Joint Implant Surgery & Research Foundation
Chagrin Falls, Ohio, USA

Strategies to Decrease Blood Loss in Patients Who Undergo Total Knee Replacement: A Prospective Study of One Hundred and Fifty Cases

Nilen A. Shah, MBBS, D. Orth., MS Orth. (Bombay, India), MCh Orth. (Liverpool, U.K.)†, Anand Gupta, DNB Orth.§, and Dipak V. Patel, MD (USA), MSc Orth. (London, U.K.), MS Orth., D. Orth., FCPS Orth. (Bombay, India)¥

Abstract

We calculated the total blood loss in a non-randomized study of 150 total knee replacements which were performed under regional anaesthesia by a mini-subvastus surgical approach without the use of a tourniquet. In all knees, tranexamic acid was used perioperatively. The skin, subcutaneous tissue and joint capsule were infiltrated with saline adrenaline prior to making surgical incision. After cementing the prostheses, the surgical wound was packed alternately with hydrogen peroxide and Feracrylum-soaked packs for 3 minutes. Tourniquet and postoperative drain were not used in any of the knees. In our series, the mean perioperative blood loss was 433 mL (SD 74), the mean RBC volume loss was 234 mL (SD 40.4), and the mean reduction in hemoglobin level was 1.6 gm/dL. The mean preoperative hemoglobin was 12.01gm/dL (SD 1.4) and the mean postoperative hemoglobin was 10.4 gm/dL (SD 1.4). The mean preoperative hematocrit was 37.04 (SD 2.8) and the mean postoperative hematocrit was 31.29 (SD 2.7). One of our patients developed cerebral thromboembolism three days after the surgery. Postoperative hemoglobin of less then 8 g/dL was considered an indication for blood transfusion; however, none of our patients required blood transfusion in the present series.

Study Design: *Therapeutic case series; Level of Evidence, IV.*

Keywords: *Tranexamic acid; Antifibrinolytic agent; Decreased blood loss; Total knee arthroplasty*

Introduction

Total knee arthroplasty is associated with postoperative blood loss necessitating allogeneic blood transfusion in 10% to 38% of patients [1-4]. The reported amounts of blood loss have ranged from 1,450 to 1,790 mL [5-9]. It is well known that allogeneic blood transfusion carries the risk of immunological and non-immunological adverse effects (such as a higher rate of postoperative infections and transmission of diseases), and furthermore has a high medical cost.

Several techniques are available to minimize

† Orthopaedic and Joint Replacement Consultant
Bombay Hospital and Medical Research Centre
Maharashtra, India
§ Consultant Orthopaedic Surgeon
Bombay Hospital, Indore, India
¥ Clinical Professor of Orthopaedic Surgery
Seton Hall University, South Orange, NJ U.S.A.

the blood loss and decrease the likelihood of allogeneic blood transfusion after a total knee replacement. These techniques include pre-operative iron and erythropoietin administration where indicated, use of tranexamic acid perioperatively, infiltrating saline adrenalin intra-operatively, not using post-op drains or clamping the drain periodically, not using the tourniquet, and use of fibrin spray or glue.

The objective of this study is to evaluate the combined effectiveness of pharmacological and non-pharmacological measures to control perioperative blood loss. In the past, different studies have shown a decrease in blood loss in total knee replacement , whilst employing some specific means e.g. perioperative use of tranexamic acid, [10-13] use of mini-invasive surgical approach, [14-16] use of regional anaesthesia, [17] use of saline-adrenaline infiltration, [18] use of hydrogen peroxide, [19] and use of Feracrylum-soaked packs [20,21]. However, we could not identify a single study in which different measures were utilized simultaneously to study their combined effect on blood loss. We wanted to evaluate if by combining the various known factors we would be able to demonstrate a synergistic effect on blood conservation.

Materials and Methods

Patients –A non-randomized study was carried out on 150 total knee replacements for the treatment of osteoarthritis of the knee joint at three institutes in Bombay (now known as Mumbai), India from March 2007 to May 2008. The lead author (N.A.S.) of this paper is in private practice and considers it unethical to have a control group as the current regime is working so well. Our series is a cohort study. A retrospective analysis of prospectively collected data was performed.

Our series included only those patients who underwent unilateral total knee arthroplasty. Patients with unicompartmental replacement or bilateral total knee replacements were not included in this study. All surgeries were performed by a single surgeon (N.A.S.). Patients with a history of severe ischemic heart disease, chronic renal failure, cirrhosis of liver, and bleeding disorders, as well as those with past history of thromboembolic episode were excluded from this study. Thirty-seven patients in the present series were on anti-platelet drugs like aspirin. If aspirin was being taken at a dose greater than 75 mg, it was reduced to 75 mg but not stopped altogether. If the dose of aspirin was 75 mg, it was continued. The average age of the patients was 71.2 ± 4.5 years at the time of surgery. Table 1 shows the patient profile including the mean weight and height, which were 75.56 ± 9.6 kg and 160 ± 6.6 cm respectively.

Table 1. Patient profile and results.

1)	Age in years	71.2 ± 4.5
2)	Weight in kg	75 ± 9.6
3)	Height in cm	160 ± 6.6
4)	Male:Female	1.5:2
5)	Preoperative haemoglobin (gm/dL)	12.01 ± 2.7
6)	Postoperative haemoglobin (gm/dL)	10.4 ± 2.8
8)	Mean haemoglobin fall (gm/dL)	1.6 ± 0.6
9)	Preoperative haematocrit (%)	37 ± 5.6
10)	Postoperative haematocrit (%)	31 ± 5.4
11)	Mean total blood loss (mL)	433 ± 148

The baseline hemoglobin level, haematocrit, and coagulation profile with platelet counts were measured preoperatively. The hemoglobin and haematocrit values were checked again on fifth postoperative day. The mean reduction in hemoglobin was calculated by subtracting the mean postoperative hemoglobin level from the mean preoperative hemoglobin level.

Use of Tranexamic Acid

At the time surgery, tranexamic acid was given in the dose of 15 mg /kg intravenously 5 to 10 minutes before making the skin incision. Second dose (10 mg/kg intravenously) was repeated 3 hours after the first one, and the third and final dose (10 mg/kg intravenously) was given 3 hours after the second dose.

Surgical Procedure

All total knee replacements were performed by the same surgeon (N.A.S.) through a minimally invasive subvastus approach [16] under regional anaesthesia. Tourniquet was not used in any of the patients. Spinal anesthesia with Sensorcaine (0.5%) was used for all patients. All patients had 30 to 50 mL of saline with dilute adrenaline (1:300,000) infiltrated into the skin, subcutaneous tissues, and joint capsule before taking surgical incision. All patients underwent a mini-subvastus approach, and a L-shaped capsulotomy incision was made. Standard surgical techniques for intraoperative haemostasis were used. The NexGen and LPS High-flex cemented total knee endoprosthesis (Zimmer, U.S.A.) system was used for

all total knee replacements. After final implantation and prior to wound closure, the wounds were alternately packed with hydrogen peroxide and Feracrylum for three minutes. No surgical drains were used in our series.

Prophylactic antibiotic therapy consisted of intravenous administration of 1.5 gm of cephalosporin (cefuroxime) immediate preoperatively followed by 750 mg every 8 hour for 2 days postoperatively. None of the patients received any pharmacologic prophylaxis against venous thromboembolism but TED stockings were utilized postoperatively for 6 weeks. While in the hospital, patients were examined daily for any clinical symptoms of deep-vein thrombosis. All surgical and medical adverse events and any thromboembolic events occurring (if any) during the six weeks after surgery were recorded at the time of the follow-up visit with the surgeon. Femoral nerve catheter was inserted with the help of a nerve stimulator for postoperative pain control.

Assessment of intraoperative and postoperative blood loss

All patients had a complete blood count including haematocrit (Hct) before operation and on the fifth day after the procedure. By this time, the patients were haemodynamically stable and thus fluid shifts would have been largely completed. The height and weight were recorded preoperatively and the body mass index was calculated.

Calculation of Blood Loss

In our series, the patients' blood volume (PBV) was calculated using the formula of Nadler and colleagues [22].

$$PBV = k1 \times \text{height(m)}^3 + k2 \times \text{weight(kg)} + k3$$

where $k1 = 0.3669$, $k2 = 0.03219$, $k3 = 0.6041$ for men and $k1 = 0.3561$, $k2 = 0.03308$, $k3 = 0.1833$ for women

Multiplying the PBV by the haematocrit will give the total red cell volume. Any change in red cell volume can therefore be calculated from the change in haematocrit [7,23].

Total red blood cell (RBC) volume loss = PBV x (Hctpreop - Hctpostop) [7,23].

Every 100 ml of concentrated blood from the blood recovery system corresponded to 54 ml red cells.

As blood loss is occurring, the patient's circulating volume will tend to fall. However, simultaneous shift of fluid into the circulating compartment and fluid administered perioperatively maintains the circulating volume, although with increasingly more diluted blood (i.e. isovolaemic haemodilution), and the haematocrit gradually falls [7]. Consideration was given to the potential effect on calculation of this perioperative retention of fluid. Studies in cardiac surgery have demonstrated retention of approximately 2 Litres of fluid. Fluid retention in orthopaedic surgery has not been accurately studied but could perhaps be significant. Since only one-eighth of body water is in the circulating compartment (which is, on average, 5 Litres), even 2 Litres of retained fluid would amount to a maximum of 5% inaccuracy in our calculation with probably no bearing on our conclusions [7].

It has been proven and generally believed that direct blood loss estimation is not accurate and denotes much lesser blood loss than what is estimated by indirect methods. We have not estimated direct blood loss because we realized that when tourniquet is not being used there is a lot of spillage around the drapes and because a drain is not used in our series, there is ecchymosis in and around the knee region suggestive of blood loss occurring in the soft tissues later on.

Assessment of Deep-Vein Thrombosis

In our study, no routine postoperative duplex ultrasonography was undertaken for screening of postoperative venous thromboses and therefore, we are unable to comment on the true incidence of postoperative venous thromboses. However, we recorded the presence or absence of the Homans' sign and swelling of the legs for 6 weeks postoperatively. Homans' sign is a sign of deep vein thrombosis (DVT). A positive sign is present when there is resistance (not pain) in the calf or popliteal region with examiner's abrupt dorsiflexion of the patient's foot at the ankle while the knee is fully extended.

Results

In this non-randomized, study of 150 total knee arthroplasty patients, the results show significantly less blood loss with a mean perioperative blood loss of 433 mL ± 148 mL (SD 74). The distribution of patients in different range of blood loss is shown in Figure 1. The mean RBC volume loss was 234 mL (SD 40.4) and the mean reduction in hemoglobin level was 1.6 gm/dL. The mean preoperative hemoglobin was 12.01gm/dL (SD 1.4) and the mean postoperative hemoglobin was 10.4 gm/dL (SD 1.4). The mean

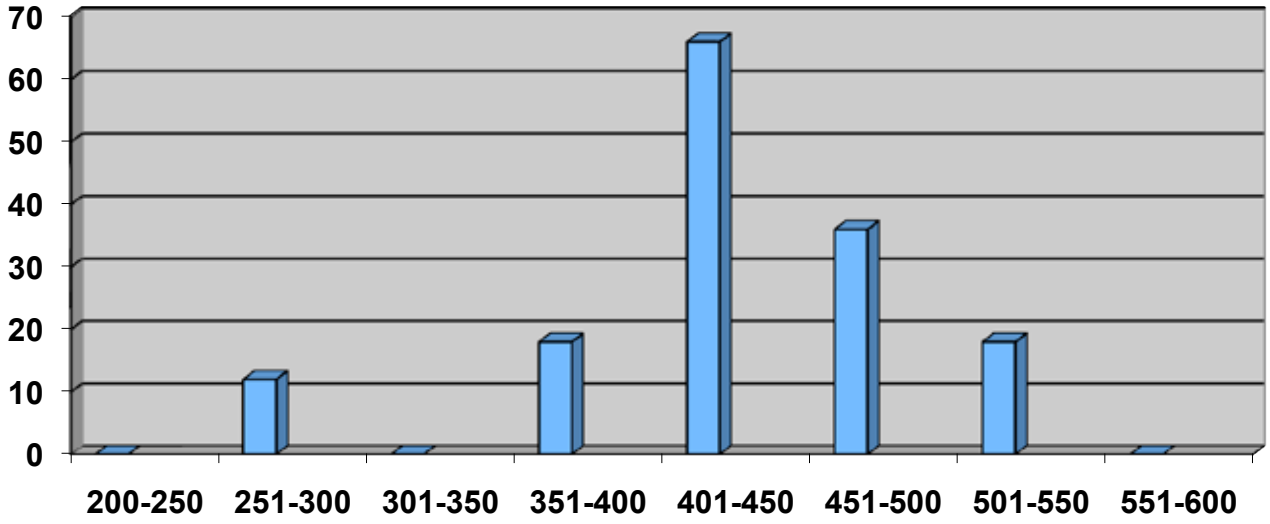

Figure 1. Distribution of total blood loss in mL. (X-axis) versus number of patients (Y-axis).

preoperative haematocrit was 37.04 (SD 2.8) and the mean postoperative haematocrit was 31.29 (SD 2.7). One of the patient in the present series developed cerebral thromboembolism three days after the surgery. Postoperative hemoglobin of less than 8 gm/dL was considered as indication for blood transfusion; however none of our patients required blood transfusion intraoperatively or postoperatively.

Apart from this study, the lead author (N.A.S.) has now an extensive experience of approximately 2,800 total knee replacements that were performed using the current regime, and only one patient out of 2,800 cases has required blood transfusion.

Table 2 shows the details of the results of our study and its comparison with the results of other similar studies.

Table 2. Comparison between results of the current study and the results of other similar studies.

	Parameters	Yamasaki et al.[53]	Camarasa et al.[42]	Our study
1.	Total blood loss (mL)	1349 ± 478	1099 ± 535	433 ± 148
2.	Hb (diff.)	1.7 ± 1.2	2.5 ± 1.0	1.6 ± 0.6
3.	Hct. (diff.)	5 ± 3.5	6.8 ± 3.0	6 ± 5.4
4.	Preop Hb (gm/dL)	12.8 ±1.3	12.4 ± 1.0	12.01 ± 2.7
5.	Postop Hb (gm/dL)	11.1 ±1.2	10	10.4 ± 2.8
6.	Preop Hct.(%)	38.6 ±3.6	36.2 ± 2.7	37 ± 5.6
7.	Postop Hct.(%)	33.7 ± 3.5		31 ± 5.4

Discussion

Blood loss management is an important issue in total knee replacement surgery. It should be made as simple as possible and should rely on common sense while also being cost-effective and having a low risk of complications [24]. Historically, correction of blood loss in surgical patients has been by transfusion of allogeneic blood to maintain or to restore the haematocrit and haemoglobin (Hb) level close to normal. However, allogeneic blood transfusion can lead to various adverse consequences such as transmission of infectious diseases, immunological reaction due to a mismatched transfusion, and increased likelihood of postoperative infection. Other effects of allogeneic blood transfusion such as multiple-organ failure or mortality have been attributed to immunomodulation by pro-inflammatory mechanisms. Allogeneic blood transfusion also adds to the cost of an operation, all the more as it has been shown to be associated with increased morbidity and prolonged hospital stay [25].

Cell salvage is another blood-saving procedure used for management of perioperative blood loss. This includes re-infusion of blood drained within six hours after operation using cell salvage. Blood shed during operation may be altered by irrigation fluid, air and cement and should therefore be washed before re-infusion to avoid coagulopathy [24]. Perioperative blood salvage has been shown to be beneficial in cases of blood loss exceeding 1000 mL but is not considered to be cost-effective in primary arthroplasty if other effective blood-saving measures have

already been taken. Its use is generally restricted to specific indications in which the anticipated blood loss is very high, such as revision total hip replacement. Postoperative cell salvage is not always cost-effective since the volume of blood recuperated is unpredictable [24]. The reported mean volume of re-infused blood has ranged between 360 mL and 880 mL [26]. It can be used in combination with other blood-saving measures if the anticipated blood loss is high, or in patients with a small blood volume and a low preoperative Hb level. Intra- and postoperative cell salvage are contraindicated in patients with infection and malignancy [24].

Autologous blood transfusion (Predonated):

Pre-operative autologous blood predonation offers a number of theoretical advantages. It has been widely used in the recent past, but has now fallen into relative disfavour for several reasons [24,27,28]. It cannot reasonably be considered in patients who are anaemic, i.e. in 20% to 30% of patients who are to undergo total hip or total knee replacement, [29] or in those with an Hb level of >14.5 g/dL since they will not require blood transfusion. It should therefore be targeted to men with an Hb level of 11.0 g/dL to 14.0 g/dL and to women with a level of 13.0 g/dL to 14.0 g/dL whose anticipated perioperative blood loss is close to 1000 mL. In older patients who are not anaemic, the capacity of the erythropoietic marrow to react to the stimulus of blood withdrawal may prove to be inadequate. Such patients may come to operation with an Hb level lower than that before pre-donation, and will need more transfusion episodes (autologous or allogeneic) than they would have otherwise needed [24]. For the same reason, many patients simply cannot complete the pre-donation program because they become increasingly anaemic. We have not used predonation of autologous blood in our study because of the above limitations.

Fibrin Sprays and Glue

The use of fibrin sprays and glue [30] can also help in reducing blood loss but these were not utilized in our study as they are costly.

Regional Anaesthesia

The type of anesthetic administered may play a role in total blood loss. Controlled hypotensive spinal or epidural anaesthesia [17,31] has been shown to reduce blood loss compared with general anaesthesia. In the current study, all knees were operated under regional anesthesia. However, specific measures to produce hypotension during surgery were not employed in this study.

Minimally Invasive Subvastus Approach

In our series, all cases were performed by a minimally invasive subvastus surgical approach. This approach has shown to be associated with less intraoperative blood loss in the literature. Boerger and colleagues [15] reported a prospective, observer-blinded study of 120 consecutive patients having total knee arthroplasty. All patients were operated by one surgeon using either the mini-subvastus approach without patellar eversion or the standard parapatellar approach with patellar eversion. Patients in the mini-subvastus group lost on average 100 mL less blood and had better pain scores on day one [visual analogue scale (VAS): mean 2.4 versus 3.89].

Roysam and Oakley [14] conducted a prospective, randomized, and blinded trial with 89 consecutive primary knee arthroplasties comparing standard medial parapatellar arthrotomy with the subvastus approach. All patients received the Insall-Burstein II prosthesis inserted by a single surgeon using an identical operative technique with the only difference being the surgical approach. Assessment revealed less blood loss (527 mL versus 748 mL, P <.001) in patients who have had a subvastus approach.

In our series, wound complications have not been a major problem with the use of a mini-subvastus approach. We have radiographs of all 150 patients (and radiographs of approximately 2,800 patients) operated by the current technique. There is no major concern of prosthetic component malalignment.

Saline Adrenaline Infiltration

There are numerous studies on the use of saline-adrenalin infiltration in plastic, gynaecology and general surgery literature showing the reduction in blood loss. Padala and colleagues [18] showed that adrenalin and saline infiltration is safe and helps reduce intra-operative blood loss in total knee arthroplasty. In the present series, we infiltrated 1:300,000 saline-adrenalin in the skin, subcutaneous tissue and the joint capsule for all cases.

Hydrogen Peroxide

Hydrogen peroxide [19] has been used for decades as an effervescent haemostatic agent in arthroplasty (especially during cemented total hip arthroplasty) to

achieve a dry bony surface prior to cementing. We have used the same principle in all knees to achieve the soft tissue haemostasis. After final implantation and prior to wound closure, the wounds were alternately packed with hydrogen peroxide and Feracrylum for three minutes while waiting for the cement to set.

Feracrylum

Feracrylum was used for all patients in our series to decrease blood loss. Feracrylum [20,21] has a wide therapeutic application as a haemostatic agent to decrease postoperative oozing. Feracrylum has a unique property of reacting with proteins including those present in blood to form an insoluble polycomplex. This property is primarily responsible for its pharmacotherapeutic utility. It reacts mainly with albumin and converts soluble fibrinogen to insoluble fibrin which then forms a coagulum. This arrests bleeding and oozing from highly vascularized tissues. The mean time for formation of this coagulum is 30 sec. Feracrylum is very effective especially against bleeding from capillaries and venules. Because of its novel mechanism of action i.e. not involving the coagulation pathway, it is useful in patients with coagulation disturbances undergoing surgery. We accept that although Feracrylum is commonly used in our part of the world, there is not enough literature to support its use.

Tranexamic Acid

Tranexamic acid (1, 4- amino- carboxylic acid) is an antifibrinolytic agent which is seven to ten times as potent as epsilon aminocaproic acid (EACA). Tranexamic acid is a synthetic derivative of the amino acid lysine that exerts its antifibrinolytic effect through the reversible blockade of lysine-binding sites on plasminogen molecules [32-34]. As tranexamic acid enters the extravascular space and accumulates in tissues for up to 17 hours, the basis for its mechanism of action is thought to be inhibition of tissue fibrinolysis and consequent stabilization of clots [35].

Tranexamic acid, a synthetic fibrinolytic inhibitor, has been used for more than 20 years in various fields such as dentistry, gynaecology, cardiac surgery, urological surgery, and liver transplantation. Multiple studies have shown that tranexamic acid can reduce blood loss and decrease the need for red blood cell transfusions in patients undergoing primary total knee arthroplasty [5,10,11,12,36-52].

Yamasaki and colleagues [53] demonstrated that tranexamic acid reduced total blood loss primarily by reducing the blood loss during the first two hours after surgery. The fibrinolytic response after trauma is biphasic with an increased activity during the first few hours, followed by a shutdown that peaks at about 24 hours. After knee arthroplasty, the early post-traumatic fibrinolysis is further augmented by that induced by the tourniquet [54]. Given that the mean duration of effect of tranexamic acid is around 3 hours, a second dose was administered after this period to prolong the effect over the first 6 hours, when 60% to 80% of the blood loss (including the hidden loss) occurs. Hence, our current dosage seems to be an adequate compromise between fibrinolytic inhibition and the risk of inducing an augmented fibrinolytic shutdown.

Our findings of reduced postoperative bleeding are consistent and comparable with the findings of previous meta-analyses of individual studies of intravenous tranexamic acid administration in patients undergoing total knee arthroplasty, which demonstrated a reduction of blood loss of about 400 mL per case [47,55,56]. The reduction in blood loss in our study is in accordance with other studies [5,12,57] that have reported a 45–54% reduction Tanaka and colleagues [38] have demonstrated a 40–58% decrease in blood loss when tranexamic acid was given preoperatively and intraoperatively.

A theoretical concern associated with the use of tranexamic acid is its potential for inducing thromboembolic events [38,55,58]. However, the use of tranexamic acid does not seem to cause any higher incidence of deep venous thrombosis [11,12,34,37,38]. Tanaka and colleagues [38] found there was no increase in deep-vein thromboses or pulmonary emboli on the basis of radioisotope venography and lung scanning in patients receiving intravenous tranexamic acid. Orpen and colleagues [43] reported that no deep-vein thromboses were detected with duplex ultrasound scanning. The reports by Alvarez and colleagues [45] and Kagoma and colleagues [47] suggest tranexamic acid does not result in an increase in thrombo-embolic events. Lozano and colleagues [46] have also reported that the use of tranexamic acid was not associated with an increase in thrombotic complications either clinically or as documented by contrast venography.

In our clinical study, one patient developed cerebral thromboembolism, who on retrospective evaluation revealed a history of similar episode in the past

from which he had recovered completely. Although thromboembolism has been reported in other studies, the authors of those studies were unable to determine whether thromboembolism resulted from the administration of tranexamic acid or other variable associated with total hip or knee arthroplasty. The use of tranexamic acid is contraindicated in patients with a history of thromboembolic disease and renal failure [5,11,34,37,58,59,60].

Use of Pneumatic Tourniquet

The use of pneumatic tourniquet does not reduce the blood loss and it may even increase it [18,61,62]. A prolonged tourniquet time may induce a post-ischemic reperfusion injury resulting in reactive hyperaemia and edema [63]. It may also stimulate fibrinolysis and increase the hidden blood loss [63]. We have not used tourniquet in any of our cases in the present series.

Nonpharmacologic Prophylaxis

In our series, none of the patients received any pharmacologic prophylaxis against venous thromboembolism but TED stockings were utilized postoperatively for 6 weeks. We believe the addition of pharmacologic prophylaxis would probably not affect the overall results although this is a conjecture. The lead author of this paper (N.A.S.) has used aspirin extensively as a form of DVT prophylaxis in his practice, although being aware that some surgeons do not prefer the use of aspirin. Moreover, the authors believe that since a tourniquet is not used during the operative procedure, the rate of DVT is extremely low. The authors are currently undertaking a detailed study looking specifically at DVT rates using the protocol described in this paper.

Avoidance of Surgical Wound Drainage

The avoidance of closed suction drainage reduces the external blood loss, but not necessarily the hidden loss, which may be increased, particularly after total knee replacement [64]. However, the overall balance appears to be towards a reduction in total blood loss [18,65].

Relationship Between Operating Time and Intraoperative Blood Loss

There have been few reports that have described the relationship between operative time and intraoperative blood loss. Salido and colleagues [66] showed a significant relationship between the operative time and the need for postoperative blood transfusion. In the study by Ekbäck and colleagues, [59] the operative time was 120 minutes. In our series, the average duration of surgery was around 90 to 100 minutes. None of the patients in our series required a blood transfusion.

Limitations of Our Study

The present study has few limitations.

(1). Our study involved a consecutive series of 150 patients. This is a non-randomized study. There is no control group.

(2). Our series is a cohort study. A retrospective analysis of a prospectively collected data was performed. Power calculation was not performed from the outset to examine the assumption that tranexamic acid can decrease the frequency of allogeneic blood transfusion, although none of the patients in our series required a blood transfusion.

(3). We used the mean reduction in hemoglobin as a surrogate marker for blood loss. We acknowledge that other factors may have led to a reduction in the mean hemoglobin, such as hemodilution from perioperative fluid resuscitation and the type of anesthetic used.

(4). We did not perform routine screening for deep-vein thromboses and pulmonary emboli; however, based on physical examination, no significant thrombo-embolic complications were noted in our series during the six-week follow-up period.

(5). This study has not addressed the subjective knee function score and objective clinical examination findings of the patients after total knee arthroplasty. Our main purpose of this paper was to report our operative technique strategies to minimize the perioperative blood loss in patients who undergo total knee replacement.

One advantage of our study is that it compares a prospective cohort of patients operated on by the same surgeon who used the same operative approach and surgical technique for all 150 cases in our series. Moreover, the same postoperative rehabilitation protocol was used for all patients.

Our study is unique as we believe there is an additive effect of various blood conserving measures that were used in our series. We believe a blood transfusion can be avoided if blood loss is minimized using our suggested blood conserving strategies. Our study reports the least hemoglobin fall after a TKR in the literature and allows us to do a TKR without the requirement of any blood transfusion.

Conclusions

Combined effectiveness of regional anaesthesia,, mini-subvastus approach, use of saline- adrenaline infiltration, hydrogen peroxide and Feracrylum-soaked packs, perioperative use of tranexamic acid, without using tourniquet and drains, reduces perioperative bleeding in patients undergoing total knee replacement, thereby reducing the blood transfusion requirement in these patients to almost negligible amount (as none of our patient required blood transfusion in the current series). Moreover, the treatment cost is low, and safety has proved to be high, there being no increased risk of thromboembolic complications in properly selected patients.

Larger prospective, randomized clinical trials are needed to further assess the safety and efficacy of our promising strategy to reduce bleeding and the need for allogeneic blood transfusion in patients undergoing total knee arthroplasty.

References:

1. Goodnough LT, Verbrugge D, Marcus RE. The relationship between hematocrit, blood lost, and blood transfused in total knee replacement: Implications for postoperative blood salvage and reinfusion. Am J Knee Surg 1995;8:83-87.
2. Bierbaum BE, Callaghan JJ, Galante JO, Rubash HE, Tooms RE, Welch RB. An analysis of blood management in patients having a total hip or knee arthroplasty. J Bone Joint Surg [Am] 1999;81-A:2-10.
3. Bong MR, Patel V, Chang E, Issack PS, Hebert R, Di Cesare PE. Risks associated with blood transfusion after total knee arthroplasty. J Arthroplasty 2004;19:281-287.
4. Freedman J, Luke K, Monga N, Lincoln S, Koen R, Escobar M, Chiavetta J. A provincial program of blood conservation: The Ontario Transfusion Coordinators (ONTraC). Transfus Apher Sci 2005;33:343-349.
5. Hiippala ST, Strid LJ, Wennerstrand MI, Arvela JV, Niemelä HM, Mäntylä SK, Kuisma RP, Ylinen JE. Tranexamic acid radically decreases blood loss and transfusions associated with total knee arthroplasty. Anesth Analg 1997;84(4):839-844.
6. Good L, Peterson E, Lisander B. Tranexamic acid decreases external blood loss but not hidden blood loss in total knee replacement. Br J Anaesth 2003;90:596-599.
7. Sehat KR, Evans RL, Newman JH. Hidden blood loss following hip and knee arthroplasty: Correct management of blood loss should take hidden loss into account. J Bone Joint Surg [Br] 2004;86-B(4):561-565.
8. Kalairajah Y, Simpson D, Cossey AJ, Verrall GM, Spriggins AJ. Blood loss after total knee replacement: Effects of computer-assisted surgery. J Bone Joint Surg [Br] 2005;87-B:1480-1482.
9. Biarnés Suñé A, Ciércoles Jiménez E, Márquez Martínez E, Medel Rebollo J, Godet Gimeno C, Roigé Solé J. [Risk factors for transfusion in primary knee arthroplasty]. Rev Esp Anestesiol Reanim 2006;53:18-24. [Article in Spanish].
10. Benoni G, Carlsson A, Petersson C, Fredin H. Does tranexamic acid reduce blood loss in knee arthroplasty? Am J Knee Surg 1995;8(3):88-92.
11. Hiippala S, Strid L, Wennerstrand M, Arvela V, Mäntylä S, Ylinen J, Niemelä H. Tranexamic acid (Cyklokapron) reduces perioperative blood loss associated with total knee arthroplasty. Br J Anaesth 1995;74(5):534-537.
12. Benoni G, Fredin H. Fibrinolytic inhibition with tranexamic acid reduces blood loss and blood transfusion after knee arthroplasty: A prospective, randomised, double-blind study of 86 patients. J Bone Joint Surg [Br] 1996;78-B(3):434-440.
13. Rosencher N, Kerkkamp HE, Macheras G, Munuera LM, Menichella G, Barton DM, Cremers S, Abraham IL; OSTHEO Investigation. Orthopedic Surgery Transfusion Hemoglobin European Overview (OSTHEO) study: Blood management in elective knee and hip arthroplasty in Europe. Transfusion 2003;43(4):459–469.
14. Roysam GS, Oakley MJ. Subvastus approach for total knee arthroplasty: A prospective, randomized, and observer-blinded trial. J Arthroplasty 2001;16(4):454-457.
15. Boerger TO, Aglietti P, Mondanelli N, Sensi L. Mini-subvastus versus medial parapatellar approach in total knee arthroplasty. Clin Orthop Relat Res 2005;440:82-87.
16. Shah N, Nilesh G, Patel N. Mini-subvastus approach for total knee arthroplasty in obese patients. Indian J Orthop 2010;44(3):292-299.
17. Juelsgaard P, Larsen UT, Sørensen JV, Madsen F, Søballe K. Hypotensive epidural anesthesia in total knee replacement without tourniquet: Reduced blood loss and transfusion. Reg Anesth Pain Med 2001;26(2):105-110.
18. Padala PR, Rouholamin E, Mehta RL. The role of drains and tourniquets in primary total knee replacement: A comparative study of TKR performed with drains and tourniquet versus no drains, and adrenaline and saline infiltration. J Knee Surg 2004;17(1):24-27.
19. Hankin FM, Campbell SE, Goldstein SA, Matthews LS. Hydrogen peroxide as a topical hemostatic agent. Clin Orthop Relat Res 1984;186:244-248.
20. Hathial MD. Feracrylum: A therapeutic profile. Indian Pract 2000;53:267–269.
21. Bhagwat AM, Save S, Burli S, Karki SG. A study to evaluate the antimicrobial activity of Feracrylum and its comparison with povidone-iodine. Indian J Pathol Microbiol 2001;44(4):431-433.
22. Nadler SB, Hidalgo JU, Bloch T. Prediction of blood volume in normal human adults. Surgery 1962;51:224-232.
23. Bourke DL, Smith TC. Estimating allowable hemodilution. Anaesthesiology 1974; 41(6):609-612.
24. Lemaire R. Strategies for blood management in orthopaedic and trauma surgery. J Bone Joint Surg [Br] 2008;90-B(9):1128-1136.
25. Newman JH, Bowers M, Murphy J. The clinical advantages of autologous transfusion: A randomized, controlled study after knee replacement. J Bone Joint Surg [Br] 1997;79-B(4):630-632.
26. Pitsaer E. Transfusion of recuperated blood in total knee arthroplasty. Rev Chir Orthop Reparatrice Appar Mot 2002;88:777-789 (Article in French).
27. Brecher ME, Goodnaugh LT. The rise and fall of preoperative autologous blood donation. Transfusion 2002;42:1618-1622.
28. Henry DA, Carless PA, Moxey AJ, O'Connell D, Forgie MA, Wells PS, Fergusson D. Preoperative autologous donation for minimising perioperative allogeneic blood transfusion. Cochrane Database Syst Rev 2002;(2):CD003602.
29. Saleh E, McClelland DB, Hay A, Semple D, Walsh TS. Prevalence of anaemia before major joint arthroplasty and the potential impact of preoperative investigation and correction on perioperative blood transfusions. Br J Anaesth 2007;99:801-808.
30. Wang GJ, Hungerford DS, Savory CG, Rosenberg AG, Mont MA, Burks SG, Mayers SL, Spotnitz WD. Use of fibrin sealant to reduce bloody drainage and hemoglobin loss after total knee arthroplasty: A brief note on a randomized prospective trial. J Bone Joint Surg [Am] 2001;83-A(10):1503-1505.
31. Sharrock NE, Mineo R, Urquhart B, Salvati EA. The effect of two levels of hypotension on intraoperative blood loss during total hip arthroplasty performed under lumbar epidural anesthesia. Anesth Analg 1993;76(3):580-584.

32. Nilsson IM. Clinical pharmacology of aminocaproic and tranexamic acids. J Clin Pathol Suppl (R Coll Pathol) 1980;14:41-47.
33. Astedt B. Clinical pharmacology of tranexamic acid. Scand J Gastroenterol Suppl 1987;137:22–25.
34. Dunn CJ, Goa KL. Tranexamic acid: A review of its use in surgery and other indications. Drugs 1999;57(6):1005-1032.
35. Mannucci PM. Hemostatic drugs. N Engl J Med 1998;339:245–253.
36. Howes JP, Sharma V, Cohen AT. Tranexamic acid reduces blood loss after knee arthroplasty. J Bone Joint Surg [Br] 1996;78-B:995-996.
37. Jansen AJ, Andreica S, Claeys M, D'Haese J, Camu F, Jochmans K. Use of tranexamic acid for an effective blood conservation strategy after total knee arthroplasty. Br J Anaesth 1999;83(4):596-601.
38. Tanaka N, Sakahashi H, Sato E, Hirose K, Ishima T, Ishii S. Timing of the administration of tranexamic acid for maximum reduction in blood loss in arthroplasty of the knee. J Bone Joint Surg [Br] 2001;83-B(5):702-705.
39. Veien M, Sørensen JV, Madsen F, Juelsgaard P. Tranexamic acid given intraoperatively reduces blood loss after total knee replacement: A randomized, controlled study. Acta Anaesthesiol Scand 2002;46(10):1206-1211.
40. Hynes M, Calder P, Scott G. The use of tranexamic acid to reduce blood loss during total knee arthroplasty. Knee 2003;10(4):375-377.
41. Cid J, Lozano M. Tranexamic acid reduces allogeneic red cell transfusions in patients undergoing total knee arthroplasty: Results of a meta-analysis of randomized controlled trials. Transfusion 2005;45(8):1302–1307.
42. Camarasa MA, Ollé G, Serra-Prat M, Martín A, Sánchez M, Ricós P, Pérez A, Opisso L. Efficacy of aminocaproic, tranexamic acids in the control of bleeding during total knee replacement: A randomized clinical trial. Br J Anaesth 2006;96(5):576-582.
43. Orpen NM, Little C, Walker G, Crawfurd EJ. Tranexamic acid reduces early post-operative blood loss after total knee arthroplasty: A prospective randomised controlled trial of 29 patients. Knee 2006;13(2):106-110.
44. Molloy DO, Archbold HA, Ogonda L, McConway J, Wilson RK, Beverland DE. Comparison of topical fibrin spray and tranexamic acid on blood loss after total knee replacement: A prospective, randomised controlled trial. J Bone Joint Surg [Br] 2007;89-B(3):306–309.
45. Alvarez JC, Santiveri FX, Ramos I, Vela E, Puig L, Escolano F. Tranexamic acid reduces blood transfusion in total knee arthroplasty even when a blood conservation program is applied. Transfusion 2008;48(3):519–525.
46. Lozano M, Basora M, Peidro L, Merino I, Segur JM, Pereira A, Salazar F, Cid J, Lozano L, Mazzara R, Macule F. Effectiveness and safety of tranexamic acid administration during total knee arthroplasty. Vox Sang 2008;95(1):39–44.
47. Kagoma YK, Crowther MA, Douketis J, Bhandari M, Eikelboom J, Lim W. Use of antifibrinolytic therapy to reduce transfusion in patients undergoing orthopedic surgery: A systematic review of randomized trials. Thromb Res 2009;123:687-696.
48. Kakar PN, Gupta N, Govil P, Shah V. Efficacy and safety of tranexamic acid in control of bleeding following TKR: A randomized clinical trial. Indian J Anaesth 2009; 53(6):667-671.
49. Charoencholvanich K, Siriwattanasakul P. Tranexamic acid reduces blood loss and blood transfusion after TKA: A prospective randomized controlled trial. Clin Orthop Relat Res 2011;469(10):2874-2880.
50. Dhillon MS, Bali K, Prabhakar S. Tranexamic acid for control of blood loss in bilateral total knee replacement in a single stage. Indian J Orthop 2011;45(2):148-152.
51. MacGillivray RG, Tarabichi SB, Hawari MF, Raoof NT. Tranexamic acid to reduce blood loss after bilateral total knee arthroplasty: A prospective, randomized double blind study. J Arthroplasty 2011;26(1):24-28.
52. Sepah YJ, Umer M, Ahmad T, Nasim F, Umer Chaudhry M, Umar M. Use of Tranexamic acid is a cost effective method in preventing blood loss during and after total knee replacement. J Orthop Surg Res 2011;May 21;6(1):22.
53. Yamasaki S, Masuhara K, Fuji T. Tranexamic acid reduces postoperative blood loss in cementless total hip arthroplasty. J Bone Joint Surg [Am] 2005;87-A(4):766-770.
54. Fahmy NR, Patel DG. Hemostatic changes and postoperative deep-vein thrombosis associated with use of a pneumatic tourniquet. J Bone Joint Surg [Am] 1981;63-A(3):461-465.
55. Ho KM, Ismail H. Use of intravenous tranexamic acid to reduce allogeneic blood transfusion in total hip and knee arthroplasty: A meta-analysis. Anaesth Intensive Care 2003;31(5):529-537.
56. Zufferey P, Merquiol F, Laporte S, Decousus H, Mismetti P, Auboyer C, Samama CM, Molliex S. Do antifibrinolytics reduce allogeneic blood transfusion in orthopedic surgery? Anesthesiology 2006;105:1034-1046.
57. Benoni G, Lethagen S, Fredin H. The effect of tranexamic acid on local and plasma fibrinolysis during total knee arthroplasty. Thromb Res 1997;85(3):195-206.
58. Lindoff C, Rybo G, Astedt B. Treatment with tranexamic acid during pregnancy, and the risk of thrombo-embolic complications. Thromb Haemost 1993;70(2):238-240.
59. Ekbäck G, Axelsson K, Ryttberg L, Edlund B, Kjellberg J, Weckström J, Carlsson O, Schött U. Tranexamic acid reduces blood loss in total hip replacement surgery. Anesth Analg 2000;91(5):1124-1130.
60. Benoni G, Fredin H, Knebel R, Nilsson P. Blood conservation with tranexamic acid in total hip arthroplasty: A randomized, double-blind study in 40 primary operations. Acta Orthop Scand 2001;72(5):442-448.
61. Aglietti P, Baldini A, Vena LM, Abbate R, Fedi S, Falciani M. Effect of tourniquet use on activation of coagulation in total knee replacement. Clin Orthop Relat Res 2000;371:169-177.
62. Tetro AM, Rudan JF. The effects of a pneumatic tourniquet on blood loss in total knee arthroplasty. Can J Surg 2001;44(1):33-38.
63. Klenerman L. The tourniquet in operations on the knee: A review. J R Soc Med 1982;75(1):31-32.
64. Mengal B, Aebi J, Rodriguez A, Lemaire R. A prospective randomized study of wound drainage versus non-drainage in primary total hip or knee arthroplasty [Article in French]. Rev Chir Orthop Reparatrice Appar Mot 2001;87(1):29-39.
65. Parker MJ, Livingstone V, Clifton R, McKee A. Closed suction surgical wound drainage after orthopaedic surgery. Cochrane Database Syst Rev 2007 Jul 18;(3):CD001825.
66. Salido JA, Marín LA, Gómez LA, Zorrilla P, Martínez C. Preoperative hemoglobin levels and the need for transfusion after prosthetic hip and knee surgery: Analysis of predictive factors. J Bone Joint Surg [Am] 2002;84-A(2):216-220.