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ORIGINAL STUDY

Blood loss following total knee replacement is reduced when using computer-assisted versus standard methods

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Perioperative blood loss was compared in 136 patients (2 groups of 68 patients) who underwent total knee arthroplasty (TKA). Blood loss was significantly lower when using a computer-navigated technique in comparison to a method employing intramedullary femoral rods.

Total blood loss was calculated from body weight, height and haematocrit change, using a model that has been shown to reliably estimate true blood loss. Average total blood loss was 1362 ml in the standard TKA group, and 1137 ml in the computer navigated TKA group. This difference was statistically significant ($p = 0.016$).

This study, as compared to previous papers assessing the effects of navigation, used a larger sample size and a more reliable method of assessing blood loss, which takes account of "hidden" losses, and confirms their findings.

Keywords : knee arthroplasty ; knee replacement ; blood loss ; computer-assisted surgery.

INTRODUCTION

Blood loss during total knee arthroplasty (TKA) may be important. Lotke *et al* (*13*) found a mean blood loss of 1518 ml in 121 patients undergoing TKA ; blood loss was lower in patients who had a tourniquet applied throughout the procedure, and in patients treated with postoperative splintage. Other methods of reducing intra-operative blood loss include the use of diathermy coagulation, fibrin sealants (*23*), and inhibitors of fibrinolysis, such as tranexamic acid (*1,6,7*). Plugging of the hole left by the use of intramedullary rod can also lead to a small but statistically significant reduction in blood loss (*10*). More recent work has suggested that the use of navigation during TKA can have a role in reducing intraoperative blood loss ; two studies (*5,9*) have shown reduced volume of blood collected in drains when navigation is used, in comparison to traditional methods.

However, it has also been reported that measuring loss in drains may significantly underestimate the true volume lost, as "hidden" losses are not

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accounted for. In TKA these losses may be twice as much as the initially apparent blood loss (*19,20*).
Our study compared a computer-navigated TKA technique with a standard instrumentation technique using intramedullary femoral alignment rods. Blood loss was calculated to account for true losses, rather than the amount measured in drains, and we used a larger sample size (n = 136) than previous studies.

MATERIALS AND METHODS

We studied retrospective perioperative data over a nine-month period for elective cemented primary knee replacements. The operations were performed by four consultant surgeons, who were experienced in the use of both navigated and non-navigated techniques.

Patients were selected sequentially from a continuously compiled database of all those undergoing arthroplasty during the period November 2005 to July 2006. We compared data from these computer navigated TKAs to those where a standard instrumentation technique was used.

All patients who underwent cemented total knee arthroplasty during the studied period were included, unless they met our exclusion criteria. Patients' haematocrit had been checked pre-operatively, and on the second postoperative day ; cases were excluded where an appropriate blood sample had not been obtained at these aforementioned times. Patients were also excluded if they had prolonged clotting times, due to either clotting disorder or anticoagulant therapy ; if tranexamic acid had not been given ; if hospital notes were unavailable ; or if data for that patient were incomplete.

Excluded patients were replaced by the next patient in chronological sequence from the arthroplasty database ; these replacement cases were then tested for the above criteria.

The data were stratified into male and female, obese and non-obese (where obese was defined as BMI of 30 or higher). An equal number of patients were selected sequentially from each of these groups. The start date of our study was the earliest date for which we had complete computerised records of operative data and blood results. The end date was dictated by a change in anaesthetic protocol ; patients thereafter could not be compared to previous ones. The database held information regarding patient's age, weight, height, date of operation, type of prosthesis implanted, and whether computer navigation was used. The case notes were then examined to determine the volume of blood in the drain, where one had been used.

When using navigation, surgeons had the option of using either the StrykerVision® system with Scorpio implants (Stryker Howmedica), or Orthopilot® system with Columbus implants (B|Braun, Aesculap). Allocation to treatment was dictated by the availability of equipment ; both systems were used with approximately equal frequency : in the 68 patients who had navigated surgery, the StrykerVision® system was used in 36 patients, and the Orthopilot® system in 32. All non-navigated procedures were performed with Scorpio implants. All implants were of the cruciate-retaining variety, whether navigation was used or not. In the standard operative group, only femoral intramedullary instrumentation was used. Tibial measurements were made with extramedullary jigs. The femoral canal was filled with a bone plug. The canals remained unopened in the navigated group.

A standardised anaesthetic technique protocol was used routinely during the period that was analysed, consisting of a spinal block with low dose Propofol. All patients were given tranexamic acid at induction. A pneumatic thigh tourniquet was used in all procedures and this was kept inflated until wound closure was complete. Thromboprophylaxis consisted of the use of dynamic calf compression, elastic stockings, and a six-week postoperative course of aspirin 150 mg, once daily.

Total blood volume (PBV) was calculated using the formula described by Nadler, Hidalgo & Bloch (*16*), explained below. This value was used together with the haematocrit (hct) and volume re-infused or transfused (if any) to calculate true blood loss, as described by Sehat, Evans and Newman (*20*). We considered this method to be more reliable than measuring drain output, as it takes account of "hidden" losses (*19,20*).

Total body blood volume was calculated using the formula :

$$PBV = (k_1 \times height^3) + (k_2 \times weight) + k_3$$

Where $k_1 = 0.3669$, $k_2 = 0.03219$, $k_3 = 0.6041$ in males, and $k_1 = 0.0.3561$, $k_2 = 0.03308$, $k_3 = 0.1833$ in females (*16*) ; height and weight are in cm and kg respectively. These values were originally derived by comparison with total blood volume as measured using radio-labelled albumin, permitting a reliable method of non-invasively calculating total blood volume (*16*).

Change in blood volume was then calculated by multiplying the total blood volume by the change in haematocrit between pre-op and post-op tests, divided by mean haematocrit (*4*).

$$\text{Change in blood volume} = (\text{PBV} \times (\text{Hct}_{\text{pre op}} - \text{Hct}_{\text{post op}})) / \text{mean Hct}$$

If no blood was transfused or re-transfused, then the change in blood volume represents the amount of blood lost. However, if any volume of blood were to be replaced by transfusion or retransfusion, then the change in blood volume would be reduced by that amount transfused. Therefore it was necessary to take account of any transfusion or re-transfusion (*20*).

$$\text{Blood loss} = \text{change in blood volume} + \text{volume transfused or retransfused}$$

We conducted a planned comparison to determine the effect of blood loss between navigated and non-navigated groups. All data were analysed using SPSS version 16.0 (SPSS Inc, Chicago, Illinois).

RESULTS

One hundred and thirty six TKA patients were included, of which 68 had TKA using standard instrumentation and 68 had computer navigated TKA. In each group, half the patients had BMI in the range 20 to 30 and the other half had BMI greater than 30. There were equal numbers of males and females, both overall and within each of the above subgroups.

Mean BMI was 30.8 (range : 21-49) in the navigated group, 30.7 (range : 21-47) in the non-navigated group. Mean age was 67.3 years (range : 50-90 years) in the navigated group, and 68.4 years (range : 49-83 years) in the non-navigated group. The blood loss data were normally distributed. The data were reviewed and analysed by an independent statistician.

The average blood loss was 1362 ml (SD 630 ml) in the standard TKA group, and 1137 ml (SD 422 ml) in the computer navigated TKA group. A comparison by independent samples T-test showed this difference to be statistically significant ($p = 0.016$). A secondary planned analysis compared the obese group (BMI ≥ 30) with the non-obese group (BMI < 30), again using an independent samples T-test. The effect of obesity on blood loss was found to be non-significant ($p = 0.967$). Significance testing was adjusted for multiple comparisons (3).

In the navigated group, one patient required a 2 unit allogenic blood transfusion. In the non-navigated group, four patients required allogenic blood transfusion (one patient had 3 units, three patients had 2 units each). Whilst more transfusions were required in the non-navigated group, the overall number of transfusions was too low to allow for a meaningful statistical comparison. No thrombo-embolic complications were reported in either group.

DISCUSSION

In this study, the group in which computer navigated surgery was employed had reduced blood losses compared to the group in which traditional instrumentation was employed. The difference was statistically significant, even though it may not be large enough to be considered clinically important in most routine cases. However, in any case a surgeon should seek to minimise blood losses, and there are some cases where it will be particularly important to do so, such as in a patient with a bleeding diathesis, or a patient with an ethical or religious objection to blood transfusion.

We identified three previous studies in the literature that have evaluated the effect of computer navigation on blood loss after TKA. Two of these were conducted in Australia, whereas we studied patients from the UK. The first was a prospective study of 70 patients, in which the main outcome measure was prosthesis alignment (as measured on CT). Blood loss, as measured by drain output, was a secondary outcome measure (*5*) ; loss was significantly reduced with the use of navigation equipment. A later study (*9*) replicated this finding, with a sample size of 60 patients. Again, blood loss in drains was a primary outcome measure ; change in haemoglobin concentration was recorded as a secondary outcome measure, but no total body blood volume calculations were used. A third study (*14*) with sample size of 60 patients, focussed on morbidly obese patients, whereas we have studied patients with both normal and raised BMI. The above studies all found that less blood was lost in drains when performing total knee replacement using computer navigation, compared with traditional methods.

Our chosen method of blood loss calculation was used because of previous research (*19,20*) showing that volumes collected in drains can give an inaccurate representation of true blood loss, since "hidden" (internal) blood losses may represent as much as double the volume collected in drains. Failure to consider these hidden losses may be considered a source of error. The calculations used in this study account for these hidden losses (*19,20*). In a clinical setting it may be more practical to simply estimate losses based on BMI and haematocrit change, rather than employ such a calculation in full.

We suspect that the reduced blood loss in the computer-navigated technique may be attributable to the fact that this method avoids the penetration of the femoral intramedullary canal. Navigation allows accurate positioning of the femoral component without the use of intramedullary alignment rods and is thus less invasive than traditional methods. However, it is possible that the difference reflects disparity in the extent of soft tissue damage between the two surgical methods, rather than the presence of the IM rod *per se*. The use of a bone plug in the instrumented cases would be expected to stall any frank bleeding, but we speculate that it may not control what Sehat *et al* term to be 'hidden' loss.

Whist we did not attempt to perform a minimally-invasive or less-invasive procedure, we speculate that the navigation may have reduced the extent of dissection required. With the use of navigation equipment, bony landmarks are registered on the computer only once and do not need to be continuously exposed throughout the procedure, which may mean that less soft tissue dissection is required. Additionally, we suspect that a reduced extent of quadriceps incision or patellar eversion may be required. Formal assessment of these speculative explanations may prove to be an interesting avenue for further research.

There may also be the additional benefit of reducing the risk of fat embolism, which can lead to respiratory symptoms, neurological symptoms and even death (*15*). Studies using transoesophageal ultrasound have demonstrated the presence of echogenic material after tourniquet release when using intramedullary rods for alignment (*2*). The use of computer-navigated techniques can reduce this risk (*8*).

All patients received tranexamic acid during these joint replacement procedures. We excluded patients who did not receive this drug, as otherwise this would have been a potential confounder. Tranexamic acid has been shown to reduce postoperative blood loss and the amount of blood needed for transfusion following TKA (*1,6,7*). We have shown that a significant further reduction can be achieved with the use of computer navigation equipment. It is worth noting that because tranexamic acid was used in all cases, overall blood loss was reduced in both groups ; we may have found a larger difference in blood loss if TXA had not been used.

We found no significant difference in average blood loss between obese and non-obese patients, which is consistent with previously published findings (*20*).

Our study's main limitation is that it is a retrospective review of data from a prospectively-compiled database. Furthermore, patients were selected sequentially, rather than being randomised. The study's strengths are : that we used a validated method of blood loss calculation, which has been shown to take account of hidden losses not accounted for when measuring blood in swabs and drains ; that a standardised anaesthetic protocol was followed in all cases and that we have reported data from a larger sample size than previous studies.

Finally, data were compiled from operations performed by four different consultant surgeons. This might be seen as both a strength and a weakness : data from multiple surgeons may be more representative of practice in the typical orthopaedic operating unit ; conversely this may have introduced some heterogeneity into the data set. However it is worth noting that all surgeons used a standard medial parapatellar approach, and an identical anaesthetic protocol was employed throughout.

It is important to consider our findings in context. There are many other methods of reducing blood loss that can, and should, be employed in addition to the methods discussed here (*12*). These begin with simple considerations such as stopping medications which predispose to bleeding ; employing a pneumatic tourniquet ; maintaining normothermia ; and employing pharmaceutical agents such as aprotonin, tranexamic acid, desmopressin or aminocaproic acid (*22*). More advanced considerations include acute normotensive anaesthesia ; preoperative blood donation ; autologous transfusion and recombinant erythropoetin administration (*11,22*). Where a drain is used, a marked reduction in blood loss may be achieved by delayed opening (*18,21*) or intermittent clamping (*17*) of the drain. Many of these techniques can be performed in parallel.

In conclusion, we found that a computer-navigated surgical technique for total knee replacement led to a small but statistically significant reduction in intraoperative blood loss. We would consider using computer navigation as an additional tool in the ongoing effort to reduce surgical blood loss, as an addition to other well-established methods of haemorrhage control.

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