# RETROSPECTIVE REVIEW OF POSTPARTUM HEMORRHAGE INCIDENCE, RISK FACTORS, AND MATERNAL MORBIDITY

by

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DISSERTATION

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ABSTRACT

RETROSPECTIVE REVIEW OF POSTPARTUM HEMORRHAGE INCIDENCE, RISK FACTORS, AND MATERNAL MORBIDITY

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**Background**: *Postpartum hemorrhage (PPH) remains one of the most common causes of maternal mortality worldwide. In the US, PPH accounts for 2-3% of yearly maternal deaths and is also associated with serious morbidity including the need for blood transfusion, ICU admission, and hysterectomy. In the recent years, PPH risk assessment tools have been widely implemented in an attempt to identify woman at risk for hemorrhage and preemptively mobilize resources. The most commonly used trinary assessment tool from the California Maternal Quality Care Collaborative (CMQCC) assigns women to a low, medium or high-risk category; however, its utility has only been validated in relation to need for blood transfusion, which can be subjective.*

**Local Problem**: *The American College of Obstetricians and Gynecologists (ACOG) recently released maternal safety bundles to reduce obstetric complications and rates of maternal morbidity and mortality. At UT Southwestern's Clements University Hospital (CUH), obstetricians and gynecologists recognized that a three-category approach to PPH risk stratification may hinder efficient PPH diagnosis and management. The*

*Maternal-Fetal Medicine team developed a quality improvement project to identify hemorrhage risk factors and implement a PPH risk score in the labor and delivery unit.*

**Methods**: *Retrospective cohort review of all deliveries at CUH between January 1, 2018 and December 31, 2018 was conducted. Data on all antepartum and intrapartum hemorrhage risk factors using the trinary risk score developed by the CMQCC was analyzed and used to assign a risk category low, medium or high. A validated formula, utilizing maternal height, weight, ante- and post-partum hematocrits, was used to calculate each patient's blood loss. Calculated blood loss, need for intervention (uterotonic administration) and maternal morbidities (need for blood transfusion, intensive care unit (ICU) admission, and/or hysterectomy) were correlated to PPH risk categorization as well as to a developed numeric risk score. PPH was defined as blood loss exceeding 1,000 mL. Data was analyzed using standard methods of rates and proportions, Chi-square, and Wilcoxon rank-sum tests with $p<0.05$ considered significant. Quality improvement tools, including PDSA cycles, process maps, a SIPOC diagram, and FMEA were developed.*

**Interventions:** *A modified PPH risk assessment score that assigned a point value of 1 or 2 to hemorrhage risk factors based on their perceived potential to lead to PPH was developed.*

**Results**: *Of the 1855 deliveries, the median calculated blood loss was 879 mL. The overall PPH rate was 25.9%. The rates according to PPH risk groups were 19.5%, 36.6%,*

*and 27.9%, respectively. The rate of PPH was significantly lower in the low risk group (p<0.001) but did not differ between the medium and high-risk groups (p= 0.11). The median blood loss was lowest in the low risk group (p<0.001). The transfusion rate correlated with risk stratification, with rates of 0.9%, 2.7% and 7% in the low, medium and high-risk groups, respectively. Overall, 178 women (9.5%) were treated with uterotonics, 38 (2.0%) required transfusion, 7 (0.4%) needed ICU admission and 12 (0.6%) underwent hysterectomy. Relative to low and medium-risk stratifications, women in the high-risk group were 2.3 times more likely to require uterotonic administration. Women in the low-risk group were 83% less likely to experience transfusion, ICU admission or hysterectomy compared to medium and high-risk women. Conversely, women in the high-risk group had a 4.1 fold increase in these same morbidities.*

**Conclusion**: *Relative to the low and medium-risk stratifications, women classified as high risk for hemorrhage are indeed more likely to require uterotonic administration and also suffer disproportionately higher maternal morbidity. The trinary risk stratification tool commonly used to predict PPH distinguishes women at lower risk for hemorrhage compared to the general population. However, determining which women are most likely to hemorrhage at delivery evades prediction using current risk assessment tools. Though hypothesized that a numeric scoring system would better predict PPH and morbidity than the currently used trinary risk assessment, this was not substantiated by our data. More work needs to be conducted to understand which of the identified risk factors is most highly associated with hemorrhage, particularly in the low and medium risk groups, since women in these groups make up the majority of the obstetric population.*

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# CHAPTER 1

## Introduction

### Problem Description

*Postpartum hemorrhage (PPH) is defined by the American College of Obstetricians and Gynecologists (ACOG) as blood loss greater than 1,000 mL at the time of delivery regardless of the mode of delivery. During pregnancy, the cardiovascular system physiologically adapts, allowing a healthy woman to tolerate acute blood losses. Obstetric patients have a greater increase in plasma volume relative to the increase in red cell mass, resulting in a hemodilution. Thus, the circulating blood volume rises from approximately 4,000 mL to 5,500 mL. With blood loss greater than 1,000 mL, signs of cardiovascular compromise, decompensation and hemorrhagic shock may develop rapidly.*

*Postpartum hemorrhage is commonly caused by uterine atony, trauma, retained placenta tissue, and/ or coagulopathy. Studies have shown a highly significant association between atonic PPH and the total administered dose of oxytocin during labor which is thought to be due to desensitized myometrial oxytocin receptors preventing adequate uterine tone after delivery. Similarly, magnesium sulfate use exerts a tocolytic effect which may lead to atony and PPH.*

*Postpartum hemorrhage has been found to be associated with serious maternal mortality and morbidity including loss of fertility, coagulopathy, shock, pituitary necrosis, and adult respiratory distress syndrome. In the US, PPH accounts for 2-3% of yearly maternal deaths and is the leading cause of pregnancy-related mortality (Berg et al). Epidemiology studies utilizing the*

*Nationwide Inpatient Sample (NIS) have shown that PPH rates in the US have increased by 27.5% over the past years, primarily due to an increase in the incidence of uterine atony (Bateman et al). Kramer et al. investigated the incidence and trend of severe PPH, defined as need for blood transfusion, hysterectomy, and/ or surgical repair of the uterus in addition to PPH. Their large, nationwide analysis of 8.5 million deliveries in the NIS over 10 years (1999-2008) demonstrated a 2-fold increase in rates of PPH plus hysterectomy in addition to a 2- to 3-fold increase in rates of PPH plus blood transfusion. This potentially preventable obstetric emergency remains one of the most common causes of maternal morbidity and mortality both in the US and worldwide.*

**Available Knowledge**

*Though rates of maternal mortality have decreased worldwide, they have increased in the US over the past 30 years from 7.2 deaths per 100,000 live births in 1987 to 16.9 deaths per 100,000 live births in 2016 (Pregnancy Mortality Surveillance System). The rising rates of maternal morbidity and mortality nationwide and statewide led to the formation of the California Maternal Quality Care Collaborative (CMQCC)'s multi-disciplinary, multi-stakeholder Quality Improvement (QI) initiative (Bingham et al). The CMQCC developed surveys that identified three key barriers to treating women with PPH: 1) inadequate assessments, 2) lack of accurate and consistent estimation of blood loss, and 3) problems with communication and teamwork between nurses and physicians. The*

*CMQCC concluded that deaths and complications from obstetric hemorrhage are preventable with standardized practice guidelines.*

*In 2010, the CMQCC disseminated PPH guidelines via an open access toolkit ("Improving Health Care Response to Obstetric Hemorrhage") to improve readiness, recognition, response, and reporting of maternal hemorrhage after delivery. To improve readiness, the committee recommended establishing general and massive hemorrhage policies and procedures; planning for the care of women with risk factors for hemorrhage; and ensuring critical supplies are accessible and available. For recognition, they stressed the importance of obtaining accurate assessment of risk factors; recognizing early clinical signs of deterioration; and recording and reporting quantified blood loss. Response to PPH was promoted through interprofessional drills and debriefing to better the administration of blood and facilitate consultations, treatments, and transfer to higher levels of care within or outside of the facility. Lastly, reporting can be improved through standardized definitions to more accurately measure hemorrhage rates.*

*Postpartum hemorrhage risk assessment tools have been widely implemented in an attempt to identify woman at highest risk for bleeding and preemptively mobilize resources. The best practice standard based on the current evidence is to categorize women into PPH risk categories. The most commonly used trinary assessment tool from the CMQCC assigns women to a low, medium or high-risk category (Figure 3). However, the CMQCC trinary risk score has only be validated in relation to need for blood transfusion, which can be subjective.*

*Furthermore, studies revealed that estimated blood loss (EBL) may be inferior to quantitative blood loss (QBL) in identifying women with PPH.*

**Rationale**

*The PPH risk assessment process begins when the patient is admitted to CUH's labor and delivery floor and ends when the patient delivers. PPH risk assessment is dynamic as a women's risk factors continue to evolve throughout pregnancy and labor. This process is important to improve, because hemorrhage is a leading cause of maternal morbidity and mortality. Early recognition of patients with increased PPH risk increases response time to hemorrhage and can potentially decrease rates of maternal morbidity and mortality.*

*This project analyzes the incidence of PPH, risk factors, and maternal morbidity in correlation to the CMQCC trinary risk assessment stratification as well as to a developed numeric risk score. The CMQCC PPH risk tool has only previously been correlated in relation to need for blood transfusion (Dilla et al). Their validation study demonstrated rates of transfusion 0.8%, 2%, and 7.3% for the low, medium, and high-risk PPH stratification groups, respectively. Dilla et al. identified additional risk factors not included in the CMQCC risk assessment that were associated with increased PPH rates including preterm delivery, uterine rupture, and hypertension. After creating a modified high-risk group with these additional PPH risk factors, their modified PPH risk group contained 85% of all women who experienced a significant PPH (defined as requiring transfusion of one unit or more of pRBCs), up from 22% with the unmodified CMQCC high risk*

*category. A modified PPH risk score including additional identified risk factors may better predict those at risk of hemorrhage after delivery.*

*The implementation of a PPH risk score assignment process is critical to providing safe obstetrical care. However, there is not a universally recognized standard method for determining blood loss at delivery and the diagnosis of PPH may be based on subjective visually estimated blood loss. Blood loss can be measured by a variety of methods. Most commonly, blood loss is estimated by calibrated under-buttocks drape and visualization. The CMQCC hemorrhage toolkit suggests that quantitative blood loss (QBL) is superior to visually estimating blood loss (EBL) at time of delivery. A 2016 retrospective chart review compared QBL with visual EBL in vaginal deliveries and cesarean sections. Jackson et al. demonstrated that physicians significantly overestimated blood loss in vaginal deliveries when comparing EBL to QBL while significantly underestimating the blood loss at cesarean deliveries. A retrospective cross-sectional study at a single institution in California found that QBL was a more accurate measure of blood loss than EBL with a Pearson correlation coefficient between change in hemoglobin and QBL of 0.28 and 0.25 with EBL, respectively (Ladella et al). A retrospective cohort study in Florida also found that QBL had higher sensitivity in predicting severe PPH (87% versus 66%) but that the need for intervention (blood transfusion) was similar between the two methods.*

*At other institutions, the implementation of a QI safety bundle initiative has been shown to decrease maternal morbidity rates. Main et al. demonstrated a reduction of severe maternal morbidity from hemorrhage utilizing a state perinatal*

*quality collaborative (99 collaborative hospitals with 256,541 annual births). They found that women with hemorrhage in collaborative hospitals experienced a 20.8% reduction in severe maternal morbidity while women in comparison hospitals had a 1.2% reduction. These reductions were attributed to fewer blood transfusions (2/3 of the reduction), procedures and medical complications. These studies illustrate the positive impact a state safety bundle can have on obstetric outcomes.*

*The implementation of a PPH risk score assignment process at aligns with a statewide maternal safety bundle initiative developed by ACOG and is supported by Clements University Hospital (CUH) administration. This project is spearheaded by the UT Southwestern Obstetrics and Gynecology faculty at CUH. Clements is a tertiary care center that houses 16 labor and delivery rooms and 3 obstetrical specialty surgical suites. The Maternal-Fetal Medicine practice at CUH operates a maternal transport serve and accepts high-risk patients from community obstetricians. The context in which this project was conducted helps the planned intervention of a numeric PPH risk assessment score to succeed.*

## Specific Aims

*The aim of this project is to improve the accuracy of PPH risk score assessment by 50% during 2019-2020. The project was completed at UT Southwestern's Clements University Hospital (CUH) in Dallas, Texas. The scope of the project will include patients that were admitted to CUH's labor and delivery floor and delivered between 2018-2019. The time frame for baseline data analysis will be set for those patients that delivered in 2018.*

## CHAPTER 2

## Methods

*The purpose of this study is to review PPH incidence, risk factors, and maternal morbidity in relation to the trinary risk stratification developed by the CMQCC. Retrospective cohort review of all deliveries at CUH between January 1, 2018 and December 31, 2018 was conducted. Patient demographics (race, gravida, parity, age, gestational age at delivery, BMI), data on antepartum and intrapartum hemorrhage risk factors (placenta previa, low-lying placenta, platelets <100K, active bleeding on admission, known coagulopathy, suspected placenta accreta, increta, or percreta, number of prior cesarean section or uterine surgery, multiple gestation, number of prior vaginal births, chorioamnionitis, history of prior postpartum hemorrhage, large uterine fibroids, prolonged second stage, prolonged oxytocin use > 24 hours, magnesium sulfate treatment, and hematocrit < 30), data on interventions (uterotonic administration, dilation and curettage, B-lynch suture), and data on maternal morbidities (defined as need for blood transfusion, ICU admission, and/ or hysterectomy) was collected into an Excel spreadsheet for analysis. Large uterine fibroids were defined as those greater than 2 cm in size detected on a third trimester ultrasound. Prolonged second stage was classified as > 3 hours in nulliparous women or > 2 hours in multiparous women.*

*Based on antepartum and intrapartum hemorrhage risk factors, patients were assigned a risk category low, medium or high using the CMQCC risk assessment. A validated formula developed by Hernandez et al., utilizing maternal height, weight, ante- and post-partum hematocrits, was used to calculate each*

*patient's blood loss (Figure 7). Quantitative (calculated) blood loss, need for intervention (uterotonic administration) and maternal morbidities were correlated to risk categorization. PPH was defined as blood loss exceeding 1,000 mL regardless of the delivery route. Data was analyzed by UT Southwestern statisticians using standard methods of rates and proportions, Chi-square, and Wilcoxon rank-sum tests with $p<0.05$ considered significant. Institutional Review Board approval was obtained from the UT Southwestern Medical Center.*

*Quality improvement tools were implemented in the study of this project. A Plan-Do-Study-Act (PDSA) cycle was enacted. During the Plan phase, extensive literature review on postpartum hemorrhage was conducted in order to understand the problem and identify data variables to be collected. A process map of the current PPH risk assessment at CUH was crafted to understand the process and possible points for intervention (Figure 1, Figure 2). A Suppliers, Inputs, Process, Outputs, Customers, Requirements (SIPOC) diagram was created to identify the relevant elements of a PPH score assignment process (Figure 4). A Failure Modes and Effects Analysis (FMEA) was made to evaluate possible failures of a PPH risk score assignment process and assess the relative impact of different failures (Figure 5). Next, retrospective chart review of 1,868 charts and data collection was completed in the Do phase. Data was analyzed during the Study phase with the help of statisticians. Lastly, during the Act phase, a numeric PPH risk assessment score was used to evaluate the retrospective data and determine if it could better predict rates of PPH (Figure 9).*

## CHAPTER 3

## Results

*Between January 1, 2018 and December 31, 2018, 1,868 women delivered at UT Southwestern's CUH in Dallas, Texas. The demographic characteristics of 1,855 women were correlated to their experience of a PPH (Table 1). Of the 1,855 women, 482 of them had a PPH. The overall PPH rate was 25.9% (482/1,855). Demographically, women who were nulliparous (p=0.013), older (p=0.007), and had a higher BMI (p<0.001) were statistically more likely to have a PPH. Furthermore, those who have had a PPH were more likely to also experience preterm birth. There was no significant difference in race, gravida, or gestational age at delivery in those who experienced a PPH.*

*Of the evaluated CMQC PPH risk factors, number of prior spontaneous vaginal deliveries, active labor duration, and magnesium sulfate administration were shown to be significant in a logistic regression model predicting PPH. Other factors not included in the CMQCC risk assessment that were proven to be significant in a logistic regression model predicting PPH include gestational age, parity, perineal lacerations, admission hemoglobin, and postpartum hemoglobin.*

*Of the 1,855 deliveries, the median calculated blood loss was 879 mL. The median blood loss was lowest in the low risk group (p<0.001) (Figure 8). The rates of PPH according to low, medium and high-risk classification were 19.5%, 36.6%, and 27.9% respectively (Figure 6). The rate of hemorrhage was significantly lower in the low risk group (p<0.001) but did not significantly differ between the medium*

*and high-risk groups (p= 0.11). Transfusion rates of blood following delivery were 0.9%, 2.7% and 7% in the low, medium and high-risk groups respectively.*

*Overall, 178 women (9.5%) were treated with uterotonics, 38 (2.0%) required transfusion, 7 (0.4%) needed ICU admission and 12 (0.6%) underwent hysterectomy (Table 4). Relative to low and medium risk PPH stratifications, women in the high-risk group were 2.3 times more likely to require uterotonic administration (Table 5). Women in the low risk PPH group were 83% less likely to experience transfusion, intensive care unit admission or hysterectomy compared to medium and high-risk women. Conversely, women in the high-risk group had a 4.1-fold increase in these same morbidities.*

## CHAPTER 4

## Discussion

*The United States has an unacceptable number of deaths in the postpartum period with a maternal mortality ratio (MMR) of 17.4 in 2018 (Hoyert et al). The World Health Organization defines maternal mortality as "death of a woman while pregnant or within 42 days of termination of pregnancy... from any cause related to or aggravated by pregnancy or its management." The MMR in the US increased in recent years likely due to the improved identification and reporting of maternal deaths after the implementation of a pregnancy status checkbox item on death certificates. However, the MMR does not account for deaths in the delayed postpartum period (beyond 42 days) from heart-related conditions and suicides.*

*Though there are concerns that MMR may be underreported in the US, there is also evidence that the method for identifying maternal deaths and calculating MMR may be flawed. The discrepancies in measuring MMR was highlighted in a population-based descriptive study in Texas. Baeva et al. revealed that relying on obstetric codes for maternal deaths has led to inaccurately high MMRs. Their study found that half of the obstetric-coded deaths in Texas had no evidence of pregnancy within 42 days.*

*Similarly, there are concerns surrounding accurately measuring blood loss at delivery and diagnosing PPH. The PPH rate at our institution using QBL was found to be 25.9%. Though this rate is higher than the rate of PPH reported nationally, there are many possible explanations including differences in PPH definition, measurements of blood loss, and patient demographics. The PPH rate seen at*

*our institution may also be due to increased recognition and reporting which has been influenced by using QBL rather than EBL in reporting blood loss.*

*Recent increases in rates of PPH in the US may be attributed to changes in obstetric practice and maternal demographics including but not limited to increased rates of cesarean deliveries, multiple gestation, and advanced maternal age. Cesarean deliveries are becoming more common and are known to cause higher blood loss at delivery in comparison to vaginal deliveries. According to data from national studies, rates of cesarean deliveries have increased from 21.2% in 1998 to 31.1% in 2005. The increased rates of cesarean deliveries also contribute to increased rates of placental accreta spectrum disorders which have been associated with PPH and with hysterectomy. The increased incidence of multiple gestations may be attributed to increasing use of assisted reproductive techniques and increasing rates of advanced maternal age. Furthermore, induction of labor and allowing women to labor for longer are becoming more common. The thresholds for hysterectomy may have decreased due to increased rates of advanced maternal age and decreased need for fertility preservation.*

*Rates of blood transfusion could be increased compared to prior years due to lowered thresholds for transfusion. Some providers elect for early transfusion given the perceived increased safety of blood transfusion (less concern for hepatitis B, hepatitis C, and HIV). These practice changes may account for the rates of PPH and morbidities (ICU admission, hysterectomy, transfusion) seen at our tertiary care referral center.*

*Our results correlating PPH cohort groups with EBL and QBL were consistent with other studies illustrating that providers are more likely to underestimate blood loss when blood volumes are high and overestimate blood loss when blood volumes are low (Table 6). The thought that providers' overestimation of blood loss could lead to more accurate PPH prediction was not shown nor does it seem as though overestimation has led to differences in rates of blood transfusion in the CMQCC risk groups. Similar to the validation study by Dilla et al., our results showed a positive correlation between the CMQCC hemorrhage risk stratification group (low, medium, and high) and the rate of transfusion (Table 3).*

*Furthermore, our results showed that the medium-risk group had a higher amount of median blood loss. However, there has not been a standardized way to measure blood loss after delivery. This study utilized a validated blood loss formula to calculate blood loss. There are several techniques to assess quantitative blood loss including the use of graduated collection containers, weighing pads/ lap sponges, and determining the blood volume equivalence of saturated pads/ lap sponges. In addition to established protocols and practice drills, there needs to be training in place to improve visual estimation of blood loss including stained/ saturated pads, soaked bed sheets, and floor spills in addition to blood measured in graduated containers.*

*In addition to differences in measuring blood loss, there have been differences in the definition for postpartum hemorrhage. Pritchard and Ueland utilized radiolabeled RBCs and human serum albumin, respectively, and demonstrated an average measured blood loss of 500 mL in vaginal deliveries and 1,000 mL in*

*cesarean deliveries. In the past, PPH was defined as a blood loss of greater than 500 mL for a vaginal delivery and greater than 1,000 mL for a cesarean delivery. The use of a unified definition for both vaginal deliveries and cesarean deliveries is reasonable given the physiologic impact of blood loss does not differ with delivery route. Given the recent change in definitions, there may be a lag in provider recognition and response to PPH. Other studies have defined PPH by a hematocrit decrease of 10 points or more from pre-delivery hematocrit (Combs et al.). The differing definitions of PPH complicates comparisons between studies.*

*Though the CMQCC has become the most commonly used PPH risk assessment tool, other published tools may have validity. Other organizations have developed PPH risk assessment tools modelled off of the CMQCC's trinary risk score. The Association of Women's Health, Obstetric and Neonatal Nurses (AWHONN) trinary risk assessment has many of the same risk factors identified in the CMQCC risk assessment; however, in the AWHONN assessment, two or more medium risk factors advance patients to the high-risk group. Studies suggest that the CMQCC risk assessment tool is missing crucial risk factors or that some may have a greater impact than previously thought. Prior studies have utilized logistic regression modeling to distinguish independent risk factors for PPH. Bateman et al. identified risk factors for uterine atony leading to PPH and need for blood transfusion which included age <20 and >40 years, cesarean delivery, hypertensive diseases of pregnancy, polyhydramnios, chorioamnionitis, multiple gestation, retained placenta, and antepartum hemorrhage. In this retrospective review, factors not included in the CMQCC risk assessment that were proven to*

*be significant in a logistic regression model predicting PPH include gestational age, parity, perineal lacerations, admission hemoglobin, and postpartum hemoglobin (Table 2). However, perineal laceration may be interpreted as a cause of PPH rather than a risk factor. The PPH risk factors identified in this analysis are consistent with those identified for PPH in other studies.*

*Currently, the CMQCC risk assessment tool identifies women at low risk for hemorrhage but is unable to identify those at higher risk and predict who will have a PPH at delivery. Our study suggests that a better risk assessment score needs to be created. A modified PPH risk assessment score that assigned a point value of 1 or 2 to hemorrhage risk factors based on their perceived potential to lead to PPH was developed (Figure 7). The cumulative scores were then compared for those women who did and did not experience PPH. While we hypothesized that a numeric scoring system would better predict PPH and morbidity than the currently used trinary risk assessment, this was not substantiated by our data. Further studies on PPH are essential due to increasing rates of PPH and its adverse consequences on maternal health.*

*There are many practical implications for our study. Currently, the CMQCC recommends obtaining clot only for low-risk patients, type and screen for medium-risk patients, and type and crossmatch for high-risk patients. Our results are in agreement with these recommendations since the rate of blood transfusion was correlated with the PPH risk category. In developing an improved modified PPH risk assessment tool and utilizing calculated blood loss in determining PPH, our study could help guide smaller hospitals where PPH assessment and*

*management guidelines may not be standardized and interventions may not be in place to respond quickly to an unexpected PPH.*

*Our study has several strengths as well as some limitations. One important strength was the use of manual retrospective chart review rather than relying on ICD-9-CM codes. Manual chart review allowed for a more thorough review of a woman's delivery course and details that may not be gleaned from ICD codes. A further strength of this study was the use of a validated calculated blood loss formula that provided a more accurate account of hemorrhage. An important limitation of our study was that some of the data involving maternal history collected in the retrospective chart review were missing or the documentation omitted in the notes. Though the presence of large uterine fibroids is a risk factor that would place a woman in the CMQCC medium risk category, many women did not have a third trimester ultrasound in our system. Such missing data may lead to an underestimation of PPH rates.*

*In summary, the trinary risk stratification tool commonly used to predict postpartum hemorrhage distinguishes women at lower risk for hemorrhage compared to the general population. In addition to analyzing the trinary risk groupings in relation to PPH, we attempted to correlate our numeric risk scores with risk of hemorrhage, need for intervention and other morbidities. Unfortunately, our data did not indicate that the numeric scoring system we proposed was any more accurate in the prediction of hemorrhage. However, this may be due to the small number of patients who were assigned risk scores greater than 3.*

*Women classified as high risk for hemorrhage using the most common trinary risk stratification are indeed more likely to require uterotonic administration and also suffer disproportionately higher maternal morbidity. However, determining which women are most likely to bleed at delivery cannot be predicted using current risk assessment tools. More work needs to be conducted to understand which of the identified risk factors is most highly associated with hemorrhage, particularly in the low and medium risk groups, since women in these groups make up the majority of the obstetric population. Additional Plan-Do-Study-Act (PDSA) cycles are needed to better the process of PPH risk assessment.*

LIST OF TABLES

**Table 1:**

| Characteristic | PPH | No PPH | P-value |
|---|---|---|---|
| N | 482 | 1373 | |
| Race | | | 0.220 |
| Black | 114 (24%) | 313 (23%) | |
| White | 147 (30%) | 439 (32%) | |
| Hispanic | 136 (28%) | 331 (24%) | |
| Asian | 26 (5%) | 105 (8%) | |
| Other | 59 (12%) | 185 (13%) | |
| Gravida | | | 0.231 |
| 1 | 173 (36%) | 436 (32%) | |
| 2 | 134 (28%) | 434 (32%) | |
| 3 | 80 (17%) | 249 (18%) | |
| >3 | 95 (20%) | 254 (18%) | |
| Parity | | | 0.013 |
| 0 | 231 (48%) | 574 (42%) | |
| 1 | 136 (28%) | 498 (36%) | |
| 2 | 73 (15%) | 183 (13%) | |
| >2 | 42 (9%) | 118 (9%) | |
| Age | 31.2+5.1 | 30.5+5.5 | 0.007 |
| GA at delivery | 38.0+2.8 | 38.3+2.4 | 0.073 |
| <37 weeks | 62 (13%) | 129 (9%) | 0.032 |
| BMI | 36.3+8.4 | 30.3+5.5 | <0.001 |

**Demographics by PPH cohort.** Demographics (race, gravida, parity, age, gestational age at delivery, preterm births <37 weeks, BMI) of 1855 patients that delivered at Clements University Hospital between January 1, 2018 and December 31, 2018.

**Table 2:**

| Variables | Odds Ratio | P-value |
|---|---|---|
| Parity (20w) | 1.428 | <0.001 |
| Gestational Age at Delivery (Week) | 1.075 | 0.0134 |
| Number of Spontaneous Vaginal Deliveries | 0.740 | 0.0024 |
| Perineal Laceration (0-4) | 1.504 | 0.0400 |
| Magnesium Sulfate Administration | 1.502 | 0.0073 |
| Active Labor Duration | 0.988 | 0.0041 |
| Admission Hemoglobin | 2.745 | <0.0001 |
| Postpartum Hemoglobin | 0.293 | <0.0001 |

**Variables significant in the logistic regression model predicting PPH.**

**Table 3:**

| | No PPH | | | PPH | | | Overall | | |
|---|---|---|---|---|---|---|---|---|---|
| **Risk Group** | Total | Percentage | Calculated Blood Loss* | Total | Percentage | Calculated Blood Loss* | Total | Total Percentage | Total Calculated Blood Loss* |
| **Low** | 865 | 63.6% | 497 [259,718] | 218 | 42.9% | 1329 [1155,1522] | 1083 | 58.0% | 607 [327,912] |
| **Medium** | 388 | 28.5% | 588 [352,774] | 241 | 47.4% | 1331 [1143,1607] | 629 | 33.7% | 827 [513,1202] |
| **High** | 107 | 7.9% | 507 [277,693] | 49 | 8.6% | 1396 [1139,1542] | 156 | 8.3% | 672 [ 406,1112] |
| **Grand Total** | 1360 | 72.8% | 529 [284,740] | 508 | 27.19% | 1332 [1145,1586] | 1868 | 100% | 684 [388, 1053] |

**PPH rates by risk stratification and median calculated blood loss.** Data shown as median [1$^{st}$ quartile, 3$^{rd}$ quartile]

**Table 4:**

| | Number of Patients | Number with morbidity* (%) | Relative Risk | P-value** |
|---|---|---|---|---|
| **Low** | 1063 | 13 (1.2) | 0.17 (0.08-0.35) | <0.001 |
| **Medium** | 629 | 8 (1.2) | 0.74 (0.32-1.66) | .46 |
| **High** | 156 | 8 (5.1) | 4.13 (1.86-9.17) | <0.001 |

**Correlation of PPH risk stratification with maternal morbidities.** *Morbidity defined as need for transfusion, hysterectomy or admission to the intensive care unit. **P values compare the risk of postpartum hemorrhage between one group and the total of the other two groups combined.

**Table 5:**

| | Number of Patients | Number requiring uterotonics (%) | Relative Risk | P-value* |
|---|---|---|---|---|
| **Low** | 1063 | 90 (8.5) | 0.76 (0.57-1.0) | .05 |
| **Medium** | 629 | 57 (9.0) | 0.91 (0.68-1.23) | .55 |
| **High** | 156 | 31 (19.9) | 2.29 (1.61-3.25) | <0.001 |

**Correlation of PPH risk stratification with uterotonic administration.** *P values compare the risk of postpartum hemorrhage between one group and the total of the other two groups combined.

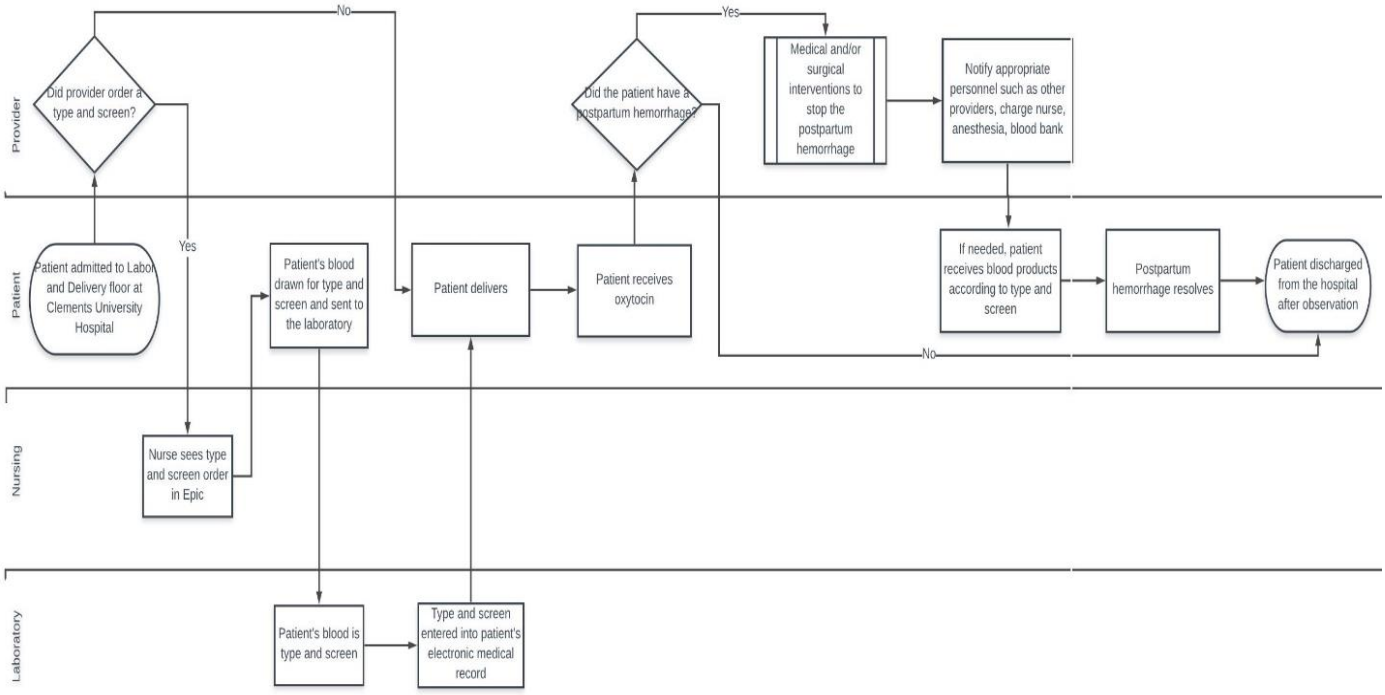
**Table 6:**

| | Average calculated blood loss (mL) | Average estimated blood loss (mL) |
|---|---|---|
| **No PPH** | 267.24 | 586.67 |
| **PPH** | 1470.96 | 848.26 |
| **Grand Total** | 461.85 | 628.96 |

**Correlation of PPH cohort group with average EBL and QBL.**

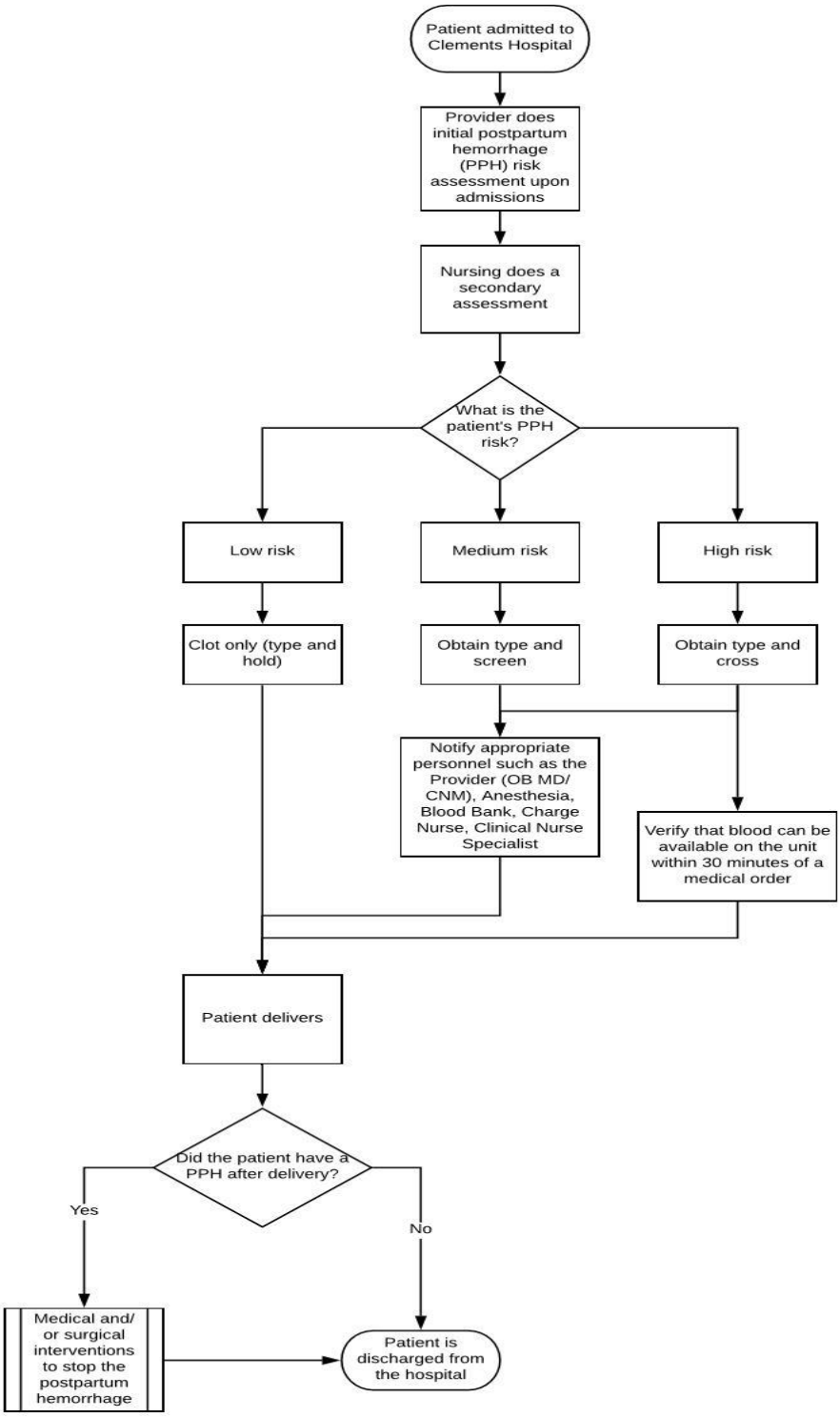
LIST OF FIGURES

**Figures 1:**




**Prior process map.** Process map reflecting the past state of postpartum hemorrhage identification and management at Clements University Hospital.

**Figure 2:**



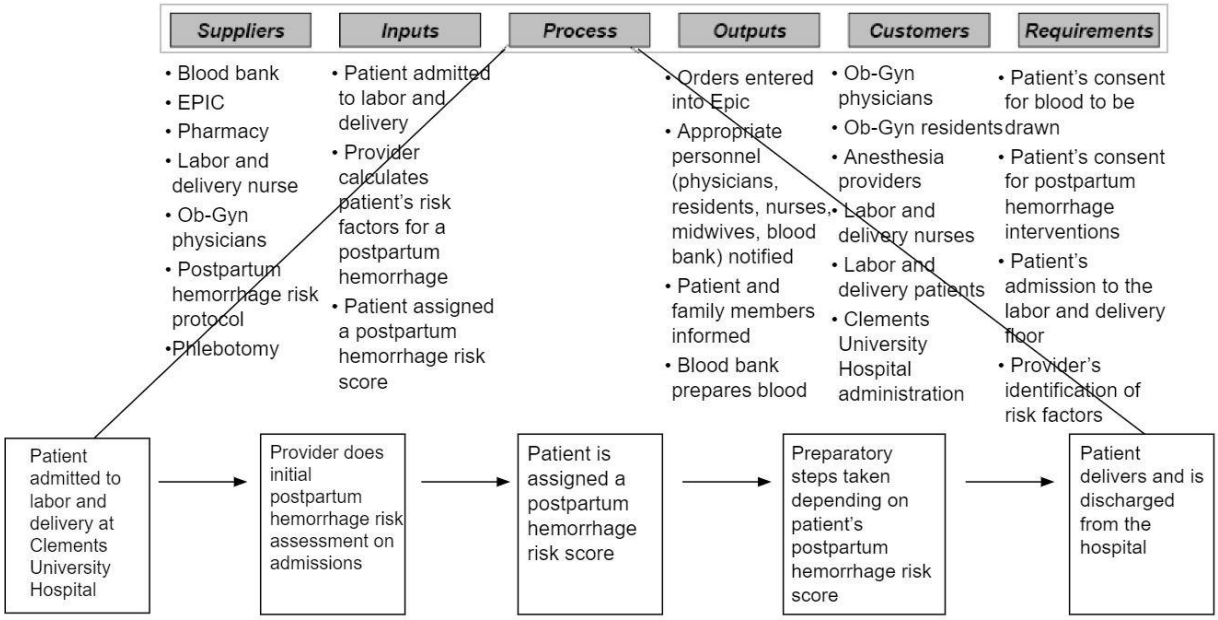

**Current process map.** Process map reflecting the current state of postpartum hemorrhage identification and management at Clements University Hospital based on the CMQCC trinary risk assessment.

**Figure 3:**

| Low | Medium | High |
|---|---|---|
| No previous uterine surgery | Prior cesarean birth(s) or uterine surgery | Placenta previa or low-lying placenta |
| Singleton pregnancy | Multiple gestation | Suspected placenta accreta, increta or percreta |
| ≤4 previous vaginal births | >4 previous vaginal births | Hematocrit <30 + another risk factor |
| No known bleeding disorder | Chorioamnionitis | Platelets <100K |
| No history of PPH | History of previous PPH | Active bleeding on admission |
| | Large uterine fibroids* | Known coagulopathy |
| | Prolonged second stage** | |
| | Prolonged oxytocin use >24 hours | |
| | Magnesium sulfate treatment | |

**California Maternal Quality Care Collaborative (CMQCC) trinary risk score.** Antepartum and intrapartum hemorrhage risk factors in postpartum hemorrhage risk categories: low, medium, and high. *Fibroids >2 cm noted on third trimester ultrasound **Prolonged second stage was defined as stage >3 hours in nulliparous women or >2 hours in multiparous women. Table from: CMQCC: California Maternal Quality Care Collaborative. (2019). OB Hemorrhage Toolkit V 2.0. Retrieved January 1, 2019, from https://www.cmqcc.org/resources-tool-kits/toolkits/ob-hemorrhage-toolkit

**Figure 4:**



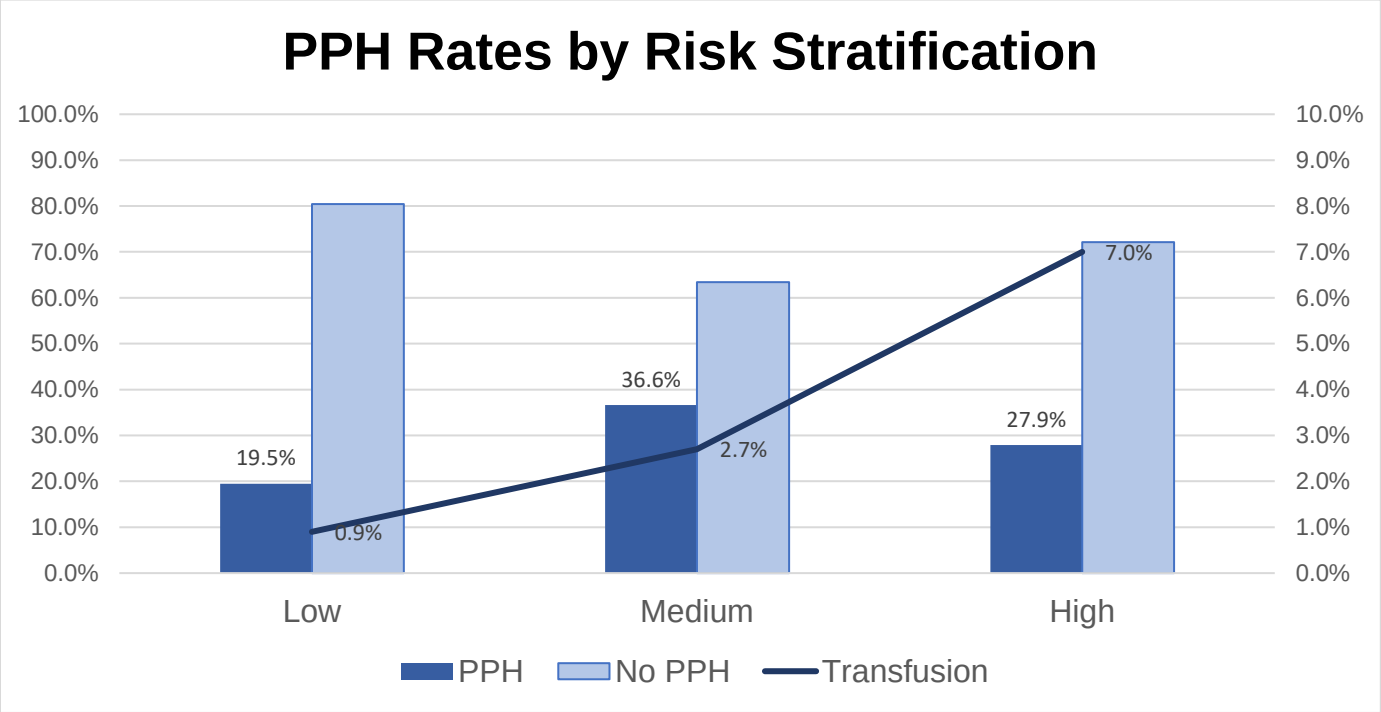

**Supplies, Inputs, Process, Outputs and Customers (SIPOC) diagram.** SIPOC diagram identifying the relevant elements of a postpartum hemorrhage risk score assignment process.

**Figure 5:**

| Process Elements (Steps) | Potential Failure Mode | Potential causes | Potential Effects of Failure | Occ 1-3 or 1-10 | Det 1-3 or 1-10 | Sev 1-3 or 1-10 | RPN | Actions to Reduce Occurrence of failure |
|---|---|---|---|---|---|---|---|---|
| Ordering a type and screen | Provider fails to order a type and screen | Provider was tied up with other patients; provider forgot to input orders, Epic system is down | Delays the process | 3 | 5 | 3 | 45 | Action plan: More than one provider per patient |
| Nurse sees type and screen order in Epic | Nurse fails to see the type and screen order | Nurse was tied up with other patients; nurse fails to see the order | Delays the process | 4 | 5 | 3 | 60 | Action plan: Checklist for nurses |
| Patient's blood drawn for type and screen and sent to the laboratory | Nurse fails to draw patient blood, nurse fails to send patient's blood to the laboratory, the blood is routed to the wrong location | Nurse was tied up with other patients; nurse forgets to draw the blood, nurse forgets to send the blood to the laboratory; patient refuses to have blood drawn; patient is delivering | Delays the process | 3 | 4 | 3 | 36 | Action plan: Checklist for nurses |
| Patient's blood is type and screen | There is not enough blood for a type and screen, machine that types and screens is broken | Nurse did not draw enough blood; patient is squeamish | Delays the process | 1 | 1 | 3 | 3 | Action plan: Standardization of phlebotomy |
| Type and screen entered into patient's electronic medical record | Computer system is down, type and screen not entered | Electricity out; EPIC undergoing updates; type and screen entered into wrong electronic medical record; lab personnel forgets to input type and screen | Delays the process | 2 | 1 | 3 | 6 | Action plan: communicate type and screen in some other manner |

**Failure Modes and Effects Analysis (FMEA)** evaluating the postpartum hemorrhage risk score assignment process to identify where and how it might fail and to assess the relative impact of different failures.

**Figure 6:**



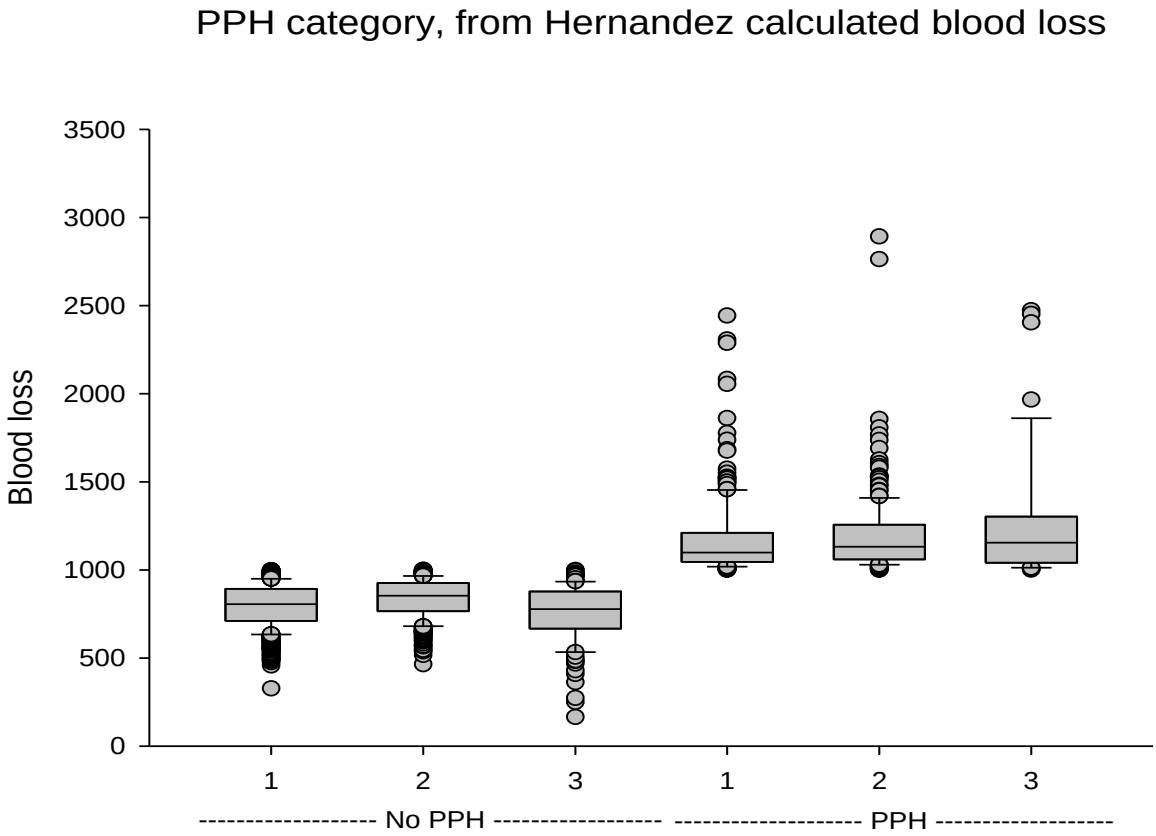

**PPH rates by risk stratification.** Correlation of postpartum hemorrhage risk stratification with rates of PPH and blood transfusion.

**Figure 7:**

| | |
|---|---|
| **Step 1** | Calculate total nonpregnant blood volume: [(height in inches x 50) + (weight in pounds x 25)] divided by 2. |
| **Step 2** | Add 50% for average pregnancy volume expansion (i.e., hypervolemia of pregnancy). |
| **Step 3** | Pregnancy total blood volume x admission HCT (vol%) = admission RBC volume. |
| **Step 4** | Assume total blood volume has returned at discharge to the nonpregnant total blood volume as a result of hemorrhage. Therefore, nonpregnant blood volume x discharge HCT (vol%) = discharge RBC volume |
| **Step 5** | Calculate total blood volume lost: (admission RBC volume - discharge RBC vol% = RBC volume transfused) divided by admission HCT (vol%). |

**Calculated blood loss formula.** From: Hernandez et al. (2012). Calculated blood loss in severe obstetric hemorrhage and its relation to body mass index. Am J Perinatol.

**Figure 8:**




**Correlation of PPH risk stratification with calculated blood loss.** Box-and-whisker plots of median blood loss in PPH cohorts stratified by low (1), medium (2), and high (3) risk for PPH. Graph created by Donald McIntire PhD.

**Figure 9:**

| 1 point | 2 points |
|---|---|
| Prior cesarean birth(s) or uterine surgery | Placenta previa |
| Multiple gestation | Low-lying placenta (within 2 cm of internal os) |
| >4 previous vaginal births | Platelets <100K |
| Chorioamnionitis | Active bleeding on admission |
| History of previous postpartum hemorrhage | Known coagulopathy |
| Large uterine fibroids* | Suspected placenta accreta, increta or percreta |
| Prolonged second stage** | |
| Prolonged oxytocin use >24 hours | |
| Magnesium sulfate treatment | |
| Hematocrit <30 | |

**Modified CMQCC PPH risk score**. *Fibroids >2 cm noted on third trimester ultrasound **Prolonged second stage was defined as stage >3 hours in nulliparous women or >2 hours in multiparous women.

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VITAE

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