Factors affecting perioperative blood loss and transfusion rates in primary total joint arthroplasty: a prospective analysis of 1642 patients

Timothy H. Bell, MD*
Donna Berta, RN†
Fiona Ralley, MD†
Steven J. MacDonald, MD*
Richard W. McCalden, MD*
Robert B. Bourne, MD*
Cecil H. Rorabeck, MD*
Douglas D.R. Naudie, MD*

From the *Division of Orthopaedic Surgery and the †Department of Anesthesia, University of Western Ontario, London, Ont.

Accepted for publication
Sep. 19, 2008

Correspondence to:
Dr. D.D.R. Naudie
London Health Sciences Centre
University Campus, A9-208
339 Windermere Rd.
London ON N6A 5A5
fax 519 663-3420
douglas.naudie@lhsc.on.ca

Background: In recent years, the use of low molecular weight heparins such as dalteparin has become attractive because of their ease of administration and superiority in preventing venous thromboembolism (VTE) compared with traditional agents. The primary purpose of our study was to evaluate the impact of dalteparin use on blood loss and transfusion rates in patients undergoing primary total joint arthroplasty. We also evaluated the effect of patient sex, releasing the tourniquet in knee arthroplasty and the turnover of house staff.

Methods: Using our hospital transfusion database, we prospectively studied the mean reduction in hemoglobin and transfusion rates of 1642 consecutive patients who underwent primary total hip arthroplasty (THA) or total knee arthroplasty (TKA) between January 2004 and December 2005. In 2004, warfarin was used exclusively for VTE prevention; however, in 2005, following the release of the 2004 American College of Chest Physicians' guidelines, our centre began using dalteparin for VTE prophylaxis. We analyzed the impact of dalteparin use and the effect of patient sex, tourniquet release in TKA and house staff turnover months on blood loss and transfusion rates.

Results: The use of dalteparin for postoperative VTE prevention in patients undergoing THA and TKA in 2005 was associated with a significantly greater mean reduction in hemoglobin compared with warfarin use in 2004 ($p = 0.014$ for patients undergoing THA, $p < 0.001$ for patients undergoing TKA). The use of dalteparin in 2005 was not associated with a significant increase in allogeneic blood transfusions compared with the use of warfarin in 2004, except in women ($p < 0.001$). Although we observed no significant differences in mean reduction in hemoglobin between men and women undergoing THA, women undergoing THA had significantly higher transfusion rates regardless of the method of VTE prophylaxis ($p = 0.037$ for warfarin, $p < 0.001$ for dalteparin). Intraoperative tourniquet release in patients undergoing TKA was associated with a significantly lower mean reduction in hemoglobin than release after wound closure ($p = 0.005$). Although house staff turnover months were associated with a significantly greater mean reduction in hemoglobin levels than nonturnover months ($p = 0.039$), these months were not associated with a significant increase in allogeneic blood transfusions ($p = 0.59$).

Conclusion: Low molecular weight heparins such as dalteparin are the most common form of VTE prophylaxis in Canada. Our results suggest that dalteparin use, timing of tourniquet release and house staff turnover can all influence transfusion rates and/or blood loss in patients undergoing primary total joint arthroplasty. This study also emphasizes that women undergoing THA are at particularly high risk for blood transfusion.

Contexte : Depuis quelques années, le recours aux héparines de bas poids moléculaire, comme la daltéparine, a gagné en popularité à cause de leur facilité d'administration et de leur plus grande efficacité à prévenir la thromboembolie veineuse (TEV), comparativement aux agents classiques. Notre étude avait pour objectif principal d'évaluer l'impact du recours à la daltéparine sur les pertes sanguines et les taux de transfusions chez les patients soumis à une arthroplastie pour prothèse articulaire totale. Nous avons aussi mesuré l'effet du sexe des patients, du desserrement du garrot posé lors de l'arthroplastie du genou et du roulement des internes et des résidents.

Méthodes : À partir de la base de données sur les transfusions de notre établissement, nous avons étudié de façon prospective la réduction moyenne des taux d'hémoglobine et les taux de transfusions chez 1642 patients consécutifs soumis à une

arthroplastie totale de la hanche (ATH) ou du genou (ATG) entre janvier 2004 et décembre 2005. En 2004, la warfarine servait exclusivement à la prévention de la TEV; toutefois, en 2005, après la diffusion des directives de 2004 de l'*American College of Chest Physicians*, notre centre a commencé à utiliser la daltéparine en prophylaxie de la TEV. Nous avons analysé l'impact du recours à la daltéparine et l'effet du sexe des patients, du desserrement du garrot dans l'ATG et des mois de roulement des internes et des résidents de l'établissement sur les pertes sanguines et les taux de transfusions.

Résultats : En 2004, le recours à la daltéparine en prévention post-opératoire de la TEV chez des patients soumis à une ATH ou à une ATG en 2005 a été associé à une réduction moyenne significativement plus grande du taux d'hémoglobine que le recours à la warfarine (p = 0,014 pour les patients soumis à une ATH; p < 0,001 pour les patients soumis à une ATG). On n'a établi aucun lien entre le recours à la daltéparine en 2005 et une augmentation significative des transfusions de sang allogènes, comparativement au recours à la warfarine en 2004, sauf chez les femmes (p < 0,001). Bien que nous n'ayons observé aucune différence significative quant à la réduction moyenne du taux d'hémoglobine entre les hommes et les femmes soumis à une ATH, les femmes qui ont subi ce type d'intervention présentaient des taux significativement plus élevés de transfusions, peu importe le mode de prophylaxie de la TEV (p = 0,037 pour la warfarine, p < 0,001 pour la daltéparine). On a établi un lien entre le desserrement peropératoire du garrot chez les patients soumis à une ATG et une réduction moyenne significativement moindre du taux d'hémoglobine, contrairement au desserrement du garrot suivant la fermeture de la plaie (p = 0,005). Bien que l'on ait établi un lien entre les mois de roulement des internes et des résidents et une réduction moyenne significativement plus marquée des taux d'hémoglobine comparativement aux mois où il n'y avait pas de roulement (p = 0,039), on n'a pas associé ces mois à une augmentation significative des transfusions de sang allogéniques (p = 0,59).

Conclusion : Les héparines de bas poids moléculaire, comme la daltéparine, sont les agents les plus couramment employés en prophylaxie de la TEV au Canada. Selon nos résultats, le recours à la daltéparine, le moment du desserrement du garrot et le roulement des internes et des résidents peuvent tous influer sur les taux de transfusions et sur les pertes sanguines chez les patients soumis à une première arthroplastie articulaire totale. Cette étude rappelle également que les femmes qui subissent une ATH sont exposées à un risque particulièrement élevé de transfusions sanguines.

Blood loss in patients undergoing total joint replacement surgery can be substantial. Studies have demonstrated that blood loss can approximate 2000 mL for a primary joint replacement.[1–3] As a result of blood loss, acute anemia can ensue, which is not without consequence. Tachycardia, hypotension and an increased risk of perioperative myocardial infarction are documented complications of perioperative anemia.[4,5] Furthermore, patients found to have acute anemia often require blood transfusions. Transmission of viral pathogens, anaphylaxis, acute lung injury and septic reaction to bacterial toxins are known adverse events associated with blood transfusions.[6] Previous studies have also demonstrated higher rates of deep joint infections following transfusions of allogeneic blood.[7] To avoid such complications, efforts have been made to identify factors contributing to perioperative anemia to decrease the need for blood transfusions.

There are many factors contributing to perioperative anemia. Patient factors, surgeon factors and the method of thromboprophylaxis to prevent venous thromboembolic events (VTEs) have all been implicated;[8,9] VTE prophylaxis for total joint replacement has received much attention in recent years. The use of low molecular weight heparins has become attractive because of their ease of administration and superiority in preventing VTE compared with traditional agents.[10] In November 2004, the American College of Chest Physicians (ACCP) released guidelines for the prevention of VTE in patients undergoing total joint replacement.[11] In 2005, as a result of these recommendations, our centre initiated the routine use of dalteparin (Fragmin) to prevent VTE perioperatively. Prior to 2005, we used warfarin (Coumadin). In clinical practice, we perceived an increase in blood transfusion rates since introducing dalteparin for VTE prevention in our primary arthroplasty practice. The purpose of our study was 2-fold. First, we wanted to evaluate the impact of routine dalteparin use on blood loss and transfusion rates in our primary hip and knee arthroplasty population. Second, we sought to identify any differences in perioperative blood loss and transfusion rates as a result of patient sex, individual surgeons and house staff turnover months.

Methods

Since 1985, all total joint replacements performed at our centre have been recorded in a computerized total joint registry database. In January 2004, a hospital transfusion database was created as part of a provincial blood conservation initiative, and maintained by a nurse coordinator.[12] We reviewed the transfusion data on consecutive patients

undergoing primary total hip and total knee arthroplasties in 2004 and 2005. We excluded patients undergoing revision arthroplasties and bilateral arthroplasty surgeries. Five orthopedic surgeons (D.N., S.M., R.M., R.B., C.R.) were responsible for all of the primary surgeries reviewed.

From January 2004 to December 2004, warfarin was used exclusively in our centre for VTE prevention. During this time period, patients received 10 mg of warfarin the evening before surgery. We followed a daily dosing regimen on subsequent days with a goal to achieve an inter-national normalized ratio between 1.8 and 2.2. We discontinued warfarin at the time of discharge if a screening Doppler ultrasound was negative before discharge from hospital.

With the release of the 2004 ACCP guidelines, our centre began exclusively using dalteparin for VTE prophylaxis.[11] This change took effect on Jan. 1, 2005. As per the ACCP guidelines, patients received 5000 IU of dalteparin subcutaneously for 10 days beginning on postoperative day 1.[11] High-risk patients received dalteparin for 28 days postoperatively, as per the ACCP guidelines.

From the database, we identified the pre- and postoperative hemoglobin levels for all primary arthroplasty patients treated during the 2-year study period. Preoperative hemoglobin levels were drawn before (within 30 days) surgery as part of a preadmission process. Postoperative hemoglobin levels were routinely drawn as part of a complete blood cell count on postoperative days 1 and 3. We calculated the mean reduction in hemoglobin by subtracting the lowest mean postoperative hemoglobin level from the mean preoperative hemoglobin level. We then identified all patients who received blood transfusions, and we recorded the number of units transfused. We used SPSS 14.0 (SPSS Inc.) for our statistical analyses, and we performed Fisher exact tests and χ^2 analysis. We set the level of significance at $p < 0.05$.

Table 1. Hemoglobin levels of patients undergoing primary arthroplasty between Jan. 1, 2004, and Dec. 31, 2005

	Drug; mean (SD)		
Hemoglobin, g/L	Warfarin*	Dalteparin†	*p* value
Overall			
Preoperative level	137.96 (13.85)	139.49 (13.30)	0.023
Women	135.37 (12.88)	134.91 (11.45)	0.56
Men	141.93 (14.35)	146.39 (12.93)	< 0.001
Postoperative level‡	94.67 (14.13)	93.30 (12.99)	0.041
Women‡	93.20 (12.41)	90.80 (11.96)	0.002
Men‡	96.91 (16.18)	97.06 (13.57)	0.90
Total hip arthroplasty			
Preoperative level	138.33 (15.18)	138.88 (13.84)	0.62
Women	134.88 (14.43)	133.58 (11.61)	0.34
Men	142.61 (15.04)	145.70 (13.51)	0.06
Postoperative level‡	94.79 (14.50)	92.72 (13.74)	0.05
Women‡	91.30 (11.88)	88.39 (12.31)	0.019
Men‡	99.12 (16.23)	98.30 (13.51)	0.63
Total knee arthroplasty			
Preoperative level	137.69 (12.79)	139.95 (12.87)	0.007
Women	135.68 (11.80)	135.81 (11.26)	0.88
Men	141.30 (13.71)	147.01 (12.39)	< 0.001
Postoperative level‡	94.58 (13.86)	93.74 (12.38)	0.33
Women‡	94.41 (12.60)	92.44 (11.45)	0.046
Men‡	94.88 (15.91)	95.96 (13.57)	0.50

SD = standard deviation.
*Administered to patients undergoing primary arthroplasty between Jan. 1, 2004 and Dec. 31, 2004.
†Administered to patients undergoing primary arthroplasty between Jan. 1, 2005, and Dec. 31, 2005.
‡The lowest postoperative hemoglobin level taken from either postoperative day 1 or 3. The lowest hemoglobin level was chosen.

RESULTS

From January 2004 to December 2005, 1642 primary total joint replacements were performed at our centre. Of these, 939 patients had total knee replacements and 703 had total hip replacements. The mean preoperative and postoperative hemoglobin levels for all primary arthroplasty patients are provided in Table 1.

Transfusion rates for patients who received warfarin and patients who received dalteparin are provided in Table 2. There was no significant difference in the overall transfusion rate in 2004 when warfarin was used for VTE prophylaxis compared with that in 2005 when dalteparin was used (20.4% v. 22.0%; $p = 0.47$). There was no difference in the percentage of men and women who received a transfusion between the warfarin and dalteparin groups. The average number of units of blood transfused was 2. There was no difference in the number of units of blood transfused in 2004 compared with 2005 ($p = 0.41$).

We evaluated the mean reduction in hemoglobin per year (Table 3). There was a significantly greater reduction in mean hemoglobin in 2005 compared with 2004 (46.1, standard deviation [SD] 13.8 v. 43.2, SD 14.5; $p < 0.001$). Analysis of the total hip (43.51, SD 14.5 v. 46.15, SD 13.8; $p = 0.014$) and knee (43.1, SD 14.1 v. 46.21, SD 13.1; $p < 0.001$) arthroplasty subgroups also revealed a significantly greater reduction between years.

We also evaluated the impact of sex on transfusion rates and the mean reduction in hemoglobin. Overall, women demonstrated lower preoperative and postoperative hemoglobin levels compared with men in both the hip and knee subgroups (Table 1). More women than men (241/989,

Table 2. Transfusion rates among patients undergoing primary arthroplasty who received warfarin and those who received dalteparin, by sex

	Drug; tranfusion rate (%)*		
Group	Warfarin†	Dalteparin‡	*p* value
Total	150/734 (20.4)	200/908 (22.0)	0.47
Men	53/291 (18.2)	56/362 (15.5)	0.34
Women	97/443 (21.9)	144/546 (26.4)	0.12

*Determined by number of patients receiving transfusion divided by the total number of patients undergoing primary arthroplasty.
†Administered to patients undergoing primary arthroplasty between Jan. 1, 2004, and Dec. 31, 2004.
‡Administered to patients undergoing primary arthroplasty between Jan. 1, 2005, and Dec. 31, 2005.

24% v. 109/653, 17%) in our total joint population received transfusions, regardless of the agent used for VTE prevention ($p < 0.001$; Table 4).

We evaluated sex differences for each method of VTE prevention. In 2004 when warfarin was used, we observed no differences in overall transfusion rates between men and women ($p = 0.26$), nor did we observe any differences in transfusion rates between men and women undergoing TKA ($p = 1.00$). However, we observed a significant difference in transfusion rates among women undergoing THA ($p = 0.037$) compared with men having that procedure when warfarin was used in 2004. In 2005, when dalteparin was used, significantly more women than men overall received transfusions ($p < 0.001$), and significantly more women than men undergoing THA received transfusions ($p < 0.001$). We observed no difference in transfusion rates between women and men undergoing TKA in 2005 ($p = 0.09$).

We also observed differences between men and women in the mean reduction in hemoglobin. Men undergoing total knee arthroplasty had a greater reduction in mean hemoglobin than women having that procedure in both the warfarin and dalteparin groups ($p < 0.001$; Table 5). We observed no sex differences in the mean reduction in hemoglobin among patients undergoing total hip arthroplasties in either the warfarin ($p = 0.93$) or dalteparin groups ($p = 0.12$).

We evaluated perioperative blood loss among patients based on the treating surgeon. We noted no differences in the total hip arthroplasty subgroup ($p = 0.32$). However, we did observe intersurgeon differences in the total knee arthroplasty subgroup. Differences in perioperative blood loss were dependent on the timing of pneumatic tourniquet release. Two of the surgeons routinely released the tourniquet intraoperatively before wound closure; the remaining 3 surgeons released the tourniquet after closure. The mean reduction in hemoglobin was significantly greater when the tourniquet was released after closure compared with intraoperative release (47.4m, SD 11.3 v. 43.9, SD 10.1; $p = 0.005$; Table 6). There was no difference in the overall transfusion rate between the groups ($p = 0.68$).

We analyzed the impact of house staff (i.e., residents and fellows) turnover on perioperative blood loss. House staff turnover occurred every 3 months. We scrutinized those months when house staff turnover occurred and compared them to nonturnover months. The mean

Table 3. Comparison of the mean reduction in hemoglobin between patients undergoing primary arthroplasty who received warfarin and those who received dalteparin

	Drug; mean (SD)		
Hemoglobin, g/L	Warfarin*	Dalteparin†	*p* value
Preoperative level	137.97 (13.8)	139.49 (13.3)	0.023
Postoperative level	94.67 (14.1)	93.30 (13.0)	0.041
Drop			
Total	43.20 (14.5)	46.10 (13.8)	< 0.001
Hip arthroplasty group	43.51 (14.5)	46.15 (13.8)	0.014
Knee arthroplasty group	43.10 (14.1)	46.21 (13.1)	< 0.001

SD = standard deviation.
*Administered to patients undergoing primary arthroplasty between Jan. 1, 2004, and Dec. 31, 2004.
†Administered to patients undergoing primary arthroplasty between Jan. 1, 2005, and Dec. 31, 2005.

Table 4. Sex comparison of transfusion rates in patients undergoing primary arthroplasty, by drug

Drug; group	Men	Women	*p* value
Combined transfusion rates, %	109/653	241/989	< 0.001
Warfarin*			
Transfusion rate, %			
Total	53/291	97/443	0.26
Hip arthroplasty group	27/140	51/172	0.037
Knee arthrplasty group	26/151	46/271	1.00
Dalteparin†			
Transfusion rate, %			
Total	56/362	144/546	< 0.001
Hip arthroplasty group	26/171	72/220	< 0.001
Knee arthrplasty group	30/191	72/326	0.09

SD = standard deviation.
*Administered to patients undergoing primary arthroplasty between Jan. 1, 2004, and Dec. 31, 2004.
†Administered to patients undergoing primary arthroplasty between Jan. 1, 2005, and Dec. 31, 2005.

Table 5. Sex comparison for mean reduction in hemoglobin among patients undergoing primary arthroplasty who received warfarin and those who received dalteparin

Drug; group	Men	Women	*p* value
Warfarin,* no. patients	291	443	
Reduction in hemoglobin, mean (SD) g/L			
Total	44.98 (16.1)	42.16 (12.96)	0.013
Hip arthroplasty group	43.44 (16.26)	43.58 (13.08)	0.93
Knee arthrplasty group	46.42 (15.87)	45.19 (14.15)	< 0.001
Dalteparin,† no. patients	362	546	
Reduction in hemoglobin, mean (SD) g/L			
Total	49.33 (13.13)	44.11 (13.17)	< 0.001
Hip arthroplasty group	47.40 (13.47)	45.19 (14.15)	0.12
Knee arthrplasty group	51.05 (12.61)	43.38 (12.44)	< 0.001

SD = standard deviation.
*Administered to patients undergoing primary arthroplasty between Jan. 1, 2004, and Dec. 31, 2004.
†Administered to patients undergoing primary arthroplasty between Jan. 1, 2005, and Dec. 31, 2005.

reduction in hemoglobin was greater during months of house staff turnover compared with nonturnover months (47.1, SD 10.3 v. 44.5, SD 11.1; $p = 0.039$). There was no difference in overall blood transfusions between turnover and nonturnover months ($p = 0.59$).

Discussion

Low molecular weight heparins are the most common form of VTE prophylaxis in Canada.[13] Many studies have evaluated their use compared with warfarin in patients undergoing total joint replacement surgery.[10,14,15] To our knowledge only 2 of these studies have specifically evaluated the use of dalteparin.[10,14]

The North American Fragmin Study by Hull and colleagues[10] involved 1501 patients undergiong total hip arthroplasty (both primary and revision arthroplasty). They conducted a randomized double-blind trial comparing subcutaneous dalteparin sodium and warfarin sulfate. The overall rate of proximal deep vein thrombosis formation was significantly reduced in the dalteparin sodium group compared with the warfarin sulfate group.[10] They found a significant increase in overall transfusion rates and a mean reduction in hemoglobin with the routine use of dalteparin sodium.

Francis and colleagues[14] conducted a randomized double-blind trial of 580 patients undergoing primary or revision total hip arthroplasty comparing subcutaneous dalteparin and warfarin. Although the primary purpose of their study was to assess any differences in the prevalence of deep vein thromboses between groups, these authors could not detect a significant difference with regard to the intraoperative and postoperative blood loss, the decrease in hematocrit and the prevalence of major bleeding complications between the 2 groups. However, they do report that patients who had received dalteparin had a significantly higher prevalence of bleeding complications involving the operative site ($p = 0.030$), and a significantly greater percentage required postoperative transfusions ($p = 0.001$). Another study that has used other low molecular weight heparins found similar trends.[16]

In contrast to the aforementioned trials, we did not find a significant difference in the overall transfusion rate at our centre since the routine use of dalteparin sodium came into effect ($p = 0.47$). A number of factors may have accounted for this. First, our study exclusively evaluated primary joint arthroplasties. Studies have demonstrated significantly greater blood loss during revision surgery because of prolonged operative time and the need for extensile exposure.[17] Second, the timing of VTE prophylaxis has been shown to influence blood loss.[18] We chose to administer dalteparin sodium at least 12 hours after surgery to reduce the risk of bleeding complications, which may have lead to a decrease in overall transfusion rates. In the North American Fragmin Trial,[10] 2 treatment regimens were used. In one arm of the study, 2500 IU of dalteparin (Fragmin) was administered within 3 hours of surgery, followed by a second dose of 2500 IU at least 4 hours postoperatively. In the second arm, patients received a placebo before surgery and then an active injection of 2500 IU of dalteparin 4 hours postoperatively. A daily dosing regimen of 5000 IU each subsequent morning followed. In the study by Francis and colleagues,[14] patients received dalteparin beginning 2 hours before the operation and continued until venography was performed. The early administration of dalteparin in these studies may have further contributed to the increased transfusion rates found.

Our study reviewed both total hip and knee arthroplasties. We feel this is a more accurate representation of actual practice in Canada. Current statistics indicate that knee replacements account for 57% of all joint replacements performed in Canada, whereas hip replacements account for 43%.[13] Furthermore, 88% of all joint replacements are primary arthroplasties.[13] Our subgroup analysis did not reveal a significant increase in transfusion rates in either the TKA ($p = 0.31$) or THA ($p = 0.98$) cohorts. Both demonstrated an increase in the mean reduction in hemoglobin compared with warfarin ($p = 0.014$ for TKA, $p < 0.001$ for THA).

Hull and colleagues[10] demonstrated an overall transfusion rate of 39%, and other studies have demonstrated similar rates. The rate observed in our study was significantly less, measuring about 20%. We felt that this improved transfusion rate was for 2 reasons. First, the cohorts in the studies of Hull and colleagues[10] and Francis and colleagues[14] included patients undergoing revision arthroplasties which, as discussed, are more likely to require blood transfusions. Second, we believe that our "transfusion trigger" has changed. Blood conservation programs have become popular throughout North America. At our centre, we have adopted guidelines to reduce the number of allogeneic blood transfusions through the use of a clinical pathway. Adherence to these guidelines may have lowered our threshold for transfusion and may potentially explain why the mean reduction in hemoglobin levels was not associated with increased transfusion rates. The former is an objective measure of blood loss and the latter a subjective decision to transfuse.

Although the mean reduction in hemoglobin in our study was statistically significant ($p < 0.001$), the clinical importance remains unclear. The overall mean difference was 3 g/L, and it is unclear if such a small difference in the reduction in hemoglobin is clinically important. Certainly this did not translate into a higher transfusion rate in our study.

Table 6. Impact of the timing of the pneumatic tourniquet release on the mean reduction in hemoglobin inpatients undergoing primary arthroplasty

Tourniquet release	Hemoglobin drop, mean (SD) g/L	*p* value
Intraoperative tourniquet release	43.9 (10.1)	
Release after wound closure	47.4 (11.3)	0.005

SD = standard deviation.

Previous studies have evaluated the impact of sex on blood transfusion requirements.[19,20] Churchill and colleagues[20] evaluated blood product utilization in patients undergoing hip and knee surgery. They found that women were more likely than men to receive transfusions. This sex difference has also been observed in other surgical specialties such as cardiac surgery. Our study is in agreement with these findings. Overall, when we combined results for both the warfarin and dalteparin groups, we found that the transfusion rate was significantly higher among women than men ($p < 0.001$). When we analyzed the warfarin and dalteparin groups individually, however, overall transfusion rates were significantly greater among only among women who received dalteparin compared with warfarin (Table 4). When we further analyzed THA and TKA transfusion rates among men and women according to the method of prophylaxis, THA transfusion rates were significantly higher among women, regardless of whether warfarin or dalteparin was administered. We observed no statistical differences among women in the TKA subgroup in either 2004 when warfarin was used ($p = 1.00$) or in 2005 when dalteparin was used for VTE prevention ($p = 0.09$).

One explanation for the increase in blood transfusion requirements in women is related to preoperative hemoglobin levels. In our study, women had lower hemoglobin concentrations than men. Nuttal and colleagues,[21] in a retrospective review of 266 patients undergoing total joint arthroplasty, noted that the preoperative hemoglobin level was the most important factor predicting the need for a postoperative allogeneic blood transfusion. Thus, women may be more predisposed to blood transfusion because their preoperative hemoglobin levels are generally lower than those of men.

The use of tourniquets during total knee arthroplasty reduces perioperative blood loss.[22] All surgeons involved in our study used pneumatic tourniquets for hemostasis and to create a bloodless field for cementing their implants. This may explain our finding that there were no sex differences in allogeneic transfusion requirements during total knee arthroplasty, and a significant difference between women and men in our total hip arthroplasty population (Table 4).

The only intersurgeon difference detected related to the timing of tourniquet release. We found a significantly greater degree of perioperative blood loss when the tourniquet was released after closure compared with intraoperative release. The literature regarding the optimal timing of tourniquet release is varied. A recent meta-analysis by Rama and colleagues[22] described benefits to both practices. They found that intraoperative tourniquet release allowed superior hemostatic control of major bleeding events that would have otherwise lead to a reoperation. They concluded that intraoperative tourniquet release was associated with a lower need for reoperation.

We also evaluated the impact of house staff turnover on blood loss. House staff turnover was not associated with an overall increase in allogeneic blood transfusions ($p = 0.66$). However, there was a significant increase in the mean reduction in hemoglobin during house staff turnover months ($p = 0.039$). The clinical importance of this finding also remains unclear. To our knowledge no studies have looked at the impact of surgical house staff on blood loss. There may be a learning curve during the early weeks of a new house staff rotation contributing to this trend. Moreover, house staff may not be completely familiar with staff preferences regarding intraoperative hemostasis, and as a result covert blood loss may occur. Regardless, every effort should be made to educate new house staff on methods to reduce blood loss and on transfusion guidelines.

Our study has several strengths: the major strength is the fact that it derives from a prospectively collected database of all arthroplasty patients, with documented hemoglobin levels and transfusion rates. Furthermore, our study population was larger than any previous study evaluating dalteparin sodium and warfarin sulfate. Moreover, we looked exclusively at a primary arthroplasty cohort.

We fully acknowledge several limitations to the current study. Foremost, we recognize that this is a database study and thus subject to the inherent limitations of the quality of data collected. We also recognize that we used the mean reduction in hemoglobin as a surrogate marker for blood loss. Other factors may have led to a reduction in the mean hemoglobin, including hemodilution from perioperative fluid resuscitation and the type of anesthetic that was used. Neuroaxial anesthesia has been associated with less perioperative blood loss in patients undergoing total knee and total hip arthroplasties than general anesthesia.[23,24] Most patients at our institution receive regional spinal anesthesia for primary joint replacement surgery.

Our study was restricted to quantifying blood loss through the mean reduction in hemoglobin and blood transfusion requirements. Other issues, such as wound hematomas and infection were beyond the scope of our study. We feel that the routine use of dalteparin has lead to a perceived increase in wound complications. Both Hull and colleagues[10] and Francis and colleagues[14] noted an increase in wound hematomas and surgical site complications with the routine use of dalteparin compared with warfarin. Further studies are needed to better address these issues.

Finally, we were not able to evaluate the effectiveness of either regimen in preventing VTE in postoperative orthopaedic patients. Extensive guidelines have been developed to evaluate these issues.[11] The effectiveness of either warfarin or dalteparin on preventing venous thromboembolic events was not a goal of this study; there are other excellent resources on this topic.[10,11,14]

CONCLUSION

In summary, the use of dalteparin for postoperative VTE prevention in patients undergoing primary total knee

and hip arthroplasties in 2005 was associated with a significantly greater mean reduction in hemoglobin compared with warfarin use in such patients in 2004. The use of dalteparin in 2005 was not associated with a significant increase in allogeneic blood transfusions compared with the use of warfarin in 2004, except in women. Although we observed no significant differences in the mean reduction in hemoglobin between men and women undergoing THA, women undergoing THA had significantly higher transfusion rates, regardless of the method of VTE prophylaxis. Intraoperative tourniquet release in patients undergoing TKA was associated with a significantly lower mean reduction in hemoglobin than release after wound closure. Although house staff turnover months were associated with a significantly greater mean reduction in hemoglobin levels than nonturnover months, these months were not associated with a significant increase in allogeneic blood transfusions. Taken together, our findings suggest that dalteparin use as VTE prophylaxis, timing of tourniquet release and house staff turnover can all significantly influence blood loss or transfusion rates in patients undergoing primary total joint arthroplasty. Our study also emphasizes that women undergoing total hip arthroplasty are at particularly high risk for blood transfusion.

Competing interests: None declared.

Contributors: Drs. Bell, Ralley and Naudie and Ms. Berta designed the study and analyzed the data, which all authors acquired. Drs. Bell and Naudie wrote the article, which all other authors reviewed. All authors approved the final version for publication.

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