or Cryopct. increases circulating Fibrinogen by 5-10 mg/dl

### Visual Estimation of Blood Loss (saturated):

1 Ray-tec	10cc
1 Lap sponge	100cc
1 Peri-pad	120cc
1 Large pad	500cc

### Role Specifics:

Primary Nurse (Always in patient room)	PPH Team Lead (Present with Stage 1 PPH)	OB Rapid Response Team (RRT) (Present with Stage 2 PPH)									
<ul style="list-style-type: none"> <li>• Announce atony diagnosis Call for second nurse and uterotonic kit</li> <li>• Manage oxytocin pump</li> <li>• Administer medications Assess / announce vital signs</li> <li>• Administer O2 to keep sat &gt;95% Perform lab draws Place IV / manage IV fluids</li> </ul>	<ul style="list-style-type: none"> <li>• Activate Stage 1 / Stage 2 PPH</li> <li>• Bring PPH cart and third nurse</li> <li>• Arrange transport of patient as needed</li> <li>• Manage family and baby needs                             <ul style="list-style-type: none"> <li>- Baby to nursery nurse</li> <li>- Family to waiting room</li> <li>- Alert chaplain and social work as needed</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Bring code cart</li> <li>• Bring iStat</li> <li>• Bring ultrasound</li> <li>• Bring rapid transfuser and blood warmer</li> <li>• Transport labs / blood products</li> </ul>									
Second Nurse (Present with atony diagnosis)	Third Nurse (Present with Stage 2 PPH)	Post Hemorrhage Roles (Following conclusion of PPH)									
<ul style="list-style-type: none"> <li>• Bring uterotonic kit</li> <li>• Announce Stage 1 PPH to Team Lead to activate</li> <li>• Place orders (if physician unable)                             <ul style="list-style-type: none"> <li>- OB PPH Order Set [pp]</li> </ul> </li> <li>• Documentation in PPH Protocol                             <ul style="list-style-type: none"> <li>- Time</li> <li>- EBL; Total (provider estimate and weighed)</li> <li>- Pulse / BPs</li> <li>- Labs / Blood products Alert team if any of below occur</li> <li>- EBL &gt; 2000cc</li> <li>- SBP &lt; 80mmHg</li> <li>- DBP &lt; 40 mmHg</li> <li>- Pulse &gt; 120 bpm</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>• Bring scale; weigh pads Bring additional medications</li> <li>• Transport labs / blood products Alert Blood Bank; give name, MRN, location Alert OR / IR of Stage 2 PPH</li> </ul> <p style="text-align: center;"><b>Contact List</b></p> <table border="1"> <tr> <td>Team Lead</td> <td rowspan="8" style="background-color: black; width: 100px;"></td> </tr> <tr> <td>Resident Pager</td> </tr> <tr> <td>Resident Room</td> </tr> <tr> <td>Anesthesia</td> </tr> <tr> <td>Blood Bank</td> </tr> <tr> <td>Universal</td> </tr> <tr> <td>Main OR</td> </tr> <tr> <td>IR ICU</td> </tr> </table>	Team Lead		Resident Pager	Resident Room	Anesthesia	Blood Bank	Universal	Main OR	IR ICU	<ul style="list-style-type: none"> <li>• Physician to debrief with family</li> <li>• Team Lead to determine support group needs</li> <li>• Support group (chaplain / social work) needed if:                             <ul style="list-style-type: none"> <li>- Massive transfusion protocol</li> <li>- Emergent surgical intervention</li> <li>- ICU admission</li> <li>- Maternal death</li> </ul> </li> <li>• Team Lead to initiate post-event debrief with team</li> </ul>
Team Lead											
Resident Pager											
Resident Room											
Anesthesia											
Blood Bank											
Universal											
Main OR											
IR ICU											

Fig. 2. Information page for postpartum hemorrhage checklist.

IM, intramuscular; q, every; HTN, hypertension; CAD, coronary artery disease; PR, per rectum; IV, intravenous; MgSO4, magnesium sulfate; CBC, complete blood count; CMP, comprehensive metabolic panel; PT, prothrombin time; PTT, partial thromboplastin time; INR, international normalized ratio; O2, oxygen saturation; PPH, postpartum hemorrhage; EBL, estimated blood loss; SBP, systolic blood pressure; DBP, diastolic blood pressure; MRN, medical record number; OR, operating room; IR, interventional radiology; ICU, intensive care unit.

and thus be supported by our large healthcare system for implementation at the other 27 hospitals within the system.

## Materials and methods

According to Banner University Medical Center Phoenix Research Determination Committee, this study met criteria for operational improvement which was deemed exempt from the Institutional Review Board. Banner Health is a non-profit United States health system which operates 28 hospitals across 6 states and is based in Phoenix, Arizona. Banner University Medical Center Phoenix (BUMCP) is a 733-bed tertiary care center that performs approximately 5000 deliveries per year with the highest level of neonatal care. In 2015, this QI initiative was awarded a finalist position in our institution's high-value healthcare competition, which provided an interdisciplinary team for project design, implementation, and analysis, as well as hospital-wide support. The team included leadership from the Department of Obstetrics and Gynecology, the Department of Anesthesia, hospital-employed physicians, non-hospital employed, private physicians, obstetrics residents, nurse managers, nurse educators, and labor and delivery nurses. This multidisciplinary team developed a checklist-based management protocol for PPH that focused on team-based and timely recognition of uterine atony and abnormal bleeding, and early administration of specific uterotonic medications. The PPH checklist was constructed using recommendations from the Council on Patient Safety in Women's Healthcare Obstetric Hemorrhage Safety Bundle and the California Maternal Quality Care Collaborative Toolkit, and was structured similarly to a uterine atony checklist previously published by some of the authors [4,6,7].

On February 1, 2016, the PPH checklist was implemented (Fig. 1). PPH carts were placed on all labor and delivery units, antepartum units, recovery rooms, operating rooms, and postpartum units. Each cart was re-equipped to contain all necessary items, including the PPH checklist, blood bank forms, and instruction cards for intrauterine balloons and compression sutures. An instruction card for compression suture placement was additionally hung in the operating rooms to be easily visualized during surgery. Each PPH cart was also equipped with a supply list with location by drawer that was placed on the surface of the cart to ensure expedited retrieval of necessary instruments. Our uterotonic kit includes methylergonovine, misoprostol, and carboprost tromethamine. The uterotonic kit was made easily available and brought at first recognition of uterine atony or early PPH. Calcium gluconate was made available in the uterotonic kit if needed for a patient on magnesium sulfate. Scales were made available in all units for quantitative measurement of saturated pads and calibrated obstetrical drapes were used in all deliveries. The underside of the checklist form outlines the primary response team, role descriptions, the uterotonic kit dosing/contraindications, a chart for visual estimation of blood loss to assist with

accuracy of cumulative blood loss measurement, debriefing/support group information, and phone numbers for additional services including blood bank, anesthesia, operating rooms, interventional radiology, intensive care units (ICU), and advanced gynecologic surgery (Fig. 2).

Every obstetric patient was stratified into average, moderate, or high risk depending on their risk factors for PPH, including prior cesarean section, multiple gestation, coagulopathy, history of PPH, etc (Table 1). Risk stratification is performed to identify patients at increased risk for hemorrhage and ensure appropriate time-sensitive orders are placed and blood samples collected. If stratified as average risk, a minimum of a clot to hold is collected for the blood bank. If moderate risk, a minimum of a blood type and screen is collected. If high risk, a blood type and crossmatch is collected and the blood bank prepares two units of packed red blood cells (PRBC) on hold.

A resident-designed education video outlining the obstetric hemorrhage QI initiative was created using a cost-free video development tool. This training video was shown one month prior to implementation to greater than 300 participating members of the checklist, including nursing staff, resident physicians, and attending physicians in the Departments of Obstetrics and Anesthesia. Educational presentations were made through Grand Rounds lectures. Educational activities including hands-on drills and simulation were performed for nursing and resident physicians. These activities included exercises on visual estimation of blood loss and targeted hands-on workshops for tamponade balloon placement and compression suture techniques. Of note, this training and implementation process was of negligible cost to the hospital system.

This quality improvement initiative was divided into two phases. The pilot phase, defined as the first three months following protocol implementation, was rolled out and outcome and process measures were analyzed to determine if improvements in maternal morbidity were shown. The implementation phase followed which totaled nine months, and included continued training and education for nursing and house-staff. Data at three months and nine months post implementation were compared to a historical group with matched months from the year prior. Women were identified for retrospective chart review using the Premier Database and International Statistical Classification of Diseases, 9th and 10th Revision (ICD-9/ICD-10) diagnostic codes for obstetric hemorrhage. We defined PPH as cumulative blood loss greater than or equal to 500 mL for vaginal deliveries or 1,000 mL for cesarean deliveries. Additional inclusion criteria included 22 weeks or greater gestational age and no previous diagnosis of or suspicion for invasive placentation (placenta accreta, increta, or percreta). Women with PPH identified from the database were individually reviewed and confirmed to meet inclusion criteria.

The pre-protocol group included all women who met inclusion criteria from February 1, 2015 to October 31, 2015 and the post-protocol group included all women who met inclusion criteria

**Table 1**  
Assessment of hemorrhage risk tool [14,15].

Average Risk	Moderate Risk	High Risk
Regular prenatal care No other risk factors listed	Prior uterine incision History of PPH Grand multiparity Macrosomia Multiple gestation Chorioamnionitis Magnesium sulfate use Declines blood products	Placenta previa Placenta accreta Severe anemia (Hct <25) Platelets <100,000/ $\mu$ L Active bleeding on admission Bleeding disorder History of endometrial ablation

PPH, postpartum hemorrhage; HCT, hematocrit.

from February 1, 2016 (implementation date) to October 31, 2016. Outcome measures were characterized as surrogates for maternal morbidity and included stage 2 or greater PPH (defined as cumulative blood loss greater than or equal to 1,500 mL), massive blood product transfusion, surgical intervention, and peripartum hysterectomy. Transfusion guidelines from the checklist state that two units of PRBC are initiated at stage 2 PPH with two more units PRBCs made available. If cumulative blood loss reaches 2,000 mL, massive transfusion protocol was initiated. The outcome measure for massive blood product transfusion was defined as four or more units of PRBC transfusions. Additional outcome measures included ICU admission and hospital length of stay (LOS). Extended postpartum hospital stays were considered greater than 50 h after a vaginal delivery and greater than 96 h after a cesarean delivery. The surgical intervention outcome measure encompassed exploratory laparotomy, compression suture, uterine artery ligation, and peripartum hysterectomy. Process measures included compliance with using the PPH checklist, adherence to the checklist measured as complete (>75% checklist completed), partial (25–50% checklist completed) or incomplete (<25% checklist completed), and compliance with using the assessment of hemorrhage risk screening tool (Table 1). Categorical variables were compared between the pre-protocol and post-protocol groups using two-tailed Fisher exact tests with  $p < 0.05$  considered statistically significant. Percentage of compliance was measured with a 95% confidence interval (CI).

## Results

During the 18 month study period, a total of 422 women were identified for review and 297 women met inclusion criteria, 147 in the pre-protocol group and 150 in the post-protocol group. Comparison of the first three months post implementation showed all outcome measures decreased compared to the pre-protocol group (Table 2). Specifically outcomes measures of surgical intervention and LOS greater than 96 h following cesarean section reached statistical significance ( $p = 0.04$  and  $p = 0.04$ , respectively). Process measures during the three month pilot phase included a 62.2% compliance with using the checklist which was scanned into the electronic medical record (95% CI, 44.8–77.5). Of the 62.2% compliance, 100% of those had adhered to >75% of the checklist (95% CI, 85.2–100). There was 75.7% compliance with documentation of the assessment of hemorrhage risk in the medical record (95% CI, 58.8–88.2). Our institution's Obstetrics Clinical Consensus Group reviewed the three month pilot phase outcomes and approved the implementation phase without any proposed changes to the PPH checklist. We did however, expand the collected outcome measures to include two additional maternal morbidity surrogates including massive blood product transfusion

and peripartum hysterectomy (separated from the surgical intervention outcome).

During the nine month implementation phase all outcome measures decreased in the post-protocol group compared to the pre-protocol group as shown in Table 3. Severe hemorrhage (stage 2.5), defined as cumulative blood loss greater than or equal to 2,000 mL, reached statistical significance with an 8.4% decrease ( $p = 0.04$ ). There were no maternal deaths in either the pre-or post-protocol groups. Our institution reviewed the nine month outcomes and approved adoption of the PPH checklist in the larger Banner healthcare system. The checklist has since been modified to include early administration of tranexamic acid as supported by the WOMAN (World Maternal Antifibrinolytic) trial [8].

The distribution of vaginal deliveries and cesarean section deliveries were similar in the two groups (66.7% and 33.3% vs 73.3% and 26.7%, respectively;  $p = 0.21$ ). Tables 4 and 5 show the outcome measures stratified by route of delivery. Although cesarean sections accounted for an average of one third of total deliveries with PPH during our study period, they did however, account for a similar or greater proportion of maternal morbidity surrogates.

## Comment

The primary purpose of this study was to determine if implementation of a checklist-based management protocol for obstetric hemorrhage at a single institution would be successful in improving maternal morbidity, and to confirm feasibility for the implementation across our larger healthcare system. We found that all surrogate measures for maternal morbidity decreased after the implementation of the PPH checklist and severe PPH rates improved significantly in the described study period. This is not the first study to show improved maternal morbidity after implementation of a standardized protocol for obstetric hemorrhage [9–11]. This study, however, shows resident-driven advances in a large healthcare system that positively affect maternal morbidity. The results of this QI project are consistent with the goals of the Council on Patient Safety in Women's Healthcare. Their National Improvement Challenges have inspired physicians in training, such as this project, to develop innovative quality improvement projects to improve women's healthcare. While only the outcome of severe postpartum hemorrhage reached statistical significance, the authors believe the clinical significance of our outcomes is more important. Every outcome measured was improved which shows a promising trend towards decreasing maternal morbidity related to obstetric hemorrhage. Additionally, outcome measures of ICU admissions and length of hospital stay decreased in the post-protocol group which has positive implications on healthcare costs.

**Table 2**  
Outcome measures from the pilot phase\* compared to the historical pre-protocol group.

Maternal Morbidity Outcomes	Pre-protocol group n = 31	Post-protocol group n = 37	p value
Stage 2 PPH <sup>†</sup>	14 (45.1)	11 (29.7)	0.19
Stage 2.5 PPH <sup>‡</sup>	5 (16.1)	3 (8.1)	0.31
Surgical intervention	4 (12.9)	0	0.04
ICU admission	3 (9.6)	0	0.09
LOS > 50 h post vaginal delivery	10 (32.3)	10 (27)	0.64
LOS > 96 h post cesarean delivery	4 (12.9)	0	0.04

PPH, postpartum hemorrhage; ICU, intensive care unit; LOS, length of stay; EBL, estimated blood loss.

Data are listed as n(%).

\* Defined as the first three months following protocol implementation.

<sup>†</sup> Defined as EBL 1,500 mL or greater.

<sup>‡</sup> Defined as EBL 2,000 mL or greater.

**Table 3**Outcome measures from the implementation phase<sup>\*</sup> compared to the historical pre-protocol group.

Maternal Morbidity Outcomes	Pre-protocol group n = 147	Post-protocol group n = 150	p value
Stage 2 PPH <sup>†</sup>	53 (36.1)	41 (27.3)	0.11
Stage 2.5 PPH <sup>†</sup>	26 (17.7)	14 (9.3)	0.04
Massive blood product transfusion <sup>‡</sup>	8 (5.4)	4 (2.7)	0.25
Surgical intervention	10 (6.8)	3 (2)	0.05
Peripartum hysterectomy	2 (1.4)	0	0.24
ICU admission	4 (2.7)	2 (1.3)	0.44
LOS > 50 h post vaginal delivery	37 (25.2)	35 (23.3)	0.71
LOS > 96 h post cesarean delivery	19 (12.9)	10 (6.7)	0.07
LOS > 120 h post cesarean delivery	6 (4.1)	1 (1)	0.07

PPH, postpartum hemorrhage; ICU, intensive care unit; LOS, length of stay; EBL, estimated blood loss.

Data are listed as n(%).

<sup>\*</sup> Defined as the first nine months following protocol implementation.<sup>†</sup> Defined as EBL 1,5000 mL or greater.<sup>‡</sup> Defined as EBL 2,000 mL or greater.<sup>§</sup> Defined as four or more units of packed red blood cells transfused.**Table 4**

Outcome measures from pre-protocol and post-protocol groups stratified by route of delivery.

Maternal Morbidity Outcomes	Pre- protocol group (n = 147)		Post-protocol group (n = 150)	
	Vaginal n = 98	CS n = 49	Vaginal n = 110	CS n = 40
Stage 2 PPH <sup>*</sup>	24 (16.3)	29 (19.7)	20 (13.3)	21 (14)
Stage 2.5 PPH <sup>*</sup>	9 (6.1)	17 (11.6)	7 (4.7)	7 (4.7)
Massive blood product transfusion <sup>‡</sup>	2 (1.4)	6 (4.1)	0	4 (2.7)
Surgical intervention	1 (0.7)	9 (6.1)	0	3 (2)
Peripartum hysterectomy	1 (0.7)	1 (0.7)	0	0
ICU admission	1 (0.7)	3 (2)	0	2 (1.3)

CS, cesarean section; PPH, postpartum hemorrhage; ICU, intensive care unit; EBL, estimated blood loss.

Data are listed as n(%).

<sup>\*</sup> Defined as EBL 1,5000 mL or greater.<sup>†</sup> Defined as EBL 2,000 mL or greater.<sup>‡</sup> Defined as four or more units of packed red blood cells transfused.**Table 5**

Total outcome measures stratified by route of delivery.

Maternal Morbidity Outcomes	Vaginal Delivery	Cesarean Section
Stage 2 PPH <sup>*</sup> (n = 94)	44 (46.8)	50 (53.2)
Stage 2.5 PPH <sup>†</sup> (n = 40)	16 (40)	24 (60)
Massive blood product transfusion <sup>‡</sup> (n = 12)	2 (16.7)	10 (83.3)
Surgical intervention (n = 13)	1 (7.7)	12 (92.3)
Peripartum hysterectomy (n = 2)	1 (50)	1 (50)
ICU admission (n = 6)	1 (16.7)	5 (83.3)

PPH, postpartum hemorrhage; ICU, intensive care unit; EBL, estimated blood loss.

Data are listed as n(%).

<sup>\*</sup> Defined as EBL 1,5000 mL or greater.<sup>†</sup> Defined as EBL 2,000 mL or greater.<sup>‡</sup> Defined as four or more units of packed red blood cells transfused.

Strengths of this study include the small scale testing and pre/post implementation analysis design which allowed for a rapid review of the intervention. Another strength was the comparison groups in 2015 and 2016 were matched months to eliminate seasonal variation that could affect the results (physician in training start dates, etc.). This also ensured the three months before implementation were not included in the pre-protocol data, as this included general education and training on PPH. This QI initiative gained buy-in from stakeholders by several strategies. First, as a finalist in our institution's high-value healthcare competition, we were provided hospital-wide support, including interdisciplinary team members, clinical informatics resources, and supplies coordination. Secondly, this initiative gained national support after being awarded a finalist position in the previously mentioned National Improvement Challenge presented by the

Council on Patient Safety in Women's Healthcare. Finally, the PPH protocol design paralleled a checklist previously published by two of the authors, that was retrospectively applied to ten cases of maternal death due to uterine atony. In this publication, the application of a highly specific PPH checklist would have resulted in a more timely administration of uterotonic medications, blood product transfusion, and definitive surgical management than actually occurred in the ten fatal cases [4].

The authors acknowledge several limitations to this project. The first is the small sample size due to the nature of a single institution study. Additionally, given the comparative analysis has only been performed at a single institution, the generalizability is unknown. Regarding the retrospective chart review, there is inherent error associated with patient selection based on ICD diagnostic codes, as these can be under-coded. Inclusion in the study and the outcome

measure of PPH stage are defined by estimated blood loss, which has been established in the literature to be inaccurate, especially at high volumes [12]. This quality improvement project did address training and education on visual estimation of blood loss and the importance of using scales and calibrated drapes, although under/over estimations of blood loss were not able to be controlled for in this study. Regarding process measures, these were only collected and analyzed for three months post-implementation. The measurement of compliance with using the checklist relied on the physical form being scanned into the electronic medical record, which could include either computer or human error in the process.

Worldwide, obstetric hemorrhage is one of the most common causes of maternal mortality and has been shown to be one of the causes that is most preventable [13]. Therefore, obstetric hemorrhage quality improvement initiatives are encouraged in all hospitals performing deliveries. The resident-driven implementation of a checklist-based management protocol for postpartum hemorrhage has shown a promising trend in improving maternal morbidity at our institution. Due to the positive findings during this study, the protocol has been approved for implementation at all 28 hospitals within our large healthcare system. The ultimate goal will be to mirror the impressive work of organizations like the California Maternal Quality Care Collaborative [6,7]. Now, more importantly than ever, is the time for initiatives aimed at improving maternal morbidity and mortality to be implemented, and these initiatives can often begin with physicians in training. The authors hope this quality improvement project inspires future resident-driven programs with the goal of improving quality and safety in women's healthcare.

#### Conflict of interest

The authors report no conflict of interest.

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