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Introduction of standardised, cumulative quantitative measurement of blood loss into routine maternity care

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Abstract

Introduction Postpartum haemorrhage (PPH) is the leading cause of maternal morbidity in the UK. Visual estimation of blood loss is unreliable yet remains common practice. As part of a national quality improvement project to improve care during PPH, standardised, quantitative measurement of blood loss (QBL) for all deliveries was introduced into a tertiary obstetric unit in Cardiff, Wales.

Methods Retrospective analysis of 875 consecutive maternities between December 2017 and February 2018 was undertaken. Of these, 372 mothers had both pre- and post-partum haemoglobin (Hb) recorded. Regression analyses were performed to investigate the relationship between change in Hb, adjusted for red cell transfusion, and QBL.

Results The correlation coefficient between QBL and adjusted change in Hb for all deliveries (n=372) was 0.57. This corresponded to an estimated fall of adjusted change in Hb of 15.3 g/L (95% CI: 13.1, 17.6) per 1000mL blood loss.

Discussion QBL has been shown to be reliable across all maternity settings, with reproducible results in both theatre and delivery room locations. QBL is moderately correlated with adjusted change in Hb for all volumes of bleeding and gives clinicians more accurate knowledge of blood loss than visual estimation. This low cost, low fidelity intervention can influence timely escalation of clinical care and therefore patient outcome.

Keywords: Quantification of blood loss; Postpartum haemorrhage; Maternal morbidity; Tertiary care; Quality improvement project; Regression analysis

Introduction

Postpartum haemorrhage (PPH) is the leading cause of maternal mortality worldwide and contributes to 80% of maternal morbidity in the UK [1,2]. PPH is categorised by the volume of blood lost and is defined as ≥500mL within 24 hours following delivery [3]. Timely and accurate quantification of blood loss is critical in the management of PPH to enable early diagnosis and prompt multi-professional intervention.

Visual estimation of blood loss is common practice but is known to under-report actual blood loss [4-12]. Cumulative, quantitative measurement of blood loss, combining gravimetric and volumetric methods (QBL), has been proposed as a more accurate alternative in both simulation and clinical settings [13-16]. Current national guidelines recommend that clinical management of PPH should depend on the volume and rate of bleeding combined with the clinical picture, however measurement of blood loss using quantitative techniques is only specifically advocated when blood loss is >1000mL or for clinical concern [3]. This practice has the potential to underestimate blood loss and delay escalation of care.

Quantitative assessment of blood loss (combining gravimetric and colorimetric methods) has been successfully introduced into clinical practice in a major academic centre in the US, with improved identification of PPH [17]. It is not known if the use of gravimetric and volumetric methods is feasible in all delivery settings, at all times of day and outside clinical trials, and whether the measured blood loss correlates with an objective marker of bleed volume such as the fall in haemoglobin (Hb). As part of a national quality improvement

project (QIP), The Obstetric Bleeding Strategy for Wales (OBS Cymru) introduced standardised, quantitative, cumulative measurement of blood loss after all types of birth and in all delivery settings [18]. The reliability of this practice using the outcome of the change in Hb at discharge was investigated in a single centre involved in this QIP.

Materials & Methods

QBL was introduced into a university hospital maternity setting (comprising an alongside midwifery and consultant unit with approximately 6000 deliveries per year) in October 2016 as part of the OBS Cymru QIP. The project was registered locally as a QIP and the NHS Research and Development office stated that the project was not research and written consent to collect and report information was not required.

Standardised QBL was undertaken after all births, including antenatal bleeding if the blood loss started before delivery. The technique required gravimetric (subtracting the dry weight from the blood-soaked weight of all swabs and pads) and volumetric assessments (e.g. suction containers at caesarean section and under buttock drapes during instrumental vaginal deliveries) of blood loss to be combined to produce a cumulative total quantitative blood loss [16]. Amniotic fluid volume in containers was viewed by the team and confirmed verbally by all members prior to subtracting this volume from the total. At vaginal delivery, pads were changed immediately following delivery and discarded to account for amniotic fluid.

A midwife with dedicated time for the project delivered training to all maternity staff with a focus on midwives, healthcare assistants and theatre staff. Scenario based teaching was complemented by an online learning tool [19]. Biannual audits of measured blood loss were performed by assessing documentation in the notes of consecutive deliveries [20]. This showed that between 11-20th December 2017, all components of QBL were performed in 90% (27/30) of deliveries, indicating high compliance with the protocol.

To assess the accuracy of QBL after all deliveries the association between QBL and change in Hb, adjusted for red blood cell transfusion, after delivery was investigated. Consecutive mothers who gave birth between 26th December 2017 and 27th February 2018 were

identified retrospectively via the hospital's maternity database. The date, location, volume of blood loss, and mode of delivery were recorded. Hb levels (prior to delivery and the last sample before discharge) were retrieved from the electronic patient record. Administration of red blood cell transfusion was collected from blood bank records.

Statistical analysis

The change in Hb was adjusted for red blood cell transfusion using the formula: adjusted change in Hb after delivery (g/L) = post-delivery Hb – [pre-delivery Hb – (red blood cell units transfused *10)] [15]. Post-delivery Hb was defined as the last Hb checked prior to hospital discharge.

A linear regression model was fitted to estimate the fall of adjusted change in Hb per 1000mL of QBL (model slope) with 95% confidence interval and Pearson correlation coefficient. To study the impact of the location of delivery (theatre vs. delivery room) we added location as a covariate to the model as well as the interaction term of QBL and location to model location-specific slopes (i.e. differential fall of adjusted change in Hb depending on the location of delivery). A similar model was fitted to analyse the impact of the mode of delivery (elective or emergency caesarean, instrumental delivery, non-instrumental vertex delivery) on adjusted change in Hb per 1000 mL of QBL. To assess the effect of the timing of blood sampling (0-12h, 12-24h, 24-48h, 48-120h) on the adjusted change in Hb after delivery we performed pairwise Tukey comparisons and calculated 95% simultaneous confidence intervals. All analyses were performed in R version 3.6.1 [21] with add-on package multcomp version 1.4-10 for multiple comparisons [22]. All graphs were generated using ggplot2 version 3.1.0 [23].

Results

Demographic data

Eight hundred and seventy-five mothers gave birth between 26th December 2017 and 27th February 2018. Of these, 374 (43%) had a laboratory Hb checked within one month before delivery and repeated within 7 days after delivery (and before hospital discharge). One woman was excluded as she had a caesarean section in the general theatre suite (not an

obstetric theatre) and standardised procedures were not followed, and another because she had a secondary PPH more than 24 hours after delivery with inconsistent quantitative measurement of blood loss. Therefore, 372 women were included in the final analysis dataset.

The mode and location of deliveries for all mothers between 26th December 2017 and 27th February 2018 and those included in the analysis are shown in Table 1. Many mothers who had a non-instrument vaginal delivery did not have a postpartum Hb test as this is not routine practice if the blood loss is less than 500mL. The proportion of mothers having a caesarean section or instrumental delivery on the obstetric unit was therefore higher in the analysis dataset. The mean measured blood loss was also higher in the group included in the analysis, since women with PPH were more likely to have their Hb checked after delivery.

	All mothers, n (%)	**Mothers included in analysis, n (%)**	**Measured blood loss for all mothers in mL, mean (SD)**	**Measured blood loss for mothers included in analysis in mL, mean (SD)**
All				
	875 (100)	372 (100)	441 (372)	643 (237)
Mode of delivery				
Caesarean section:	214 (24.5)	191 (51.3)	587 (434)	613 (409)
Elective	108 (12.4)	100 (26.9)	546 (395)	572 (397)
Emergency	106 (12.1)	91 (24.5)	649 (474)	662 (419)
Instrumental vaginal	123 (14.1)	75 (20.2)	595 (477)	798 (503)
Non-instrumental vaginal	538 (61.5)	106 (28.5)	345 (271)	604 (439)
Location of delivery				
Obstetric unit operating theatre	252 (28.8)	212 (57.0)	620 (475)	670 (450)
Birthing room (obstetric unit or alongside midwifery unit)	617 (70.5)	159 (42.7)	366 (288)	620 (419)
Homebirth	4 (0.5)	1 (0.3)	238 (75)	300
During transfer or in assessment unit	2 (0.2)	0	825 (955)	Not applicable

Table 1. Comparison of numbers (%) and mean (SD) measured blood loss for all mothers (n=875) and mothers included in the analysis dataset (n=372), by mode and location of delivery.

Haemoglobin drop and transfusion results

Timing of the post-delivery Hb sample was variable. The last Hb taken prior to discharge was used for calculation of the adjusted change in Hb and the subsequent regression analysis. 79 women had an Hb sample taken within 12 hours of delivery, whilst 139 had an Hb taken between 12 and 24 hours, 101 between 24 and 48 hours and 53 more than 48 hours and less than 7 days after delivery.

The mean (SD) Hb for mothers included in the regression analysis prior to delivery was 119.3 g/L (11.8) and after delivery was 104.9 g/L (13.0).

Twenty/875 (2.3%) mothers received a blood transfusion, 16 of whom met the criteria to be included in the analysis dataset. Reasons for women receiving a blood transfusion who were excluded from the data analysis set were: one who did not have a pre-discharge Hb, one delivered before arrival to hospital, one delivered in a non-obstetric theatre and one had a secondary PPH. The median (IQR) units transfused were 2 (2) and the largest transfusion was 3 units. For women receiving a blood transfusion, mean (SD) pre-delivery Hb was 108.9g/L (9.6) and mean (SD) QBL volume was 1407mL (833).

Of the mothers included in the analysis, 4.8% (18/372) experienced a PPH >1500mL. In 27 women with QBL of less than 700mL, the Hb level increased after delivery.

Regression analysis

The correlation between QBL and adjusted change in Hb for all modes of delivery was r=-0.57 (Figure 1), P<0.001. The estimated fall of adjusted change in Hb (slope of the regression model), per 1000mL measured blood loss was 15.3 g/L (95% CI: 13.1,17.6).

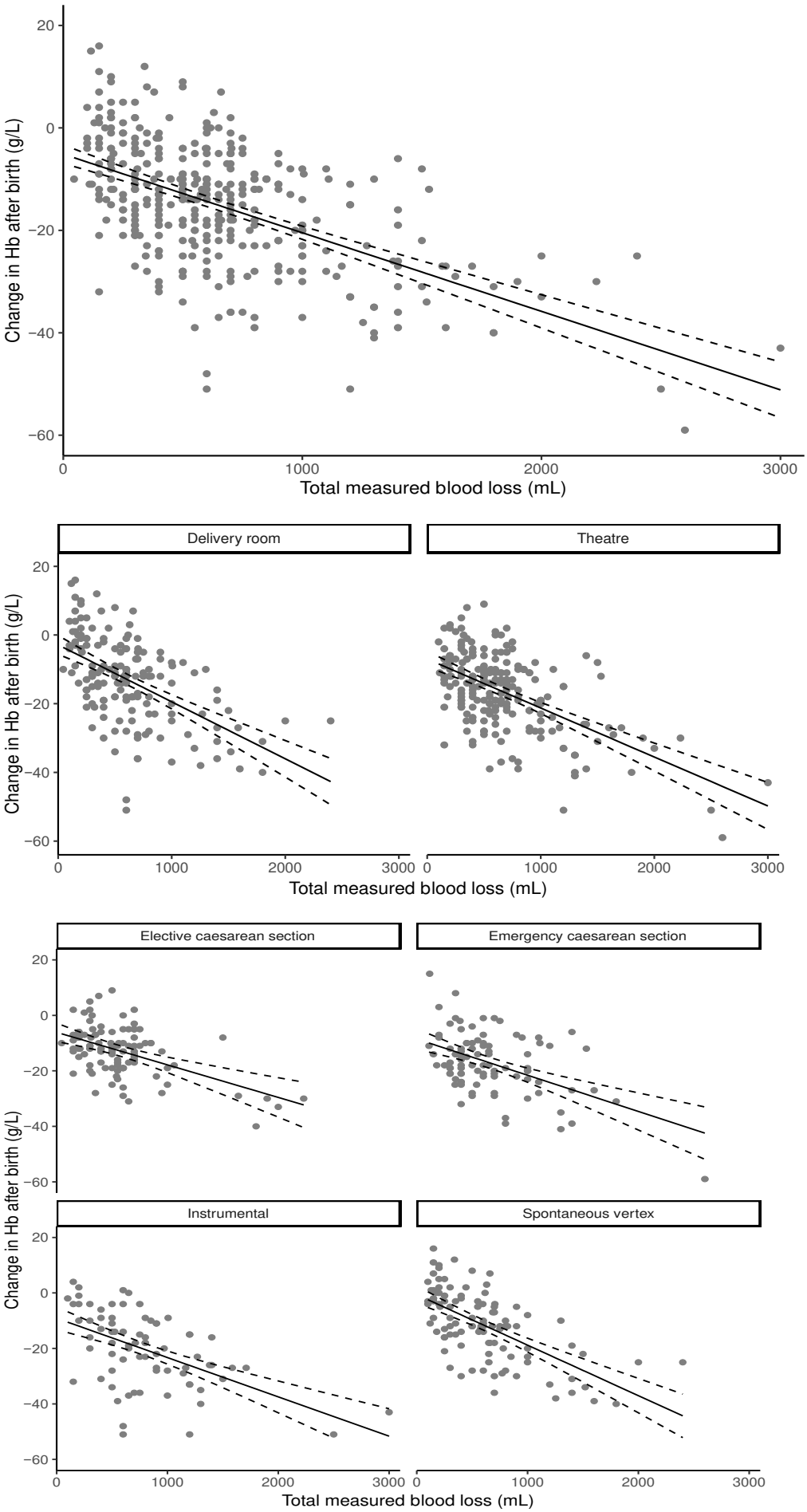


Figure 1. Scatter diagrams showing the relationship between volume of QBL and calculated change in Hb (g/L), with fitted regression model (solid line) with 95% confidence intervals (dashed line), for all deliveries (A), by location of delivery (B), and by mode of delivery (C).

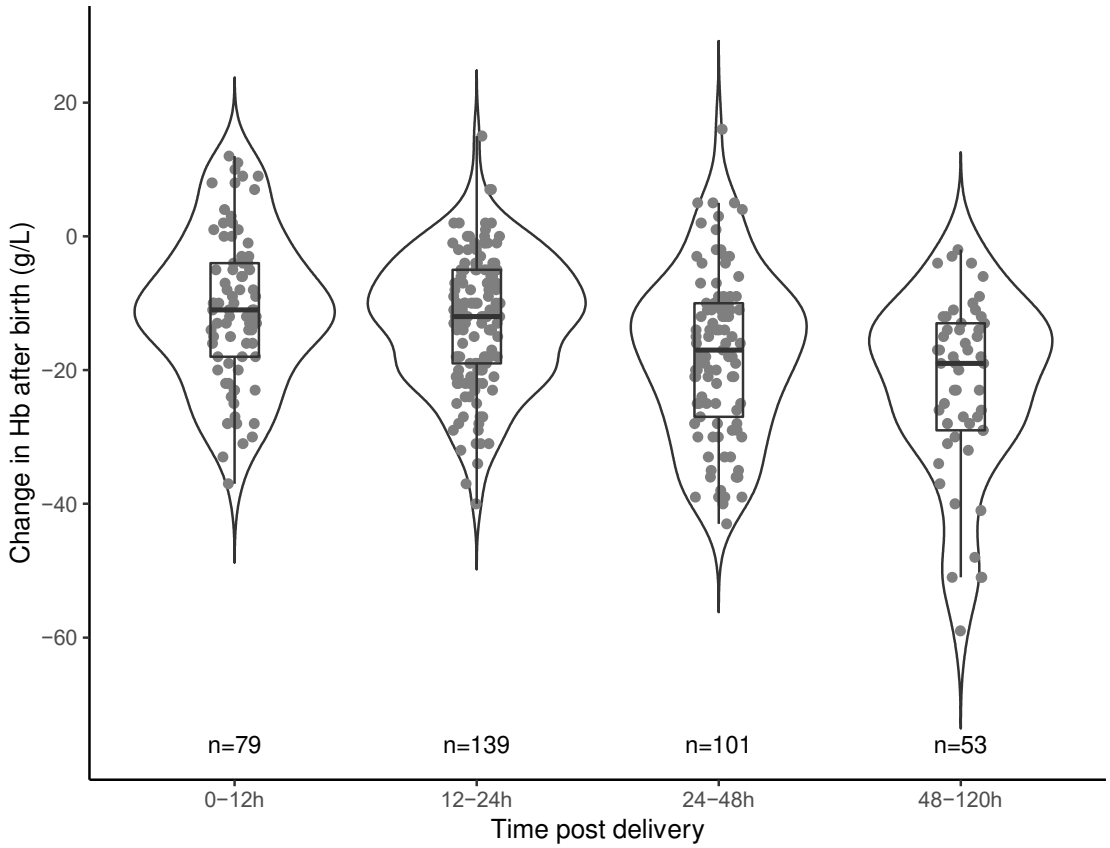
The relationship between the volume of QBL and adjusted change in Hb (g/L) for different locations and modes of delivery are shown in Figure 1. The corresponding estimated decrease in Hb (g/L) per 1000mL measured blood loss is shown in Table 2.

	Estimated fall of adjusted change in Hb (g/L) per 1000mL quantitatively measured blood loss (95% CI)	**Correlation coefficient**
All births	15.3 (13.1,17.6)	-0.57
Location of delivery		
Obstetric unit operating theatre	14.3 (11.4, 17.2)	-0.58
Birthing room (obstetric unit or alongside midwifery unit)	16.6 (12.9, 20.3)	-0.55
Mode of delivery		
Elective caesarean	11.7 (6.9, 16.5)	-0.52
Emergency caesarean	13.0 (8.3, 17.8)	-0.49
Instrumental vaginal	14.2 (9.8, 18.5)	-0.53
Non-instrumental vaginal	18.2 (14.0, 22.4)	-0.64

Table 2. Estimated fall of adjusted change in Hb (g/L) per 1000mL measured blood loss with 95% confidence interval and correlation coefficient for different locations and modes of delivery.

Timing of Hb testing and impact on adjusted Hb change

The mean adjusted change in Hb was similar in mothers for whom it was measured within 12 hours of delivery (10.85 g/L) and 12-24 hours after delivery (12.69 g/L), but notably greater in those women in whom it was measured 24-48 hours after delivery (17.75 g/L) or after 48 hours (22.51 g/L); see Supplementary Figure S1.



Supplementary Figure S1. Violin plots with embedded boxplots and dotplots of adjusted change in Hb after birth according to timing of blood sampling.

Discussion

This study shows that quantitative measurement of blood loss correlates with adjusted change in Hb in a cohort of mothers with all volumes of blood loss (45 to 3000mL) and for all locations and modes of delivery. For all mothers included in the study there was a correlation coefficient of -0.57, with an estimated fall of adjusted change in Hb of 15.3g/L (95% CI: 13.1-17.6) per 1000mL blood loss. This study provides evidence for the accuracy of quantitative measurement of blood loss when compared to an objective endpoint.

The location of birth (delivery room vs theatre) did not have a significant influence on the relationship between total blood loss and the adjusted change in Hb, indicating that QBL after all deliveries is feasible in all locations. The fall of adjusted change in Hb varied depending on the mode of delivery, with the greatest change observed in non-instrumental vaginal deliveries and the least in elective caesarean section. This difference may be

attributed to the use of predominantly gravimetric measurement during non-instrumental vaginal delivery, compared to both gravimetric and volumetric in all other settings, and or, the impact of amniotic fluid complicating the measurement.

Kahr et al undertook a prospective study of 921 women experiencing vaginal or caesarean deliveries and found correlations between QBL and adjusted change in Hb (adjusted for blood volume using Brecher's formula [37]) of 0.7 and 0.4, respectively [24]. The results are similar to our study for vaginal deliveries but the correlation is lower for caesarean section. The authors postulated that amniotic fluid was impacting on the accuracy of measured blood loss, especially at elective caesarean section, and suggested that further research was required to assess the impact of amniotic fluid on QBL after different modes of delivery.

There is a possibility that measurement of blood loss after all births may over-estimate actual blood loss leading to unnecessary escalation of care, but these data do not support this. The Hb increased in a small proportion of women, but they had all experienced smaller blood losses (less than 700mL), which would not have led to escalation of care beyond the midwifery team. Increases in postnatal Hb has been previously reported and is likely to be due to placental autotransfusion [25,26].

The use of quantitative measurement techniques has been reported in trials evaluating PPH outcomes [27,28] and advocated in large scale PPH quality improvement initiatives [29,30]. Studies investigating the correlation between QBL and adjusted Hb change have found variable results. Lilley et al [16] found in the context of a PPH study that gravimetric measurement of blood loss was closely correlated with fall in Hb adjusted for red blood cell transfusion in PPH greater than 1500mL (r=0.8), but there was no such relationship in smaller volume bleeds (r = 0.07). It was suggested that accurate measurement was more likely to occur once a major PPH had been identified. This contrasts to the study presented here where blood loss was measured from delivery in all cases, notably the relationship between adjusted change in Hb and QBL was seen at all bleed volumes. Hamm et al [31] concluded that QBL does not predict adjusted change in Hb at 12 hours significantly better than estimated blood loss. However, in this study, less than half of the women in the post-intervention group had quantitative blood loss measurement recorded and post-delivery bloods were sampled at 12 hours. Our data show that fall in Hb is maximal after 48 hours

and measurement at 12 hours may be an underestimation. Hamm et al commented that quantitative blood loss measurement may be more accurate for larger bleeds, although due to small numbers, they were unable to find a statistically significant relationship.

Photometric methods have been proposed as an alternative method of measuring blood loss [32,33]. Doctorvaladan et al observed 50 mothers undergoing caesarean delivery and reported a correlation between gravimetric methods and an extraction assay of 0.57 [32]. The correlation between photometric methods and the extraction assay was strong (0.95); but post-natal Hb analysis was not described. This photometric technique is currently routine clinical practice in two institutions who have both reported that estimated blood loss measurement was under-recognising the incidence of PPH [33,34]. With the introduction of photometric and gravimetric measurement, both groups described improved identification of blood loss and earlier intervention, leading to a reduction in number of red blood cell units transfused [33]. Photometric measurement is not currently standard practice in the UK and has greater financial implications when compared to the low-fidelity gravimetric techniques.

Day of sampling has a significant impact on fall in Hb. Lilley et al showed that the Hb fell until day 3 and Breyman et al suggested that 48h postpartum is the most clinically useful Hb due to restoration of plasma volume following delivery [16,34]. Richter and Huch [35] observed that in 98 non-anaemic healthy women, the Hb decrease had plateaued by the fourth day postpartum. It is possible that in our data the observed drop in Hb was larger after 48 hours because mothers experiencing larger bleeds were staying in hospital longer after delivery and having more blood samples taken. Fedoruk et al [36] studied 61 mothers undergoing caesarean delivery and observed only a weak correlation (r=-0.2) between gravimetric measurement and post caesarean delivery Hb taken 10 minutes after arrival into the recovery room. These results highlight the importance of cautious interpretation of Hb levels taken shortly after delivery, since results are likely to change substantially therefore affecting correlations.

The regression analysis was limited to women who had an Hb level assessment as part of their standard care. There was no protocol to define the timings of the pre and post-delivery Hb sampling because the data was collected as part of a QIP (using routinely collected data)

rather than a clinical study. In our institution it is usual practice to perform Hb analysis after caesarean section delivery, for women in whom blood loss is over 1000mL and in women with anaemia or concurrent medical conditions (e.g. cardiovascular or haematological conditions). This led to overrepresentation of women belonging to these groups, with a lower proportion of mothers experiencing an uncomplicated vaginal delivery compared to the maternity population giving birth during the data collection. The total quantitatively measured volume of blood loss was also frequently rounded to the nearest 50mL. This is likely due to clinicians acknowledging the difficulties in exact quantification of amniotic fluid.

Confounding factors that may have had an influence on plasma volume (such as dehydration, pre-eclampsia, sepsis or size of the mother) were not recorded and hence not adjusted for in the analysis. Kahr et al used Brecher's formula to adjust blood volume according to maternal weight, but did not observe an improvement in the correlation, indicating that more research is required to understand the impact of the physiological increase in plasma volume associated with pregnancy using this calculation [24,37].

The main impact of this analysis is that the correlation between QBL and adjusted change in Hb described is comparable to that demonstrated in previous research studies [16,24]. This shows that QBL is achievable in routine clinical practice after all types of delivery and in different locations. This practical, low cost intervention is feasible and the relationship between adjusted change in Hb and measured loss indicates that this methodology is reproducible allowing clinicians to be confident in measured blood loss. Measurement of blood loss alone does not reduce PPH [38], but contemporaneous recording of blood loss after delivery enables early recognition and timely intervention during PPH. By incorporating measured blood loss into a clinical care pathway which includes cumulative measurement over time (i.e. rate of blood loss), clinical concern and bedside review at pre-determined triggers, measurement of blood loss can impact on clinical care and patient outcome.

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