VoxSanguinis
The International Journal of Transfusion Medicine
ISBT International Society of Blood Transfusion
Vox Sanguinis (2015) **108**, 37–45

ORIGINAL PAPER

DOI: 10.1111/vox.12186

What factors contribute to hospital variation in obstetric transfusion rates?

J. A. Patterson,[1] C. L. Roberts,[1] J. P. Isbister,[2] D. O. Irving,[3] M. C. Nicholl,[4] J. M. Morris[1] & J. B. Ford[1]

[1]*Clinical and Population Perinatal Health, Kolling Institute, University of Sydney, Sydney, NSW, Australia*
[2]*Sydney Medical School, University of Sydney, Sydney, NSW, Australia*
[3]*Research and Development, Australian Red Cross Blood Service, Sydney, NSW, Australia*
[4]*Obstetrics and Gynaecology, Royal North Shore Hospital, Sydney, NSW, Australia*

Vox Sanguinis

Background and Objectives To explore variation in red blood cell transfusion rates between hospitals, and the extent to which this can be explained. A secondary objective was to assess whether hospital transfusion rates are associated with maternal morbidity.

Materials and Methods Linked hospital discharge and birth data were used to identify births (n = 279 145) in hospitals with at least 10 deliveries per annum between 2008 and 2010 in New South Wales, Australia. To investigate transfusion rates, a series of random-effects multilevel logistic regression models were fitted, progressively adjusting for maternal, obstetric and hospital factors. Correlations between hospital transfusion and maternal, neonatal morbidity and readmission rates were assessed.

Results Overall, the transfusion rate was 1·4% (hospital range 0·6–2·9) across 89 hospitals. Adjusting for maternal casemix reduced the variation between hospitals by 26%. Adjustment for obstetric interventions further reduced variation by 8% and a further 39% after adjustment for hospital type (range 1·1–2·0%). At a hospital level, high transfusion rates were moderately correlated with maternal morbidity (0·59, P = 0·01), but not with low Apgar scores (0·39, P = 0·08), or readmission rates (0·18, P = 0·29).

Conclusion Both casemix and practice differences contributed to the variation in transfusion rates between hospitals. The relationship between outcomes and transfusion rates was variable; however, low transfusion rates were not associated with worse outcomes.

Received: 23 February 2014,
revised 9 July 2014,
accepted 11 July 2014,
published online 4 August 2014

Key words: clinical practice variation, obstetric delivery, red blood cell transfusion.

Background

In recent years, there has been growing consideration of the need to limit the use of blood transfusions. Although allogeneic blood transfusion in Australia is extremely safe from an infection-transmitted disease perspective, it is a limited and expensive resource that has significant potential non-infectious hazards [1]. There is now an increased emphasis on patient blood management, an individualized approach which aims to manage patients in such a way as to reduce the need for transfusion and therefore avoid unnecessary exposure to blood and blood products [1, 2]. This emphasis has been reflected in blood usage guidelines and standards proposed internationally [3, 4]. The Australian National Blood Authority has developed national standards on use of blood components and products to 'ensure that the patients who receive blood and blood products do so appropriately and safely' [5]. Benchmarking studies have recognized that in disciplines where

Correspondence: Jillian A. Patterson, Clinical & Population Perinatal Health Research, c/- University Dept of O&G, Building 52, Royal North Shore Hospital, St Leonards, NSW 2065, Australia
E-mail: jillian.patterson@sydney.edu.au

there is wide variation in transfusion rates between hospitals, there is the potential for transfusion rates to be reduced, without affecting patient outcomes [6].

Variation in blood transfusion rates between hospitals has been studied for over twenty years. In 1991, Goodnough published an influential study on transfusion rates in coronary artery bypass graft (CABG) surgery, showing that large variation in transfusion rates between hospitals persisted despite adjustment for some casemix factors [7]. These findings have been replicated in areas such as cardiac surgery, orthopaedics and other elective surgery, with some attempts to identify possible factors accounting for the observed variation [8–10]. The discipline of obstetrics has been largely absent from these studies [6], and current Australian national guidelines on obstetric blood component use, although proposed, do not exist [11]. Blood transfusion in obstetric practice differs from other fields; in that, the majority of transfusions are in response to unexpected obstetric haemorrhage occurring in otherwise healthy women [12, 13]. Variation in clinical practice has been demonstrated for other obstetric interventions such as caesarean section rates and induction of labour [14, 15], so one may reasonably expect that blood transfusion rates will differ between hospitals.

Internationally, obstetric transfusion rates range from 0·1–1·9% [16, 17], and have been increasing in recent years [13, 18]. The most common indication for transfusion in the obstetric setting is postpartum haemorrhage (PPH; excessive bleeding postchildbirth), but it can also be used to treat anaemia from other causes [19, 20], and in patients with inherited bleeding disorders [21]. Quality evidence to inform clinical practice around transfusion in obstetrics is limited [21]. It is clear that in cases of massive haemorrhage, failure to transfuse a patient could cause harm, as could poor management of bleeding disorders; however, the benefits of transfusion for anaemia in haemodynamically stable patients are less clear [2].

This study aims to (1) explore variation in transfusion rates between hospitals, and to what extent this can be explained by casemix, interventions and hospital-level factors; and (2) determine whether high or low hospital transfusion rates are associated with higher rates of maternal morbidity.

Methods

The study population for this research consisted of all women giving birth in NSW hospitals from 2008–2010 to an infant(s) of at least 20 weeks gestation. NSW is the largest state in Australia, with over 90 000 births per year. Hospitals and women giving birth in those hospitals were excluded if there were fewer than 10 births per year across the study period. Women with missing covariate data were also excluded. Data on maternal characteristics, pregnancy, labour and birth were obtained from the Perinatal Data Collection ('birth data'), a population-based collection of data on all births of at least 400-g birthweight or 20-week gestation. Data on maternal risk factors, procedures and fact of transfusion were obtained from the Admitted Patients Data Collection ('hospital data'), a census of all public and private hospital inpatient separations in NSW coded to the Australian Classification of Health Interventions [22] and International Classification of Diseases Australian Modification (ICD-10-AM) [23]. Infant hospital data were also linked to the birth data to provide information on neonatal readmission within 6 weeks, diagnoses and procedures. NSW Centre for Health Record Linkage performed probabilistic data linkage between the two data sets, with linkage proportions over 98%. Only the deidentified data were provided to researchers.

Transfusion of red blood cells (RBC) during the birth admission included any record of transfusion of packed cells or whole blood in the procedure codes for the maternal hospital admission. For the purposes of this study, the transfusion rate refers to transfusion of RBC either alone or in conjunction with other blood products. A range of factors that could potentially affect the hospital transfusion rate were considered and categorized according to whether they were maternal casemix factors, obstetric interventions at an individual level, or hospital-level characteristics or intervention rates (Appendix S1).

Maternal conditions associated with a high risk of bleeding were identified from the hospital records. These were placenta praevia, antepartum haemorrhage [APH; including placental abruption), and bleeding/platelet disorder (including thalassaemia, haemolytic and aplastic anaemias, and coagulation defects (ICD10-AM codes D56-D61, D63-D64, D66-D69, D72-D77)]. Other maternal and pregnancy factors identified from the hospital data, birth data or both (depending on reporting) were maternal age (under 25 years, 25–34 years, 35 years or older), maternal country of birth (Australia/other), parity, maternal smoking, previous caesarean, hypertension (chronic or pregnancy), diabetes (gestational or other), multiple pregnancy, gestational age [very preterm (<33 weeks), preterm (33–36 weeks), term (≥37 weeks)], large for gestational age infant (>90th centile). Socio-economic status was measured using the Socioeconomic Indicator For Areas index of relative disadvantage [24]. In Australia, some maternity patients are privately insured or private payers and can receive care as a private patient in a public or private hospital; 'private patient' is used to refer to either situation. A woman was considered to be at low risk antenatally for transfusion if she was delivering a singleton infant at term and did not have a condition placing her at high risk of bleeding (APH, placenta praevia, bleeding/platelet disorder) or other

medical condition (diabetes, hypertension). Interventions were obtained from the birth data (induction, instrumental delivery, caesarean section (intrapartum/prelabour), regional analgesia, augmentation), or both hospital and birth data (episiotomy).

In NSW, some private hospitals are located in close proximity to or on the same grounds as a public hospital, and in these cases, there is sharing of staff between the two hospitals. In this case, the private hospital is defined as case as a 'colocated private' hospital and the public hospital as a 'colocated public' hospital. Hospitals were also coded as primary, secondary or non-obstetric training hospitals (where primary refers to hospitals co-ordinating registrar training, and secondary to hospitals where registrars may be sent on placement). Hospital intervention rates (caesarean section, induction, instrumental delivery, regional analgesia), private insurance and preterm birth rates amongst all patients were also considered. As information on the anaesthetic cover for each hospital was unavailable, the proportion of caesarean sections performed under general anaesthesia (GA) was used as a proxy (with a higher proportion of caesarean sections under GA indicating a lower level of specialist obstetric anaesthetic cover).

Maternal morbidity was assessed using a validated composite indictor which included obstetric embolism, organ failure, mechanical ventilation, hysterectomy, shock and other diagnoses and procedures associated with severe morbidity [25]. While the published indicator includes transfusion of blood and blood products, these were removed from the indicator for the purposes of this study. Readmission within 6 weeks of the birth and 5-min Apgar <7 (as a marker of neonatal morbidity) was also considered. Only reliably reported, validated variables were used in analysis [26–29].

To explore the degree of variation in RBC transfusion rates between hospitals, a series of random-effects multilevel logistic regression models were fitted, progressively adjusting for maternal, intervention and hospital factors [30]. Maternal factors significant in univariable analysis were included in the maternal factors model, and non-significant variables progressively removed until only variables significant at alpha = 0·05 remained. All significant variables in the maternal model were retained for the intervention model, and intervention variables were removed until only significant variables remained. Hospital factors were added into the intervention model one at a time, and the variable which most reduced the between-hospital variation was retained. This process was repeated to identify further significant hospital factors. Factors considered at each stage are listed in Appendix S1. A random-effects model was used to both account for clustering of similar women and practices within hospitals, and to 'shrink' (or weight) hospitals with the greatest variability towards the overall transfusion rate. The hospital specific odds of transfusion were converted to risk-adjusted transfusion rates by multiplying by the overall transfusion rate. Results are presented graphically, showing the transfusion rate with 95% confidence interval for each hospital (dots), ordered by the unadjusted transfusion rate. Separate panels show the progressive impact of adjustment for casemix, intervention and hospitals factors on variation in rates. Variability is indicated by the extent to which hospitals differ from the statewide transfusion rate (horizontal line). The variability between hospitals was quantified using the variance of the random effect, and the percentage change between models used to show reduction in variation after adjustment. A sensitivity analysis was performed considering transfusions amongst low-risk women. All models were fitted in SAS version 9·3 (SAS Institute Inc., Cary, NC, USA).

To assess the appropriateness of high and low transfusion practice, the correlation between hospital-adjusted rates of blood transfusion and maternal casemix-adjusted rates of each of maternal morbidity, readmission and neonatal Apgar <7 at 5 min were calculated using multivariate multilevel models, jointly considering the morbidity and transfusion as outcomes.

Ethical approval for this study was obtained from the NSW Population and Health Services Research Ethics Committee.

Results

Between 2008 and 2010, there were 281 543 births across 117 hospitals. After excluding births in hospitals of <10 births per year, there were 280 245 births across 89 hospitals. A further 1100 women with missing values for confounding variables were excluded, leaving 279 145 (99%) births for analysis.

Overall, the RBC transfusion rate was 1·4% (n = 3914). Women receiving transfusions were more likely to be primiparous (51·7% vs. 42·4%), undergoing an instrumental delivery (21·2% vs. 11·6%), having a large for gestational age (16·2% vs. 10·9%) or preterm infant (14·9% vs. 6·4%), twins or higher-order birth (4·4% vs. 1·5%), or have a bleeding or platelet disorder (9·0% vs. 0·7%) and were less likely to be delivering vaginally (41·9% vs. 58·6%), or private patients (22·7% vs. 34·4%) (Table 1).

Unadjusted hospital transfusion rates ranged from 0·6% to 2·9%. Adjusting for the differing casemix (maternal factors) between hospitals reduced the variation by 26·5% (Table 2), with adjusted rates ranging from 0·6% to 2·8%. After adjusting for intervention factors, the variation was further reduced by 8·0% (range 0·7% to 2·5%), and after adjusting for hospital factors, this reduced a further 38·6% (range 1·1%, 2·0%) (Fig. 1).

Table 1 Characteristics of women giving birth in NSW, 2008–2010

		Total	RBC transfusion	No RBC transfusion
Total		279 145 (100·0)	3914 (100·0)	275 231 (100·0)
Maternal age	Under 20	9647 (3·5)	208 (5·3)	9439 (3·4)
	20–34	202 953 (72·7)	2746 (70·2)	200 207 (72·7)
	35+	66 545 (23·8)	960 (24·5)	65 585 (23·8)
Private patient	Yes	95 568 (34·2)	890 (22·7)	94 678 (34·4)
	No	183 577 (65·8)	3024 (77·3)	180 553 (65·6)
Smoker	Yes	33 306 (11·9)	530 (13·5)	32 776 (11·9)
	No	245 839 (88·1)	3384 (86·5)	242 455 (88·1)
Multiple birth	Yes	4195 (1·5)	172 (4·4)	4023 (1·5)
	No	274 950 (98·5)	3742 (95·6)	271 208 (98·5)
Primiparous	Yes	118 830 (42·6)	2023 (51·7)	116 807 (42·4)
	No	160 315 (57·4)	1891 (48·3)	158 424 (57·6)
Previous caesarean	Yes	42 493 (15·2)	601 (15·4)	41 892 (15·2)
	No	236 652 (84·8)	3313 (84·6)	233 339 (84·8)
Gestational age	20–32	3946 (1·4)	194 (5·0)	3752 (1·4)
	33–36	14 116 (5·1)	388 (9·9)	13 728 (5·0)
	37+	261 083 (93·5)	3332 (85·1)	257 751 (93·6)
Mode of birth	Normal vaginal delivery[a]	162 835 (58·3)	1641 (41·9)	161 194 (58·6)
	Caesarean section	85 044 (30·5)	1476 (37·7)	83 568 (30·4)
	Prelabour caesarean	49 268 (17·6)	733 (18·7)	48 535 (17·6)
	Intrapartum Caesarean	35 773 (12·8)	742 (19·0)	35 031 (12·7)
	Instrumental Delivery	32 738 (11·7)	830 (21·2)	31 908 (11·6)
	Forceps	11 247 (4·0)	408 (10·4)	10 839 (3·9)
	Vacuum	21 491 (7·7)	422 (10·8)	21 069 (7·7)
Induction		76 938 (27·6)	1329 (34·0)	75 609 (27·5)
Birthweight[b]	SGA	24 271 (8·7)	237 (6·1)	24 034 (8·7)
	LGA	30 741 (11·0)	636 (16·2)	30 105 (10·9)
Hospital type	Tertiary	11 6951 (41·9)	2069 (52·9)	114 882 (41·7)
	Regional	58 187 (20·8)	850 (21·7)	57 337 (20·8)
	Urban/other	35 304 (12·6)	507 (13·0)	34 797 (12·6)
	Private	68 703 (24·6)	488 (12·5)	68 215 (24·8)
Bleeding/platelet disorder		2329 (0·8)	352 (9·0)	1977 (0·7)

[a]without forceps or vacuum.

[b]SGA, small for gestational age (<10th-centile); LGA, large for gestational age (>90th centile).

When potential hospital-level factors were included individually in the interventions model, colocation, the proportion of private patients, the rates of caesarean section, instrumental delivery, episiotomy, analgesia and caesarean section under GA and augmentation, the average socioeconomic status for women in the hospital, and location (metropolitan/regional) demonstrated a statistically significant association with the hospital transfusion rate and reduced the variation between hospitals. Colocation most reduced the variation between hospitals, and no other factor retained significance in a model including colocation. Patients at a private hospital (whether colocated or not) had lower odds of receiving a transfusion, with patients at a private hospital colocated with a public hospital being at the lowest risk [OR 0·47 95% CI (0·37,0·59)] compared with non-colocated public hospitals. Overall, 73·0% of the hospital variation in the crude model could be explained by the combination of casemix, intervention and hospital factors (Table 2).

Compared with a hospital in the middle quintile, the adjusted odds of transfusion in a high-transfusing hospital were 1·6 (95% CI 1·4, 1·7) and in a low-transfusing hospital 0·4 (95% CI 0·4, 0·5).

A sensitivity analysis amongst women at low antenatal risk for postpartum haemorrhage at term showed a similar reduction in variability after adjusting for casemix (39·6%), a slight reduction after adjustment for intervention (1·5%) and a further 24·6% reduction having adjusted for hospital factors. Again, colocation of facilities most reduced the variation at a hospital level. Casemix, intervention and hospital factors explained 65·7% of the overall variation between hospitals.

Maternal morbidity and readmission rates were higher amongst women receiving a transfusion (maternal

Table 2 Risk factors for red blood cell transfusion in the birth admission, with each model progressively adjusting for maternal factors, intervention factors and hospital factors, NSW, 2008–2010[a]

Variable	Category	Maternal model OR (95% CI)	Intervention model OR (95% CI)	Hospital model OR (95% CI)
Maternal age	Under 20	1·27 (1·09,1·47)	1·40 (1·21,1·63)	1·40 (1·20,1·63)
	20 to 34	1.00 (ref)[b]	1·00 (ref)	1·00 (ref)
	35+	1·14 (1·05,1·23)	1·13 (1·04,1·22)	1·12 (1·04,1·21)
Private patient		0·69 (0·62,0·77)	0·69 (0·62,0·77)	0·81 (0·72,0·91)
Australian born		0·82 (0·76,0·88)	0·85 (0·78,0·91)	0·84 (0·78,0·91)
Blood/platelet disorder		12·5 (11·0,14·1)	11·8 (10·4,13·4)	11·8 (10·4,13·4)
Primipara		1·57 (1·46,1·69)	1·17 (1·07,1·27)	1·16 (1·07,1·26)
Previous caesarean		1·26 (1·14,1·40)	1·33 (1·18,1·50)	1·33 (1·19,1·50)
Pregnancy hypertension		1·75 (1·60,1·92)	1·67 (1·52,1·84)	1·67 (1·52,1·83)
Antepartum haemorrhage		2·49 (2·20,2·82)	2·34 (2·07,2·65)	2·34 (2·07,2·65)
Placenta praevia		8·55 (7·47,9·78)	9·95 (8·56,11·6)	9·96 (8·56,11·6)
Multiple birth		2·22 (1·87,2·63)	2·45 (2·05,2·91)	2·43 (2·04,2·90)
LGA		1·69 (1·55,1·85)	1·66 (1·51,1·81)	1·65 (1·51,1·81)
Gestation	<32 weeks	1·00 (ref)	1·00 (ref)	1·00 (ref)
	33–36	0·73 (0·60,0·87)	0·71 (0·59,0·86)	0·72 (0·60,0·87)
	37+	0·54 (0·46,0·64)	0·50 (0·42,0·60)	0·51 (0·43,0·61)
Regional analgesia			0·64 (0·59,0·70)	0·65 (0·59,0·71)
Labour induction			1·39 (1·29,1·51)	1·39 (1·29,1·51)
Augmented labour			1·42 (1·27,1·59)	1·42 (1·27,1·59)
Episiotomy			1·50 (1·35,1·68)	1·51 (1·36,1·69)
Mode of birth	Normal vaginal delivery		1·00 (ref)	1·00 (ref)
	Instrumental		2·29 (2·05,2·57)	2·30 (2·05,2·57)
	Intrapartum caesarean		2·14 (1·91,2·39)	2·13 (1·90,2·38)
	Prelabour caesarean		1·40 (1·22,1·60)	1·40 (1·22,1·60)
Colocation	Public (not colocated)			1·00 (ref)
	Colocated public			0·94 (0·78,1·13)
	Colocated private			0·47 (0·37,0·59)
	Other private			0·54 (0·43,0·69)
Variance	Unadjusted	Maternal	Intervention	Hospital
	0·17 (0·04)	0·12 (0·03)	0·11 (0·03)	0·05 (0·02)
% reduction from unadjusted model		26·5	34·4	73·0

[a]For full list of variables considered at each stage, see Appendix S1.

[b](ref) denotes reference category for calculation of odds ratios.

morbidity: 13·4% vs. 0·6%; readmission: 6·3% vs. 2·6%). The proportion of infants having a low Apgar score was also higher for women receiving a transfusion (6·9% vs. 1·8%) (Table 3). At a hospital level, maternal morbidity was moderately correlated with transfusion rates (0·59, $P = 0·01$), with higher transfusing hospitals having higher rates of maternal morbidity. Transfusion rates were not significantly correlated with readmission rates (0·18, $P = 0·29$), or infants with low Apgar scores (0·39, $P = 0·08$) (Fig. 2).

Discussion

Overall, 1·4% of birth admissions between 2008 and 2010 involved a RBC transfusion. Considerable variation in obstetric transfusion rates was evident between hospitals in NSW, with the highest transfusing hospital having four times the transfusing rate of the lowest transfusing hospital. Models that adjusted for patient, intervention and hospital factors demonstrated some reduction in variation. Adjustment for casemix (factors not amenable to change) explained 26% of variation, obstetric interventions explained a further 8% of variation, and hospital factors a further 39%, reducing the unexplained variation compared with the unadjusted rates by 73%. A similar pattern was seen when the analysis was limited to women at low antenatal risk for postpartum haemorrhage. Despite the range of transfusion rates across hospitals, there was little evidence of a difference in maternal outcomes with a changing transfusion rate.

The transfusion rates observed in NSW are at the higher end of the range of transfusion rates observed

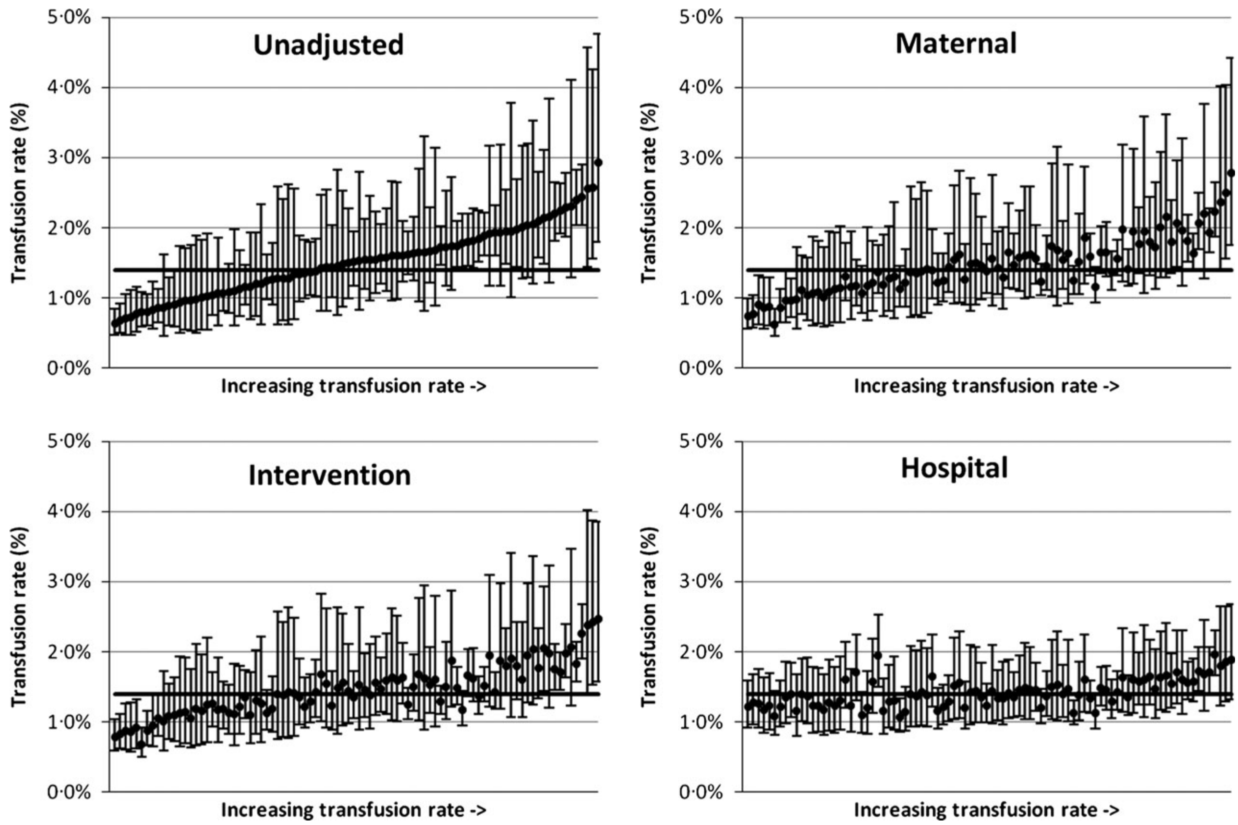

Fig. 1 Variation in hospital transfusion rates for red blood cell transfusion in the birth admission, NSW, 2008–2010[a]. [a]Dots represent hospital red blood cells transfusion rates, with 95% confidence intervals, and the horizontal line the average rate.

Table 3 Maternal and neonatal adjusted outcome rates, NSW, 2008–2010

	Apgar <7 at 5 min *n* (%)	Maternal morbidity *n* (%)	Readmission rate *n* (%)
Overall rate	5124 (1·84)	2042 (0·73)	7432 (2·66)
Rate in women receiving transfusion	270 (6·90)	524 (13·39)	248 (6·34)
Rate in women not receiving transfusion	4854 (1·76)	1518 (0·55)	7184 (2·61)

elsewhere. While Danish and Finnish studies have reported obstetric transfusion rates of around 2% [16, 31], rates in the USA were 1·0% in 2009 [18], and in Ireland increased from 0·05% to 1·29% between 1999 and 2009 [17]. Although differences in the maternal population may partially explain the difference in rates between countries, such variation suggests the potential to reduce transfusion rates without associated negative outcomes.

Casemix factors unsurprisingly explained some of the variation in transfusion rates that was seen between hospitals. Consistent with other studies, the greatest maternal risk factors for transfusion during the birth admission were bleeding/platelet disorders, placenta praevia, APH and multiple births [19, 31–33]. Although these conditions are rare, they are potentially treated in tertiary hospitals, resulting in appropriately higher transfusion rates in tertiary hospitals. Because a hospital's casemix is largely not amenable to change, it is important to take this into account before comparing hospital rates.

Adjustment for intervention or management factors over which the clinician has some control contributed little to explaining remaining variation between hospitals (8·0%). Although intervention factors contribute to the risk of transfusion [17, 19, 31] the practices associated with these interventions vary significantly between hospitals [14, 15]. Such unmeasured differences in clinical practice mean that taking into account the management of women of similar risk profiles in different settings did not contribute greatly to our understanding of variation between hospitals.

Hospital-level factors explained a considerable proportion of the remaining variation, suggesting that there are clinical practice and hospital culture factors affecting transfusion rates. Type of hospital (in particular public vs. private) was associated with reduction in variation in transfusion rates. It is not clear whether this is related to

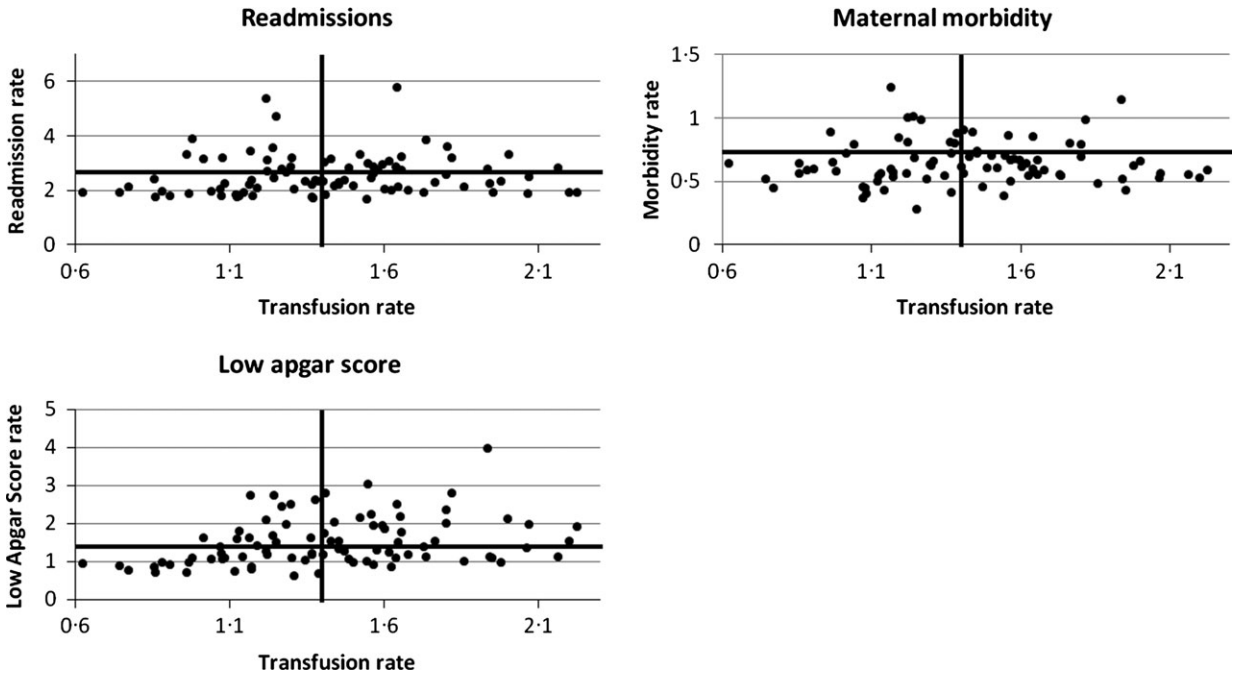

Fig. 2 Adjusted rates of maternal and neonatal morbidity and transfusion, NSW, 2008–2010. *Dots represent hospital transfusion and morbidity rates. In each graph, the bold horizontal line is the average morbidity rate, and the bold vertical line is the average transfusion rate.

patients being appropriately risk managed, or if there are some issues in access to blood products that may explain this finding. Sharing of consultants between colocated private and public hospitals may be a factor, with consultants preferentially booking women with higher risk of bleeding at the public hospital where there are 24-h onsite facilities. Guidelines on the management of women at high risk of bleeding involve consideration of an appropriate place of birth, with ready access to blood and blood products [21, 34], such as a larger urban hospital or tertiary centre. Thus, it is possible that some reduction in variability due to hospital type is related to private hospitals having a lower-risk subset of women [35], which was not fully accounted for in the adjustment. It is also possible, however, that this represents a true, unmeasured, difference in practice between public and private hospital clinicians. Access to blood and blood products may vary by hospital type. Blood and blood products are provided free of charge to private hospitals [36], so it is unlikely that financial considerations are influencing blood use.

The relationship between hospital transfusion rates and maternal outcomes was variable. At a hospital level, there was moderate correlation between transfusion rates and maternal morbidity; however, there was no correlation with readmission rates or neonatal morbidity. Readmission rates are potentially less robust markers of outcome that may reflect differing admission practices and access to local care rather than serious adverse outcome. The correlation between transfusion and maternal morbidity may suggest that either there is some aspect of practice which contributes to jointly higher morbidity and transfusions, or that there are aspects of casemix leading to both higher morbidity and transfusion rates that are not accounted for completely in modelling. Evidence on improved outcomes associated with either a restrictive or liberal transfusing strategy in obstetric practice is limited [37]. A recent Cochrane review on restrictive vs. liberal transfusion thresholds in any setting supported the use of a restrictive transfusion thresholds [38]; however, none of the studies included obstetrics patients. In the context of obstetric transfusions, the majority of which are in response to unpredictable obstetric haemorrhage, one cannot assume that a low-transfusing hospital represents best practice. However, high-transfusing hospitals may also not represent optimal care, with evidence of overtransfused obstetrics patients noted in hospital audit studies [37, 39], and studies of transfusion to treat anaemia in women postnatally finding no clear benefit of this practice [20, 40]. Thus, it is important for research exploring variation in transfusion rates to concurrently take into account outcomes, to ensure that efforts to reduce blood use and variation do not cause harm.

The extent of variation observed in this study after adjusting for casemix is considerable, with an over fourfold difference in transfusion rate between the lowest and highest transfusion hospital. The variation seen here is somewhat lower than observed in other specialties. Bennett-Guerrero *et al.* [8] report an almost eightfold

difference in transfusion rates for coronary artery bypass graft surgery, and for non-cardiac surgery, Qian *et al.* [10] found upwards of thirty-fold differences in transfusion rates. The lower transfusion rate in obstetric practice compared with other specialties may be partially responsible for the lower variation. Additionally, as most obstetric transfusions are given in the context of haemorrhage, for which transfusion is often recommended [12], there may be less room for variable practices. Karkouti *et al.* [9] found lower variation between hospitals of large volume transfusion rates and rates of transfusion for excessive blood loss compared with any transfusion.

The strengths of this study lie in its use of reliably reported, population data to identify variation in blood transfusion rates between hospitals. Use of multilevel models allowed for differences in casemix to be taken into account, as well as similarities in births within hospitals. This then allowed for identification of potentially modifiable clinical practice factors which could be targeted to reduce variation in transfusion rates between hospitals. This study also potentially highlights target hospitals for audit studies, where clinical decision-making aspects of care that are not captured in these routinely collected data have been identified. Identification of such factors may contribute to explaining the remaining variation. A limitation of this study is that only fact of transfusion was available, rather than the quantity transfused. It has been suggested elsewhere that there is less variation between hospitals in large volume transfusion rates [9], as these represent severe cases with clearer transfusion need. An additional limitation is that casemix factors not adjusted for at an individual level would appear as between-hospital variation; however, a wide range of risk factors were considered, so the effect of this would be small. Because of the reliance on administrative data, it is sometimes unclear whether poor outcomes are the result of transfusion, or the transfusion was a response to a developing poor outcome. There is some potential for introducing bias in consideration of outcomes by not taking into account the number of bags transfused and incomplete adjustment for the severity of illness; however, a range of maternal medical conditions, related to severity, were incorporated in casemix adjustment.

Differences in obstetric transfusion rates were evident in NSW, and these differences persisted after adjustment for differing casemix between hospitals. This suggests the presence of clinical practice factors which influence blood use, and the presence of potential over- or under-transfusion in some hospitals. Investigation of these factors through audits or qualitative research could inform practice guidelines or quality improvement processes, which could result in decreased variation in transfusion rates, without compromising quality of care.

Acknowledgements

Jillian Patterson analysed the data, and all other authors were involved in the interpretation of the data and provided advice on improvements and further analyses. Jillian Patterson, Christine Roberts and Jane Ford drafted this manuscript. James Isbister, David Irving, Michael Nicholl and Jonathan Morris critically reviewed the manuscript and provided guidance on clinical and health service interpretations. This work was supported by a Partnership Grant from the Australian National Health and Medical Research Council NHMRC (#1027262), the Australian Red Cross and the NSW Clinical Excellence Commission. Christine Roberts is supported by a NHMRC Senior Research Fellowship (#1021025). Jane Ford is supported by an ARC Future Fellowship (#120100069). We thank the NSW Ministry of Health for access to the population health data and the NSW Centre for Health Record Linkage for linking the data sets.

References

1 Spahn DR, Moch H, Hofmann A, *et al.*: Patient blood management: the pragmatic solution for the problems with blood transfusions. *Anesthesiology* 2008; **109**:951–953

2 Isbister JP: The three-pillar matrix of patient blood management–an overview. *Best Pract Res Clin Anaesthesiol* 2013; **27**:69–84

3 Carson JL, Grossman BJ, Kleinman S, *et al.*: Red blood cell transfusion: a clinical practice guideline from the AABB*. *Ann Intern Med* 2012; **157**:49–58

4 World Health Organization (WHO): 63rd World Health Assembly. Availability, safety and quality of blood products. 2010.

5 Australian Commission on Safety and Quality in Health Care (ACSQHC): National Safety and Quality Health Service Standards. Sydney, 2011.

6 Murphy MF, Stanworth SJ, Yazer M: Transfusion practice and safety: current status and possibilities for improvement. *Vox Sang* 2011; **100**:46–59

7 Goodnough LT, Johnston MF, Toy PT: The variability of transfusion practice in coronary artery bypass surgery. Transfusion medicine academic award group. *JAMA* 1991; **265**:86–90

8 Bennett-Guerrero E, Zhao Y, O'Brien SM, *et al.*: Variation in use of blood transfusion in coronary artery bypass graft surgery. *JAMA* 2010; **304**:1568–1575

9 Karkouti K, Wijeysundera DN, Beattie WS, *et al.*: Variability and predictabil-

ity of large-volume red blood cell transfusion in cardiac surgery: a multicenter study. *Transfusion (Paris)* 2007; **47**:2081–2088
10 Qian F, Osler TM, Eaton MP, *et al.*: Variation of blood transfusion in patients undergoing major noncardiac surgery. *Ann Surg* 2013; **257**:266–278
11 National Blood Authority A: Patient Blood Management Guidelines. (Last accessed 17 December 2013).
12 McLintock C, James AH: Obstetric hemorrhage. *J Thromb Haemost* 2011; **9**:1441–1451
13 Patterson JA, Roberts CL, Bowen JR, *et al.*: Blood transfusion during pregnancy, birth and the postnatal period. *Obstet Gynecol* 2014; **123**:126–133
14 Lutomski JE, Morrison JJ, Lydon-Rochelle MT: Regional variation in obstetrical intervention for hospital birth in the Republic of Ireland, 2005–2009. *BMC Pregnancy Childbirth* 2012; **12**:123
15 Glantz JC: Obstetric variation, intervention, and outcomes: doing more but accomplishing less. *Birth* 2012; **39**:286–290
16 Holm C, Langhoff-Roos J, Petersen KB, *et al.*: Severe postpartum haemorrhage and mode of delivery: a retrospective cohort study. *BJOG* 2012; **119**:596–604
17 Lutomski JE, Greene RA, Byrne BM: Severe maternal morbidity during childbirth hospitalisation: a comparative analysis between the Republic of Ireland and Australia. *Eur J Obstet Gynecol Reprod Biol* 2012; **163**:148–153
18 Callaghan WM, Creanga AA, Kuklina EV: Severe maternal morbidity among delivery and postpartum hospitalizations in the United States. *Obstet Gynecol* 2012; **120**:1029–1036
19 Jou HJ, Hung HW, Yan YH, *et al.*: Risk factors for blood transfusion in singleton pregnancy deliveries in Taiwan. *Int J Gynaecol Obstet* 2012; **117**:124–127
20 Palo R, Ahonen J, Salo H, *et al.*: Transfusion of red blood cells: no impact on length of hospital stay in moderately anaemic parturients. *Acta Anaesthesiol Scand* 2007; **51**:565–569
21 Royal College of Obstetricians and Gynaecologists: Blood transfusion in obstetrics. Green-top Guideline No. 47. Royal College of Obstetricians and Gynaecologists. 2007.
22 National Centre for Classification in Health: *Australian classification of health interventions*. Sydney: National Centre for Classification in Health; 2006.
23 National Centre for Classification in Health: *Tabular list of diseases ICD 10 AM*. Sydney: National Centre for Classification in Health; 2006.
24 Pink B: Information Paper: An introduction to Socio-Economic Indexes for Areas (SEIFA) 2006. Australian Bureau of Statistics, 2008.
25 Roberts CL, Cameron CA, Bell JC, *et al.*: Measuring maternal morbidity in routinely collected health data: development and validation of a maternal morbidity outcome indicator. *Med Care* 2008; **46**:786–794
26 Hadfield RM, Lain SJ, Cameron CA, *et al.*: The prevalence of maternal medical conditions during pregnancy and a validation of their reporting in hospital discharge data. *Aust N Z J Obstet Gynaecol* 2008; **48**:78–82
27 Lain SJ, Roberts CL, Hadfield RM, *et al.*: How accurate is the reporting of obstetric haemorrhage in hospital discharge data? A validation study. *Aust N Z J Obstet Gynaecol* 2008; **48**:481–484
28 Roberts CL, Bell JC, Ford JB, *et al.*: Monitoring the quality of maternity care: how well are labour and delivery events reported in population health data? *Paediatr Perinat Epidemiol* 2009; **23**:144–152
29 Taylor LK, Travis S, Pym M, *et al.*: How useful are hospital morbidity data for monitoring conditions occurring in the perinatal period? *Aust N Z J Obstet Gynaecol* 2005; **45**:36–41
30 MacNab YC, Qiu Z, Gustafson P, *et al.*: Hierarchical Bayes analysis of multilevel health services data: a Canadian neonatal mortality study. *Health Serv Outcomes Res Method* 2004; **5**:5–26
31 Jakobsson M, Gissler M: Tapper AM: risk factors for blood transfusion at delivery in Finland. *Acta Obstet Gynecol Scand* 2013; **92**:414–420
32 Ehrenthal DB, Chichester ML, Cole OS, *et al.*: Maternal risk factors for peripartum transfusion. *J Womens Health* 2012; **21**:792–797
33 Mhyre JM, Shilkrut A, Kuklina EV, *et al.*: Massive blood transfusion during hospitalization for delivery in New York State, 1998–2007. *Obstet Gynecol* 2013; **122**:1288–1294
34 The Royal Australian and New Zealand College of Obstetricians and Gynaecologists: Management of Postpartum Haemorrhage (PPH). The Royal Australian and New Zealand College of Obstetricians and Gynaecologists. 2011.
35 Olive EC, Roberts CL, Algert CS, *et al.*: Placenta praevia: maternal morbidity and place of birth. *Aust N Z J Obstet Gynaecol* 2005; **45**:499–504
36 Sapere Research Group: Analysis of cost drivers and trends in the blood sector. Options to manage appropriate use of blood and blood products. Sapere Research Group. 2011.
37 So-Osman C, Cicilia J, Brand A, *et al.*: Triggers and appropriateness of red blood cell transfusions in the postpartum patient–a retrospective audit. *Vox Sang* 2010; **98**:65–69
38 Carson JL, Carless PA, Hebert PC: Transfusion thresholds and other strategies for guiding allogeneic red blood cell transfusion. *Cochrane Database Syst Rev*. 2012;**4**: CD002042.
39 Silverman JA, Barrett J, Callum JL: The appropriateness of red blood cell transfusions in the peripartum patient. *Obstet Gynecol* 2004; **104**:1000–1004
40 Prick BW, Jansen AJG, Steegers EAP, *et al.*: Transfusion policy after severe postpartum haemorrhage: a randomised non-inferiority trial. *BJOG* 2014; **121**:1005–1014

Supporting Information

Additional Supporting Information may be found in the online version of this article:
Appendix S1. Variables considered in multilevel logistic regression model exploring risk factors for blood transfusion in the birth admission, by level of model.