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Research article

Design of a postpartum hemorrhage and transfusion risk calculator

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ABSTRACT

Background: Postpartum hemorrhage is the major cause of maternal deaths due to childbirth and also responsible for maternal morbidity.
Objectives: In this study we set out to look the incidence of postpartum hemorrhage in our population, to identify the most important risk factors for postpartum hemorrhage and thus develop a predictive risk calculator for postpartum hemorrhage and transfusion.
Study design: data was taken from patients who presented vaginal delivery or cesarean section from January 1 to December 31, 2016, the variables taken into account as risk factors were as follows: Gestational age, history of chronic or gestational hypertension, preeclampsia, previous abortions, parity, previous cesarean section, placenta previa, labor time, and postpartum hemorrhage as the event of interest. An objective quantification was performed on a weight scale in grams for the estimation of bleeding, considering postpartum hemorrhage those with >500 ml in vaginal delivery and >1000 ml of blood loss in cesarean section. Subsequently, a predictive risk calculator was developed using the Naïve Bayes algorithm.
Results: A success rate of 58% was obtained in the identification of patients at high risk of hemorrhage, and 36% for transfusion, with a sensitivity of 50.7% and specificity of 64.06%, identifying as risk factors for postpartum hemorrhage gestational age between 35 and 40 weeks, hypertension and preeclampsia, previous cesarean section, duration of labor <1 h or more than 10 h, placenta previa and previous history of postpartum hemorrhage.
Conclusion: A postpartum hemorrhage risk calculator has been designed, which due to its improved accuracy after incorporation of data becomes a useful tool that will require a larger study population to improve its performance in clinical practice and more similar studies to validate it.

1. Introduction

Postpartum hemorrhage (PPH) is the most frequent obstetric complication of childbirth. It is responsible for about 25% of pregnancy-related maternal deaths reported by the World Health Organization (WHO) [1]. Although the prevalence varies between

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Abbreviations

PPH	Postpartum hemorrhage
SMM	Severe maternal morbidity
SAMM	Severe acute maternal morbidity
MNM	Maternal near miss
RBC	Red blood cells

developed and developing countries [2], it remains the major cause of both mortality and morbidity in developing countries with an estimated mortality rate of 140,000 per year [3].

The incidence of PPH has shown an increase in the United States in recent years, despite a decrease in the mortality rate attributed to it, with a reported rate of 11.2% between 2011 and 2015 [4–6]. They also report an increasing trend of PPH in Australia, Canada, Norway, UK and other high resource countries [7,8].

The WHO working group review in 2004 [9] on the prevalence of severe maternal morbidity (SMM), found that in developed countries 0.4% of women with hospital deliveries experienced severe acute maternal morbidity (SAMM) or maternal near miss (MNM) which could increase up to 1% depending on the criteria used. These include transfusion of more than 4 units of red blood cells (RBC), hysterectomy or those derived from hypovolemia such as thromboembolic events, Sheehan's syndrome or psychological stress among others [10,11].

Multiple risk factors associated with postpartum hemorrhage have been described, and some of them can be identified during the prenatal visit, admission to labor or during labor. This would allow us to be warned or prepared for high blood loss [12]. The following are described: maternal age >35 years, gestational age, preeclampsia, previous abortions, overdistended uterus, previous cesarean section, parity, placenta previa, previous history of postpartum hemorrhage, anemia, induction of labor, prolonged first, second and third stages of labor [13–18].

The early identification of PPH is also important in order to implement the entire protocol of care and identification of the causes. The classic definition of PPH refers to the loss of more than 500 ml of blood within the first 24 h after vaginal delivery or more than 1000 ml after cesarean delivery. PPH can be minor (500–1000 ml) or major (more than 1000 ml). Major can be subdivided into moderate (1001–2000 ml) and severe (more than 2000 ml) [13,16,19].

Several methods exist for estimating blood loss. Visual estimation has been shown to be inaccurate, even in settings with experienced personnel [20–23]. As an alternative, blood collection bags or under-buttocks drapes during vaginal deliveries and gram scales for weighing blood-soaked materials have been proposed as one of the most accurate objective measures. This will allow earlier intervention and create a culture of care for blood loss, as well as being a cost-effective and economical strategy for delivery units [12,24,25].

The aim of this study was to define the prevalence of PPH and the risk factors associated with it in an obstetrics unit in the south of Madrid, Spain, in order to identify women with a higher risk of developing PPH and to elaborate a calculator that indicates the probability of PPH and transfusion with the intention of improving work and prevention strategies.

2. Material and methods

2.1. Study population

The study included all women who underwent vaginal or cesarean delivery in the Obstetrics Unit of the University Hospital HM Puerta del Sur (South Madrid, Spain) from January 1 to December 31, 2016. Data were collected in the clinical history by obstetricians during the prenatal visit or during delivery.

The risk factors described in literature [13–18] taken into consideration associated with PPH were: maternal age (less than 25 years, between 25 and 35 years, between 35 and 40 years and more than 40 years), gestational age (less than 35 weeks, between 35 and 40 weeks, more than 40 weeks), preeclampsia, eclampsia, help syndrome, history of chronic or gestational hypertension, smoking, diabetes, antiphospholipid syndrome, prothrombotic state, use of heparin during pregnancy, previous abortions, overdistended uterus (multiple pregnancy, polyhydramnios, estimated fetal weight <2500 gr, between 2500 and 3800 gr, more than 3800 gr), labor time (less than 1 h, more than 1 h and less than 5 h, between 5 and 10 h, more than 10 h of labor), previous cesarean section (1 previous cesarean section or more than 1), parity (no previous deliveries, 1 previous delivery, 2 or more previous deliveries), body mass index, presence of fibroids, placenta previa, previous history of postpartum hemorrhage and anemia.

The estimation of bleeding was carried out objectively, using the weight system of compresses, drapes and collection bag used during labor. PPH was defined as bleeding greater than 500 ml after vaginal delivery or more than 1000 ml after cesarean delivery.

Women with missing data in the clinical history or loss of data during labor and bleeding calculation were excluded.

According to the unit's protocol, all women admitted for vaginal delivery or cesarean section have a venous access catheter. During delivery, an obstetrician, a midwife and a circulating assistant are present. In the third stage of labor, active management is performed with the use of uterotonics such as oxytocin. Induction for prolonged gestation is usually performed around 41 weeks ± 3 days with the use of vaginal prostaglandins, amniotomy or oxytocin, depending on the Bishop's scale score at the time of admission. The onset of labor is considered when the woman reaches a cervical dilatation of 3–4 cm and the criteria for transfusion of blood red cells is

Table 1
Population and initial variables in the design of the postpartum hemorrhage calculator.

Number of Participants by Category		Percentage				Relative Provability	
		No Hemorrhage		Hemorrhage		No Hemorrhage π1	Hemorrhage π2
		N°	%	N°	%		
Age of mother	**Less than 25 years old**	15	1.00%	4	0.27%	0.0140	0.0094
	Between 25 and 35 years old	556	37.07%	218	14.53%	0.5177	0.5117
	Between 35 and 40 years old	400	26.67%	156	10.40%	0.3724	0.3662
	More than 40 years	103	6.87%	48	3.20%	0.0959	0.1127
1500	**TOTAL**	**1074**	**71.60%**	**426**	**28.40%**		
Weeks of gestation	**Less than 35 weeks**	8	0.54%	0	0.00%	0.0075	0.0000
	Between 35 and 40 weeks	179	12.05%	101	6.80%	0.1684	0.2388
	More than 40 weeks	876	58.95%	322	21.67%	0.8241	0.7612
1486	**TOTAL**	**1063**	**71.53%**	**423**	**28.47%**		
Hypertensive condition	**No High blood pressure**	1041	69.40%	403	26.87%	0.9693	0.9460
	Chronic hypertension	7	0.47%	3	0.20%	0.0065	0.0070
	Gestational hypertension	26	1.73%	20	1.33%	0.0242	0.0469
1500	**TOTAL**	**1074**	**71.60%**	**426**	**28.40%**		
Preeclamspsia	**No**	1053	70.20%	406	27.07%	0.9804	0.9531
	Mild	14	0.93%	10	0.67%	0.0130	0.0235
	Severe	7	0.47%	10	0.67%	0.0065	0.0235
1500	**TOTAL**	**1074**	**71.60%**	**426**	**28.40%**		
Eclamspsia	**No**	1074	71.60%	425	28.33%	1.0000	0.9977
	Yes	0	0.00%	1	0.07%		0.0023
1500	**TOTAL**	**1074**	**71.60%**	**426**	**28.40%**	0.0000	
HELLP Syndrome	**No**	1071	71.40%	421	28.07%	0.9972	0.9883
	Yes	3	0.20%	5	0.33%	0.0028	0.0117
1500	**TOTAL**	**1074**	**71.60%**	**426**	**28.40%**		
Smoking habit	**No**	927	62.13%	369	24.73%	0.8696	0.8662
	Yes, before pregnancy	58	3.89%	33	2.21%	0.0544	0.0775
	Yes, during gestation	81	5.43%	24	1.61%	0.0760	0.0563
1492	**TOTAL**	**1066**	**71.45%**	**426**	**28.55%**		
Diabetes	**No**	1025	68.3%	406	27.07%	0.9544	0.9531
	Pre-gestational	7	0.47%	7	0.47%	0.0065	0.0164
	Gestational diabetes	42	2.80%	13	0.87%	0.0391	0.0305
1500	**TOTAL**	**1074**	**71.60%**	**426**	**28.40%**		
Anti-phospholipid syndrome	**No**	1071	71.40%	424	28.27%	0.9972	0.9953
	Yes	3	0.20%	2	0.13%	0.0028	0.0047
1500	**TOTAL**	**1074**	**71.60%**	**426**	**28.40%**		
Pro-thrombotic condition	**No**	1060	70.67%	418	27.87%	0.9870	0.9812
	Yes, but asymptomatic	10	0.67%	6	0.40%	0.0093	0.0141
	Yes, with a history of thrombosis	0	0.27%	2	0.13%	0.0037	0.0047
1500	**TOTAL**	**1070**	**71.60%**	**426**	**28.40%**		
Use of Heparin during Pregnancy	**No**	1045	69.67%	406	27.07%	0.9730	0.9531
	yes	29	1.93%	20	1.33%	0.0270	0.0469
1500	**TOTAL**	**1074**	**71.60%**	**426**	**28.40%**		
Pre-pregnancy abortion	**No**	772	51.81%	296	19.87%	0.7242	0.7064
	1 previous abortion	294	19.73%	123	8.26%	0.2758	0.2936
	2 or more previous abortions	3	0.20%	2	0.13%	0.0028	0.0048
1490	**TOTAL**	**1069**	**71.74%**	**421**	**28.26%**		
Number of fetuses	**Single fetus**	1050	70.19%	412	27.54%	0.9804	0.9694
	Multiple gestation	21	1.40%	13	0.87%	0.0196	0.0306
1496	**TOTAL**	**1071**	**71.59%**	**425**	**28.41%**		
Amniotic fluid amount	**Oligohydramnios**	25	1.67%	7	0.47%	0.0233	0.0164
	Normal amount	1044	69.60%	415	27.67%	0.9721	0.9742
	Polihydramnios	5	0.33%	4	0.27%	0.0047	0.0094
1500	**TOTAL**	**1074**	**71.60%**	**426**	**28.40%**		
Parity	**No previous deliveries**	600	40.13%	221	14.78%	0.5607	0.5200
	1 previous delivery	382	25.55%	175	11.71%	0.3570	0.4118
	More than 1 previous delivery	88	5.89%	29	1.94%	0.0822	0.0682
1495	**TOTAL**	**1070**	**71.57%**	**425**	**28.43%**	0.8937	0.8803
Previous cesarean section	**No**	958	63.95%	375	25.03%	0.1063	0.1197
	1 previous cesarean section	114	7.61%	51	3.40%	0.0000	0.0000
	More than 1 previous cesarean	0	0.00%	0	0.00%		
1498	**TOTAL**	**1072**	**71.56%**	**426**	**28.44%**		
	Less than 2500 g	78	5.23%	27	1.81%	0.0733	0.0634

(*continued on next page*)

Table 1 (*continued*)

Number of Participants by Category		Percentage				Relative Provability	
		No Hemorrhage		Hemorrhage		No Hemorrhage π1	Hemorrhage π2
		N°	%	N°	%		
Estimated fetal weight in third trimester, gram (g)	**Between 2500 g and 3800 g**	875	58.72%	351	23.56%	0.8224	0.8239
	Equal to or more than 3800 g	111	7.45%	48	3.22%	0.1043	0.1127
1490	**TOTAL**	**1064**	**71.41%**	**426**	**28.59%**		
Labor hours	**Less than 1 h**	52	4.11%	27	2.14%	0.0579	0.0738
	More than 1 h and less than 5 h	435	34.41%	141	11.16%	0.4844	0.3852
	Between 5 and 10 h	313	24.76%	140	11.08%	0.3486	0.3825
	More than 10 h	98	7.75%	58	4.59%	0.1091	0.1585
1264	**TOTAL**	**898**	**71.04%**	**366**	**28.96%**		
Body mass index (BMI)	**BMI < 30**	616	54.85%	292	26.00%	0.7990	0.8295
	BMI > or = 30	155	13.80%	60	5.34%	0.2010	0.1705
1123	**TOTAL**	**771**	**68.66%**	**352**	**31.34%**		
Uterine fibroids	**No**	187	54.36%	147	42.73%	0.9740	0.9671
	Yes	5	1.45%	5	1.45%	0.0260	0.0329
344	**TOTAL**	**192**	**55.81%**	**152**	**44.19%**		
Placenta previa	**No**	192	55.01%	148	42.41%	0.9897	0.9548
	Yes	2	0.57%	7	2.01%	0.0103	0.0452
349	**TOTAL**	**194**	**55.59%**	**155**	**44.41%**		
History of postpartum hemorrhage	**No**	147	52.69%	130	46.59%	1.0000	0.9848
	Yes	0	0.00%	2	0.72%	0.0000	0.0152
279	**TOTAL**	**147**	**52.69%**	**132**	**47.31%**		
Anemia	**No**	136	48.75%	116	41.58%	0.9252	0.8788
	Yes	11	3.94%	16	5.73%	0.0748	0.1212
279	**TOTAL**	**147**	**52.69%**	**132**	**47.31%**		

π1: probability assigned by the algorithm for no postpartum hemorrhage, **π2:** probability assigned by the algorithm for postpartum hemorrhage.

hemoglobin equal to or less than 7 g/dL.

The study was approved by the ethics committee of the University Hospital HM Puerta del Sur and did not require informed consent from the participants.

2.2. Statistical analysis

The present work is carried out with the aim of providing a "calculator" that obtains as output, an orientation of the risk of postpartum hemorrhage (one of the variables), of the case/woman under evaluation, based on probabilistic criteria.

A solution adjusted to the previous objectives is provided with the data collected, observing a clear framing of the problem in the context of automatic learning (artificial intelligence) providing it with a manual way to promote learning that motivates a progressive growth of the sample, although obtaining an expert system of artificial intelligence is beyond the scope of this work, since it demands a much higher contribution of resources, limiting the work done here to the initial phase of analysis of what would be the project leading to that higher objective.

We have opted for the choice of a simple Bayes Model (based on the Naïve Bayes algorithm). It is a set of probabilistic classifier algorithms that assign class labels to the instances, represented by vectors of values. All of them assume that the values of the variables are independent of each other.

Naïve Bayes is based on Bayes' theorem and is possibly the simplest of the probability-based algorithms. It was described by Duda and Hart in 1973, and is commonly used in both data mining and machine learning (artificial intelligence) for classification problems [26,27]. It consists of a network where the nodes are either true or false facts and the links between the nodes are the conditional probabilities of some facts with respect to others. The chosen algorithm allows us in the same act, to provide automatic learning capabilities, which allow an evolution of the sample size, with the consequent progressive improvement in statistical reliability.

Regarding the identification and analysis of variables, of the 23 starting variables (selected from the evidence and its association with PPH) we discarded those that did not have correct data or those for which there was not a significant percentage or did not contribute significantly to the final prediction results.

Of all the variables initially considered, maternal age, eclampsia, HELLP syndrome, smoking, diabetes, antiphospholipid syndrome, prothrombotic state, use of heparin during gestation, number of fetuses, amount of amniotic fluid, estimated third trimester fetal weight, body mass index (BMI), uterine fibroids, and anemia were discarded due to small sample size or low probabilistic contribution to the risk score.

Other variables have been processed to obtain value information, for example in the case of dates, which allowed us to obtain age or gestation period, we have kept the years and weeks respectively, and subsequently we have defined the most suitable intervals in view of the distribution of cases, to obtain discrete/qualitative values, as a general rule for the few cases that directly or as a result of the transformation referred to, we arrived at continuous/quantitative variables.

Likewise, the implementation of the model adopted has provided us with a certain flexibility when dealing with variables with a certain degree of errors, where the cardinality of that particular variable has required a certain reduction with respect to the sample size.

The variables with which the model finally operates are nine, as follows:

Gestational age, history of chronic or gestational hypertension, preeclampsia, previous abortions, parity, previous cesarean section, placenta previa, labor time, and postpartum hemorrhage as the event of interest. See Table 1.

3. Results

In the period of one year, data was collected from the medical records of 1532 patients, among them 32 were excluded because they did not have data on the estimated bleeding during labor due to lack of registration. Therefore, the study population is reduced to 1500 women. Among them 426 (28.4%) presented PPH of which 61 (4.0%) required transfusion of one or more units of RBC in the first week postpartum.

After application of the PPH risk calculation algorithm, an estimated bleeding risk was obtained for 538 women (35.8%), with a predicted risk of transfusion in 147 women (9.8%). See Fig. 1.

The success rate after PPH risk calculation was 58%. This percentage improved gradually as data were collected from more participants. We obtained 216 true positives, 210 false negatives, 688 true negatives and 386 false positives, with a sensitivity of 50.7% and specificity of 64.06%.

Regarding the transfusion prediction of 61 transfused women, our calculator was able to predict 22 of them, 36%, a more objective measure of predicting a severe hemorrhage. See Table 2.

Regarding the distribution of the variables taken to elaborate the predictive algorithm and the incidence in each group of postpartum hemorrhage, we obtained:

About weeks of gestation, the group with the highest incidence of bleeding was between 35 and 40 weeks with a total of 280 women of which 101 (36.07%) developed PPH.

The variable of hypertensive condition highlights a higher percentage in the group with gestational hypertension, with a total of 46 patients of whom 20 (43.4%) presented PPH. Likewise, the presence of preeclampsia showed that the groups with mild and severe preeclampsia had a PPH percentage of 41.6% and 58.8%, respectively.

In the group with previous abortions, there was a slight upward trend in the groups with 1 previous abortion with 29.4% and those with more than 1 abortion with 40% incidence of PPH compared to those with no history of abortion.

In the parity group, the distribution of PPH incidence was more or less similar, and regarding the history of previous cesarean section, there was a slight increase in the incidence of PPH in the group with 1 previous cesarean section with 30.9% compared to 28.1% in those women without previous cesarean section.

The duration of labor showed a tendency at the extremes to present PPH. In the group with delivery of less than 1 h, 34.1% of cases, and deliveries lasting more than 10 h 37.1% of cases were PPH.

In the placenta previa group, although the sample size was small, there was a marked tendency towards bleeding risk. Of 9 women with placenta previa, 7 presented PPH (77.7%). . The same trend was observed in those women with a history of PPH in previous deliveries. Of 2 women with a history of confirmed PPH, 2 had bleeding >500 ml.

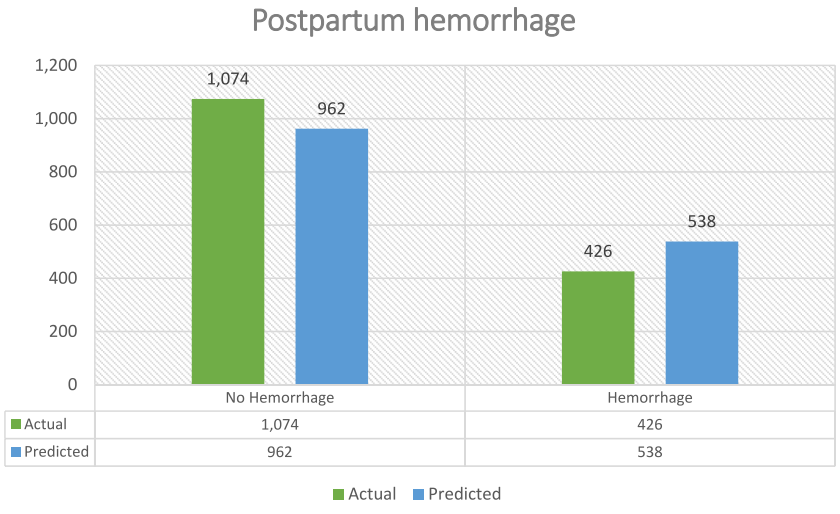

Fig. 1. Number of women with actual PPH compared to that estimated by the risk calculator.

Table 2
Definitive variables included in the postpartum hemorrhage risk calculator.

NUMBER OF PARTICIPANTS BY CATEGORY		TOTAL N° in sub-categories	N° No Hemorrhage	% No Hemorrhage in sub-category	N° Hemorrhage	% Hemorrhage in sub-category	No Hemorrhage π1	Hemorrhage π2
Weeks of gestation 1486	**Less than 35 weeks**	**8**	8	100%	0	**0%**	0.0075	0.0000
	Between 35 and 40 weeks	**280**	179	63.92%	101	**36.07%**	0.1684	0.2388
	More than 40 weeks	**1198**	876	73.12%	322	**26.8%**	0.8241	0.7612
Hypertensive condition 1500	**No High blood pressure**	**1444**	1041	72.09%	403	**27.9%**	0.9693	0.9460
	Chronic hypertension	**10**	7	70%	3	**30%**	0.0065	0.0070
	Gestational hypertension	**46**	26	56.52%	20	**43.4%**	0.0242	0.0469
Preeclamspsia 1500	**No**	**1459**	1053	72.17%	406	**27.8%**	0.9804	0.9531
	Mild	**24**	14	58.33%	10	**41.6%**	0.0130	0.0235
	Severe	**17**	7	41.17%	10	**58.8%**	0.0065	0.0235
Pre-pregnancy abortion 1490	**No**	**1068**	772	72.2%	296	**27.7%**	0.7242	0.7064
	1 previous abortion	**417**	294	70.5%	123	**29.4%**	0.2758	0.2936
	2 or more previous abortions	**5**	3	60%	2	**40%**	0.0028	0.0048
Parity 1495	**No previous deliveries**	**821**	600	73.08%	221	**26.9%**	0.5607	0.5200
	1 previous delivery	**557**	382	68.5%	175	**31.4%**	0.3570	0.4118
	More than 1 previous delivery	**117**	88	75.2%	29	**24.7%**	0.0822	0.0682
Previous cesarean section 1498	**No**	**1333**	958	71.86%	375	**28.1%**	0.8937	0.8803
	1 previous cesarean section	**165**	114	69.09%	51	**30.9%**	0.1063	0.1197
	More than 1 previous cesarean	**0**	0	0%	0	**0%**	0.0000	0.0000
Labor hours 1264	**Less than 1 h**	**79**	52	65.82%	27	**34.1%**	0.0579	0.0738
	More than 1 h and less than 5 h	**576**	435	75.5%	141	**24.4%**	0.4844	0.3852
	Between 5 and 10 h	**453**	313	69.09%	140	**30.9%**	0.3486	0.3825
	More than 10 h	**156**	98	62.82%	58	**37.1%**	0.1091	0.1585
Placenta previa 349	**No**	**340**	192	56.47%	148	**43.5%**	0.9897	0.9548
	Yes	**9**	2	22.22%	7	**77.7%**	0.0103	0.0452
History of postpartum hemorrhage 279	**No**	**277**	147	53.06%	130	**46.9%**	1.0000	0.9848
	Yes	**2**	0	0%	2	**100%**	0.0000	0.0152

%: percentages in each variable subcategories for both patients without hemorrhage and those with PPH.
π1: probability assigned by the algorithm for no postpartum hemorrhage, **π2:** probability assigned by the algorithm for postpartum hemorrhage.

4. Discussion

4.1. Principal findings

The aim of this study was to determine the incidence of postpartum hemorrhage in our population and to identify the most important risk factors in order to develop a risk algorithm for PPH and transfusion.

In order to develop these objectives, we chose the Naïve Bayes algorithm for its ability to provide results based on the sum of probabilities and the learning and improvement with the sum of information, being a statistical strategy different from the one used in other studies interested in achieving similar objectives to this study [28–30]. or similar in those employing artificial intelligence tools [31,32].

The results obtained with our predictive algorithm show a tendency to overestimate PPH (35.8%) and the estimated risk of transfusion (9%), with a 58% accuracy rate in those patients who presented the event of interest, reaching a sensitivity of 50.7% and

specificity of 64.06%. It certainly fails to identify some cases that present PPH, almost half, which suggests that in a less enriched model of cases the results could be worse and that a much larger prospective cohort would be necessary to improve the results obtained.

It is known from other studies that PPH can occur in women who do not present any risk factors in up to 20% [33,34], so it seems essential to prepare the healthcare team to face the situation and to take all the necessary preventive measures such as active management of the third stage of labor, which has proven to be effective in reducing the risk of hemorrhage [35,36].

Of the 1500 women included in our study, we obtained an incidence of PPH of 28%, higher than previous studies [8,37–39], which range from 0.5% to 16%, although it is closer to that found in an Italian study [28] that reports 24%. It may be possible due to a thorough strategy for quantifying the bleed and for recording the data, taking into account that an objective measurement of bleeding is performed, which makes us think that in reality we may miss many cases of PPH when performing a subjective or visual estimation of bleeding because it could be imprecise. However, it seems important to consider the criteria in each study to define PPH and the characteristics of each population, which could explain the wide range of results.

The 4% transfusion rate is similar to that reported in a French study [40], although it is slightly above that the most widely accepted rate and reported in other studies, ranging from 0.2 to 2.27% [6,41–43].

The prediction of transfusion risk is substantially overestimated by 9% in the calculator, with a 36% accuracy in identifying actual cases of transfusion, recognizing this measure as more objective in measuring the risk of severe PPH. The major concern in clinical practice is not only to identify bleeding but to reduce the number of transfusions and hysterectomies. To be most useful, this tool should be able to identify a high percentage of cases at risk of transfusion or hemoglobin <7 g/dL. We believe that this would be possible by increasing the number of cases to improve learning and use in different cohorts.

Regarding the risk factors for PPH found in our population, gestational age between 35 and 40 weeks presented a higher percentage of PPH (36.07%) with respect to the gestational age group >40 weeks (26.8%) It could be explained by the fact that the cervical conditions at delivery are worse, which could lead to a higher rate of cesarean sections or prolonged deliveries.

These findings do not correspond to the findings of a study comparing the incidence of PPH in Sweden and California and the risk of PPH associated with gestational age, where the risk is higher in deliveries between 41 and 42 weeks compared to deliveries between 37 and 38 weeks [44].

Hypertension and preeclampsia were also observed as risk factors for PPH, which coincides with the HYPITAT study [45], in which PPH is more frequent in women with hypertensive disease of pregnancy at term (10% vs. 0.4–1.3% for those at low risk) and with others that found a significant association between preeclampsia and PPH [38,46–48].

Other risk factors found, such as previous cesarean section, duration of labor <1 h or more than 10 h, are consistent with the results found in other studies [34,48–50]. We also found a significant increased risk of bleeding in women with placenta previa and previous history of PPH.

4.2. Research and clinical implications

A strong point of the algorithm created is that it learns consecutively as more information is added to its database. Thus, it could be interesting to test it in other population contexts and with a larger number of samples. It is also proposed as a tool that can help to optimize expenses such as those related to the stock of products for transfusion, which was one of the points of interest in our study, since there was an upward trend in the need for transfusion during the period of the study.

4.3. Strengths and limitations

The strength of this study is the selection of a homogeneous and consecutive group of women who delivered in our unit during the study period, allowing us to identify risk factors in our population and thus develop a predictive algorithm for PPH risk that would continue learning thanks to artificial intelligence. This feature makes it feasible to test in larger populations or with other characteristics, and could become a useful tool in the prevention of PPH, severe maternal morbidity, and transfusion risk.

As weaknesses, the time limitation for our research did not allow us to have a larger number of participants to include and to be able to use or consider other variables that were discarded due to the low number of participants. For this reason, we believe that the predictive capacity of this calculator can be improved, and more studies are needed to make it really useful in clinical practice, especially in identifying the risk of transfusion, taking into account that it will always be very important to keep the assistance team prepared to face a PPH situation. It is currently presented as a proposal that can motivate further prospective studies.

5. Conclusions

A postpartum hemorrhage and transfusion risk calculator has been designed that can be improved thanks to artificial intelligence. It is a study that may motivate other researchers to test it in their environment and with a larger number of participants.

Ethical approval

Project approved by the ethics committee of the Hospital Universitario HM Puerta del Sur under code 40_18.

Design of a postpartum hemorrhage and transfusion risk calculator

Postpartum hemorrhage risk calculator

A. Why was the study conducted?
Postpartum hemorrhage continues to have a high incidence worldwide causing maternal morbidity and mortality.
B. What are the key findings?
To obtain an approximation of each woman's individual risk of postpartum hemorrhage and transfusion.
C. What does this study add to what is already known?
Provides a new tool for the calculation of bleeding and transfusion risk that can be improved by artificial intelligence.

Declaration of competing interest

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