Viscoelastometry guided fresh frozen plasma infusion for postpartum haemorrhage: an observational study: OBS2

Concise title: Rotem guided FFP infusion for PPH.

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Summary

Background

Postpartum haemorrhage (PPH) may be exacerbated by haemostatic failure. Based on data from trauma studies, empirical infusions of fresh frozen plasma (FFP) are often given during severe PPH if coagulation tests are unavailable. This study observed a cohort of women with moderate/severe PPH in whom FFP infusion was guided by the use of viscoelastometric point-of-care testing (VE-POCT) and clinical assessment.

Methods

Women were enrolled into this observational study when blood loss was measured or suspected to be about 1000 mL. If Fibtem A5 remained >15 mm, or bleeding stopped, FFP was withheld. If Fibtem A5 was ≤15 mm and bleeding ongoing women were randomised into an interventional study as previously reported. Clinical and laboratory outcomes were recorded.

Results

The study recruited 605 women and 98% had FFP withheld. The median (25th-75th centile) total blood loss was 1500 (1300-2000) mL with 300 (50-545) mL occurring after enrolment. Total blood loss was >2500 mL in 40/605 (6.6%) women. RBCs were transfused in 141/605 (23.3%) cases and 11 (1.8%) received ≥4 units. At least one invasive procedure was performed in 283/605 (46.8%) women. Level 3 care was required for 10/605 (1.7%) women. No women developed clinically significant haemostatic impairment.

Conclusions

A restrictive use of FFP guided by clinical assessment of bleeding and VE-POCT is feasible and did not result in clinically significant haemostatic impairment. Studies should compare the clinical and cost effectiveness of empirical FFP infusions, according to current guidelines, with a targeted use of FFP based on VE-POCT.

Key words: Postpartum haemorrhage; fresh frozen plasma; viscoelastometric test,

**Introduction**

Postpartum haemorrhage (PPH) is precipitated predominantly by obstetric causes but may be exacerbated by haemostatic impairment. Some bleeds resolve before clinically significant coagulopathy develops whilst others are associated with severe haemostatic impairment. The likelihood of coagulopathy depends on the cause and size of the bleed.  

The Royal College of Obstetrics and Gynaecology (RCOG) defines established haemostatic impairment as ongoing bleeding associated with a prothrombin time (PT) or activated partial thromboplastin time (aPTT) >1.5 times normal and recommend infusing fresh frozen plasma (FFP) to maintain PT/aPTT below this ratio.  

Guidelines recommend maintaining a fibrinogen >2 g L\(^{-1}\) and, if bleeding has stopped, no blood product replacement is required.  

Haemostatic impairment may evolve rapidly and routine laboratory coagulation tests are often not available soon enough to be clinically useful. Clinicians, therefore, may not know whether a coagulopathy is developing. This has led to guidelines recommending empirical fixed-ratios of red blood cells (RBC) and FFP to manage PPH.  

This strategy is based on data derived from trauma with limited evidence in PPH. The haemostatic system at term is hypercoagulant compared to the healthy non-pregnant population and trauma-induced-coagulopathy differs markedly from the coagulopathy associated with PPH. It may be inappropriate, therefore, to extrapolate treatment strategies from trauma to PPH. Fixed-ratio transfusion may result in unnecessary transfusion of FFP and be associated with complications such as transfusion associated circulatory overload and allergic reactions.

During PPH, fibrinogen falls earlier than other coagulation factors suggesting that if fibrinogen is maintained then other coagulation factors will be adequate. A viscoelastometric point-of-care test (VE-POCT), Fibtem A5 performed on the Rotem® machine, is a surrogate measure of fibrinogen and results are available within 10 minutes. Fibtem A5 correlates with laboratory fibrinogen during PPH and is predictive of progression from moderate to severe PPH.

The aim of the study was to investigate a cohort of women experiencing moderate to severe PPH. Women with Fibtem A5 ≤15 mm (Clauss fibrinogen about 3g/L) and ongoing bleeding were eligible to be randomised to the interventional part of the study comparing the effectiveness of fibrinogen concentrate or placebo. The randomised women showed that, if plasma fibrinogen was >2 g/L or Fibtem A5 >12 mm, infusion of fibrinogen concentrate did not affect outcomes. The
protocol instructed that for women in whom the Fibtem A5 was >15 mm, or in whom bleeding had stopped, FFP should be withheld. These women are reported here.

**Methods**

This was an observational study conducted in teaching hospital obstetric units and formed part of a multicentre trial to randomise women to fibrinogen or placebo. The protocol is published. Trial registration: ISRCTN46295339 (http://www.isrctn.com/ISRCTN46295339), EudraCT 2012-005511-11 (https://www.clinicaltrialsregister.eu/ctr-search/search?query=2012-005511-11). The study was approved by Edinburgh, Multicentre Research Ethics Committee (13/SS/0008).

Women age ≥18 year and ≥24 weeks gestation experiencing major PPH (measured or suspected to be about 1000 mL) could be enrolled. Women were excluded if they declined blood transfusion, had placenta accreta diagnosed antenatally or there was clinical suspicion of amniotic fluid embolus. Women received written information in their maternity notes. Verbal consent to participate was sought at enrolment and confirmed in writing once the woman had recovered. At study entry a Fibtem was performed on delivery suite and samples sent to the laboratory for a full blood count (FBC), Clauss fibrinogen, PT and aPTT. Blood loss was estimated gravimetrically as described. If the A5 was ≤15 mm, the baby delivered and bleeding ongoing, the woman was randomised to fibrinogen concentrate or placebo. If the A5 was >15 mm local standard treatment for PPH was given except that FFP should not have been infused (cryoprecipitate infusion was not excluded). A Fibtem was repeated after each additional 500 mL blood loss or for clinical concern and FFP continued to be withheld if the A5 remained ≥15 mm or if the bleeding stopped (Figure 1).

Information was collected electronically. A full description of data points has been published. Analysis of the observational group reported here was descriptive and no hypotheses were tested, therefore, a sample size calculation was not conducted. Established laboratory haemostatic failure was defined in accordance with RCOG guidelines as PT or aPTT >1.5 times the midpoint of the normal range (in this study ≥16.5 sec and ≥48 sec, respectively) or a fibrinogen <2 g L⁻¹. Clinically significant haemostatic impairment was defined as established laboratory haemostatic failure associated with continuing bleeding. Level 3 care was advanced respiratory support or receiving 2 other organs support (usually renal or cardiac).

Descriptive summaries of maternal characteristics at study entry by cohort (observational or intervention) were performed and the means of the continuous variables were compared using
Student’s t-test for continuous variables (Mann-Whitney for non-normal distributions) and proportions of the binary variables were compared using the $\chi^2$ test. Analyses were performed using SPSS version 23 (IBM SPSS Inc, Chicago, USA).

**Results**

The observational study cohort comprised 606 women with moderate to severe PPH recruited between 29th June 2013 and 26th November 2015 who were not eligible to be randomised to the interventional trial because either their Fibtem A5 remained >15 mm or bleeding stopped. One woman withdrew consent, therefore, 605 women are reported who were managed though the observational arm of the protocol and should have had FFP withheld (Figure 2). The outcomes of the 57 women recruited to the interventional arm are reported elsewhere.

Subject characteristics at enrolment, mode of delivery and cause of bleeding are shown in table 1, the enrolment characteristics of the women who were randomised are shown for comparison. Women in the observational group had smaller bleeds at study entry and, as a direct consequence of study design, had higher fibrinogen and Fibtem A5 than the interventional group although PT and aPTT were similar.

The outcomes of women in the observational group are shown in table 2 and the interventional group is shown for comparison. The median (25th to 75th centile) total blood loss was 1500 (1300-2000) mL with 300 (50-545) mL blood loss occurring after enrolment. Total blood loss was >2500 mL in 40/605 (6.6%) women. RBCs were transfused in 141/605 (23.3%) women and 11 (1.8%) received ≥4 units RBCs. At least one invasive procedure was performed in 283/605 (46.8%) cases, most commonly repair of perineal trauma (25.5%) or vaginal packing (13.2%). Level 3 care was required for 10/605 (1.7%) women.

Fibtem A5 was ≤15 mm in 97/605 (15.7%) women at some time during the observational study. The median (25th to 75th centile) blood loss after the A5 fell to ≤15 mm was 100 (0-335) mL indicating that bleeding was rapidly controlled by obstetric intervention in most cases. To investigate whether withholding FFP may have influenced outcomes, women who developed laboratory evidence of established haemostatic failure (n=8) (Table 3), were treated with FFP contrary to the protocol (n=12) (Table 4), admitted to ITU (n=10) (Table 4) or bled >2500 mL were reviewed in detail. Some women appear in more than one of these groups.
**Women with laboratory tests associated with established haemostatic failure**

The longest PT, aPTT and lowest fibrinogen are shown in Table 2. Where data were available, 3/537 (0.6%) had a PT ratio >1.5, 0/544 (0%) had an aPTT >1.5 and 6/544 (1.1%) had a fibrinogen <2 g L⁻¹ at some time during the study. Eight women developed laboratory evidence of established haemostatic failure as defined by RCOG⁴ (Table 3), these women had a median (25th to 75th centile) 50 (0-280) mL blood loss after study entry. In all cases bleeding stopped rapidly, despite the abnormal coagulation results, following obstetric interventions and hence did not fulfil the criteria for clinical significant haemostatic impairment.

**Women who received FFP or were admitted to level 3 care**

Twelve women (2.0%) received between 1-4 units of FFP despite this being contrary to the protocol. Individual details of coagulation tests, blood products received and outcomes are described in (Table 4). Ten/605 women (1.7%) were admitted to level 3 care, 4 of whom received FFP and one cryoprecipitate (Table 4). In the 7 women on whom data were available, none had laboratory evidence of established haemostatic impairment or a low Fibtem.

**Women with a total measured blood loss more than 2500 mL**

Forty/605 (6.6%) women bled >2500 mL. Five women also received FFP and are reported in detail in table 4. In the 35 women who did not received FFP the median (25th to 75th centile, range) blood loss was 3000 (2700-3000, 2530-5500) mL and the lowest Fibtem A5 was 19 (16-22, 10-34) mm. The lowest laboratory fibrinogen was known for 32 and was 3.4 (2.4-4.6, 2.3-6) g/L. None of the woman, on whom data were available (n=32), had laboratory evidence of established haemostatic failure at any time and lowest Fibtem A5s in the other 3 women were 20, 22 and 34 mm. In total 24/35 (68.6%) received RBCs and 23/35 (65.7%) women had between 1 and 4 invasive procedures to control bleeding. Five/35 (14.2%) women had a Fibtem A5 ≤15 mm but bleeding stopped soon afterwards and so they were not randomised. One woman bled an additional 1500 mL after the Fibtem A5 was 11 mm. She bled a total of 3000 mL in 25 minutes due to uterine atony which was controlled with an intra-uterine balloon. The Fibtem A5 result of 11 mm was available about 10 minutes before the bleeding stopped and hence she was not randomised, she received 4 units of RBC and no FFP.
Discussion

This study reports on a cohort of women with moderate to severe PPH whose blood product management was stratified according to the criteria of ongoing bleeding and Fibtem A5. Of the 663 women recruited into the OBS2 study, including both the randomised and observational groups, 605 (91.2%) maintained a Fibtem A5 >15 mm or, if the Fibtem fell below 15 mm, the bleeding was rapidly controlled by obstetric intervention. Despite a restrictive use of FFP, none of the 605 women reported in this study developed clinically significant haemostatic impairment, defined as laboratory evidence of established haemostatic failure associated with continuing bleeding.

A lower proportion of the observational group had a placental abruption than the interventional group. This might be explained because abruption is known to be associated with a reduced fibrinogen\(^1,23-25\) and this precipitated randomisation. In contrast, the observational group had a higher proportion of bleeds due to genital tract trauma which is known to be less often associated with reduced fibrinogen.\(^19,26\) The observational group had higher laboratory fibrinogen and Fibtem levels at study entry as dictated by the study design. Despite this, PT and aPTTs were similar between the observational and randomised groups. This supports previous observations that fibrinogen falls earlier than other coagulation factors during PPH\(^17\) and that an adequate fibrinogen can be used as a surrogate for normal laboratory haemostasis during PPH.

The women who were not randomised had better outcomes than the women who were not. This is because the two groups were stratified by Fibtem A5 and Clauss fibrinogen levels which are known to be predictive of progression of PPH\(^19,27-29\). The difference in outcomes between the two groups does not allow any conclusions to be drawn on whether a restrictive use of FFP based on Fibtem A5, as described here, is an appropriate treatment strategy.

Guidelines recommend maintaining PT and aPTT <1.5 times normal and fibrinogen >2 g L\(^{-1}\).\(^2,4,8\) The randomised arm of this study showed that if the Fibtem A5 was >12 mm or the Clauss fibrinogen >2 g L\(^{-1}\) infusion of fibrinogen concentrate did not affect outcomes, supporting the conclusion that a fibrinogen of 2 g L\(^{-1}\) (or Fibtem >12 mm) is adequate for haemostasis during PPH.\(^20\) In the cohort of women reported here, FFP was withheld if the Fibtem A5 remained >15 mm, or a fibrinogen of about 3 g L\(^{-1}\).\(^20\) Only eight women subsequently developed laboratory evidence of established haemostatic failure. In all of these cases the Fibtem A5 was ≤15 mm but bleeding stopped soon after enrolment through obstetric intervention indicating that bleeding was not caused primarily by coagulopathy. Therefore, withholding FFP guided by Fibtem did not result in clinically significant haemostatic impairment because bleeding was controlled with obstetric intervention in all cases.
Twelve women received FFP and it is not possible to be certain whether FFP infusion influenced outcomes in these women. In 9 cases FFP was infused when the bleeding had stopped and tests of haemostasis were normal therefore giving FFP is unlikely to have influenced outcomes. FFP infusion in these cases may have been influenced by human factors such as concern about the risk of further bleeding or the desire not to waste FFP that had been thawed. The study involved a large number of investigators and these factors may have varied between individuals.

None of the 40 women with a total blood loss >2500 mL developed laboratory evidence of established haemostatic failure and it is unlikely that fibrinogen or FFP infusion would have reduced bleeding. Clinicians would not have known the results of laboratory coagulation tests for about 60 minutes, therefore, early knowledge of the Fibtem A5 appears to have been useful in managing blood product replacement, even in women with massive PPH. If a strategy of empirical, fixed-ratio FFP had been used some of these women would have been exposed to FFP because 73% received RBCs. These findings suggest that withholding FFP based on clinical assessment of bleeding and the Fibtem A5 is unlikely to result in clinically significant haemostatic impairment.

None of the 10 women admitted to level 3 care had a Fibtem ≤15 mm or laboratory tests consistent with established haemostatic failure, although 4 received FFP and 1 cryoprecipitate. It is unlikely that a more liberal use of FFP would have improved outcomes, however, it is not possible to exclude that giving FFP may have influenced outcomes unrelated to haemostasis, for example development of respiratory complications. Four women were admitted to level 3 care for respiratory distress or fluid overload, 3 had received FFP and one had not. Some of the women had received large volumes of fluids, although this did not lead to evidence of haemostatic failure in any case. No data were collected on catecholamine usage. Careful review of fluid balance is an important part of the management of PPH.

The 605 women reported in this study are a selected cohort because women with ongoing bleeding and a Fibtem A5 ≤15 mm entered the randomised study. In the whole OBS2 study (the cohort reported here and the randomised women combined) 26.8% received RBCs, 4.1% received ≥4 units RBC and 9.2% had total blood loss >2500 mL. In our previously published, unselected, consecutive cohort of 356 women recruited with similar inclusion criteria, 29.7% received a RBC transfusion, 9% received ≥4 units RBC and 10.7% had a bleed of >2500 mL. This suggests that some women with larger bleeds were not recruited into the study compared to an unselected cohort of women with PPH. It is likely, therefore, that a higher proportion of women with PPH would develop a coagulopathy than reported here because some cases of severe bleeding, where coagulopathy may develop rapidly, appear to be under-represented in this study.
Despite these limitations, our data support the observation that, if the Fibtem A5 is maintained or bleeding has stopped, FFP is not required to maintain clinically adequate haemostasis, as previously reported.\textsuperscript{14,15} Restrictive use of FFP, guided by Fibtem, is not standard practice and many guidelines recommend empirical, fixed-ratio FFP if laboratory results are not available.\textsuperscript{2,4,8} The challenge facing clinicians treating PPH is that they do not have timely tests of coagulation and, to treat the minority of women with haemostatic compromise, women with normal haemostasis must also be treated.\textsuperscript{6,7,9-11} At present NICE does not support the use of VE-POCTs during PPH but recommends studies investigating the clinical and cost effectiveness of this technology. This is an appropriate assessment of available data and our study further highlights the need for larger more definitive studies.

The strengths of this study include the large number of women treated on a standardised haemostasis management protocol. There was good compliance with the protocol despite the involvement of large numbers of clinicians, with varying levels of experience, at multiple sites suggesting that it is feasible to integrate VE-POCT into the management of PPH. The main weaknesses are that the study is observational and there is no control arm of women who received fixed-ratio RBC:FFP transfusion for comparison. It remains possible that a more liberal use of FFP, as recommended by many clinicians,\textsuperscript{6,7,9,10} may have prevented some women developing haemostatic impairment and entering the randomised arm of the study. Some critically unwell women were not recruited because clinicians could not follow trial procedures whilst managing these challenging cases. Whether a restrictive use of FFP, guided by VE-POCTs, is appropriate for these women is unknown and requires future study.

\textbf{Conclusion}

This study shows that, in the cohort of women recruited, a restrictive use of FFP based on clinical observation of bleeding and Fibtem A5 is feasible and did not result in clinically significant haemostatic impairment. Studies that recruit women with all severities of PPH are needed to compare the clinical and cost effectiveness of a liberal, empirical use of FFP, as recommended by current guidelines,\textsuperscript{2,4,8} with a restrictive use of FFP and early fibrinogen replacement based on point-of-care testing.
Funding

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Sponsorship and trial governance

The study was sponsored by Cardiff University. An independent data monitoring committee, reporting to an independent steering committee, oversaw the study.

Author contributions

PWC: study design, data interpretation, data analysis and writing the first draft of the manuscript

RC-J: study design, data analysis, data interpretation and critical revision of manuscript

DB: development of study procedures including blinding methodology, recruitment, data interpretation and critical review of manuscript

SM: recruitment of patients, data interpretation and critical review of manuscript

JD: recruitment of patients, data interpretation and critical review of manuscript

CE: recruitment of patients, data interpretation and critical review of manuscript

AW: recruitment of patients, data interpretation and critical review of manuscript

JS: study design, recruitment, data interpretation and critical revision of manuscript

NA: study conduct and governance, oversight of data integrity, data interpretation and critical revision of manuscript

JT: study conduct and governance, oversight of data integrity, data interpretation and critical revision of manuscript
K Hood: study design and sample size calculation, oversight of study conduct and governance, oversight of data analysis, data interpretation and critical revision of manuscript

K Harding: recruitment of patients, data interpretation and critical review of manuscript

RG: recruitment of patients, data interpretation and critical review of manuscript

JEH: study design, recruitment, data interpretation and critical revision of manuscript

REC: study design, recruitment, data interpretation and critical revision of manuscript

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Paul Ayuk (site obstetric lead), Andrea Fenn (recruitment and data collection)

South East Wales Trials Unit and Centre for Trials Research, Cardiff University

Shantini Paranjothy (study design), Gwennllian Moody (database collation), Vincent Poile (database development), Aude Espinasse (study conduct and governance, oversight of data integrity), Judith Evans (study coordination)

Reference List


<table>
<thead>
<tr>
<th>Variable</th>
<th>Observational cohort (n=605)</th>
<th>Intervventional cohort (n=55)</th>
<th>p-value</th>
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<td><strong>Delivery</strong></td>
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<td>Onset of labour N (%)</td>
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<td>Spontaneous</td>
<td>214 (35.4)</td>
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<td>No labour</td>
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<td>Multiple gestation N (%)</td>
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<tr>
<td>Singleton</td>
<td>564 (93.2)</td>
<td>49 (89.1)</td>
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<tr>
<td>Twins</td>
<td>41 (6.8)</td>
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<tr>
<td>Reported causes of postpartum haemorrhage* N (%)</td>
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<tr>
<td>Uterine atony</td>
<td>373 (61.7)</td>
<td>39 (70.9)</td>
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<tr>
<td>Surgical bleeding</td>
<td>207 (34.2)</td>
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<tr>
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Estimated blood loss at study entry (mL)  
*Median (25th to 75th centiles)*

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Haemostatic tests at study entry  
*Median (25th to 75th centiles)*

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<td>Fibtem A5 (mm)</td>
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<td>Prothrombin time (s)</td>
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<tr>
<td>Activated partial thromboplastin time (s)</td>
<td>25.0 (23.2 to 27.2)</td>
<td>26.0 (22.8 to 30.0)</td>
<td>0.2</td>
</tr>
<tr>
<td>Missing</td>
<td>86</td>
<td>7</td>
<td></td>
</tr>
</tbody>
</table>

* women may have had more than one cause of bleeding, †for multiple pregnancies, the most invasive mode is taken, NA is not available because many women had multiple causes of bleeding
Table 2. Study outcomes by cohort

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Observational cohort (n=605)</th>
<th>Interventional cohort (n=55)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Blood loss</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood loss after study entry</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (25th to 75th centile)</td>
<td>300 (50-545)</td>
<td>896 (500 to 1400)</td>
</tr>
<tr>
<td>range</td>
<td>0 to 3800</td>
<td>0 to 3600</td>
</tr>
<tr>
<td>Missing</td>
<td>12†</td>
<td></td>
</tr>
<tr>
<td>Total blood loss</td>
<td>1500 (1300 to 2000)</td>
<td>2480 (1982.5 to 3260)</td>
</tr>
<tr>
<td>Median (25th to 75th centile)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>range</td>
<td>650 to 5500</td>
<td>1028 to 5300</td>
</tr>
<tr>
<td>Total blood loss &gt;2500 mL N (%)</td>
<td>40 (6.6)</td>
<td>26 (47.3)</td>
</tr>
<tr>
<td><strong>Transfusion</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red blood cells</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (25th to 75th centile) units</td>
<td>0 (0 to 0)</td>
<td>2 (0 to 4)</td>
</tr>
<tr>
<td>Number transfused N (%)</td>
<td>141 (23.3)</td>
<td>35 (63.6)</td>
</tr>
<tr>
<td>Number transfused 4 or more units N (%)</td>
<td>11 (1.8)</td>
<td>16 (29.1)</td>
</tr>
<tr>
<td>Fresh frozen plasma</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (25th to 75th centile) units</td>
<td>0 (0 to 0)</td>
<td>0 (0 to 1)</td>
</tr>
<tr>
<td>Number transfused N (%)</td>
<td>12 (2.0)</td>
<td>14 (25.5)</td>
</tr>
<tr>
<td>Cryoprecipitate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (25th to 75th centile) units</td>
<td>0 (0 to 0)</td>
<td>0 (0 to 0)</td>
</tr>
<tr>
<td>Number transfused N (%)</td>
<td>2 (0.3)</td>
<td>2 (3.6)</td>
</tr>
<tr>
<td>Platelets</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (25th to 75th centile) units</td>
<td>0 (0 to 0)</td>
<td>0 (0 to 0)</td>
</tr>
<tr>
<td>Number transfused N (%)</td>
<td>1 (0.2)</td>
<td>7 (12.7)</td>
</tr>
<tr>
<td>Cell salvage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (25th to 75th centile)</td>
<td>0 (0 to 0)</td>
<td>0 (0 to 0)</td>
</tr>
<tr>
<td>Number transfused N (%)</td>
<td>27 (4.5)</td>
<td>3 (5.5)</td>
</tr>
<tr>
<td><strong>Obstetric interventions to control bleeding</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of uterotonic doses used</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (25th to 75th centile)</td>
<td>2 (2 to 4)</td>
<td>3 (5 to 6)</td>
</tr>
<tr>
<td>range</td>
<td>1 to 9</td>
<td>2 to 8</td>
</tr>
<tr>
<td>Number of invasive procedures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Median (25th to 75th centile)</td>
<td>0 (0 to 1)</td>
<td>1 (0 to 2)</td>
</tr>
<tr>
<td>range</td>
<td>0 to 5</td>
<td>0 to 4</td>
</tr>
<tr>
<td>Women requiring no invasive procedure N (%)</td>
<td>322 (53.2)</td>
<td>22 (40.0)</td>
</tr>
<tr>
<td>Women requiring one invasive procedure N (%)</td>
<td>173 (28.6)</td>
<td>10 (18.2)</td>
</tr>
<tr>
<td>Women requiring two invasive procedures N (%)</td>
<td>80 (13.2)</td>
<td>11 (20.0)</td>
</tr>
<tr>
<td>Women requiring three invasive procedures N (%)</td>
<td>21 (3.5)</td>
<td>11 (20.0)</td>
</tr>
<tr>
<td>Women requiring four invasive procedures N (%)</td>
<td>7 (1.2)</td>
<td>1 (1.8)</td>
</tr>
<tr>
<td>Women requiring five invasive procedures N (%)</td>
<td>2 (0.3)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Type of invasive procedure†</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hysterectomy N (%)</td>
<td>1 (0.2)</td>
<td>(0)</td>
</tr>
<tr>
<td>Uterine balloon catheter N (%)</td>
<td>45 (7.4)</td>
<td>15 (27.3)</td>
</tr>
<tr>
<td>Uterine compression sutures N (%)</td>
<td>9 (1.5)</td>
<td>2 (3.6)</td>
</tr>
<tr>
<td>Manual removal of placenta N (%)</td>
<td>57 (9.4)</td>
<td>4 (7.2)</td>
</tr>
<tr>
<td>Perineal repair N (%)</td>
<td>154 (25.5)</td>
<td>11 (20)</td>
</tr>
<tr>
<td>Vaginal pack N (%)</td>
<td>80 (13.2)</td>
<td>15 (27.3)</td>
</tr>
<tr>
<td>Examination under anaesthetic N (%)</td>
<td>62 (10.2)</td>
<td>18 (32.7)</td>
</tr>
<tr>
<td>Laparotomy N (%)</td>
<td>2 (0.3)</td>
<td>4 (7.3)</td>
</tr>
</tbody>
</table>

† Excludes patients who did not require any invasive procedure.
<table>
<thead>
<tr>
<th>Outcome</th>
<th>Observational cohort (n=605)</th>
<th>Interventional cohort (n=55)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bimanual compression N (%)</td>
<td>14 (2.3)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Other not stated N (%)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Interventional radiology N (%)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Uterine artery ligation N (%)</td>
<td>0 (0)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Use of tranexamic acid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number treated N (%)</td>
<td>182 (30.1)</td>
<td>55 (100%)</td>
</tr>
</tbody>
</table>

**Hospital stay and Level 2 and 3 care**

<table>
<thead>
<tr>
<th>Outcome</th>
<th>Observational cohort (n=605)</th>
<th>Interventional cohort (n=55)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 3 care N (%)</td>
<td>10 (1.7)</td>
<td>4 (7.3)</td>
</tr>
<tr>
<td>Length of stay of women admitted to level 3 care (hrs)</td>
<td>21 (9.25 to 25.25)</td>
<td>2, 4, 18, 168‡</td>
</tr>
<tr>
<td>Level 2 care N (%)</td>
<td>518 (85.6)</td>
<td>51 (94)</td>
</tr>
<tr>
<td>Length of stay of women admitted to level 2 care (hrs)</td>
<td>10 (6 to 18)</td>
<td>17 (10 to 26)</td>
</tr>
<tr>
<td>Length of hospital stay (days)</td>
<td>2 (2 to 4)</td>
<td>3 (2 to 4)</td>
</tr>
</tbody>
</table>

*Total blood loss was reported to be less than blood loss at study entry and so cases were excluded from this analysis, †women may have had more than one invasive procedure, ‡number of hours for each woman is given due to low number of cases.