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Research Article

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Hypotensive Anesthesia may Result in False Anemia and Increase Transfusion Requirements in Total Hip Arthroplasty

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Abstract

Background: Deliberate hypotension under spinal or epidural anesthesia is a readily available and effective method to reduce intraoperative blood loss in total hip arthroplasty. However, induced hypotension has been shown to alter the physiologic handling of crystalloid solutions, with blood volume increasing in proportion to the drop in blood pressure. This study aims to investigate the effect of hemodilution secondary to hypotensive anesthesia and volume loading on postoperative hemoglobin levels.

Methods: 211 non-anemic adult patients who underwent primary total hip arthroplasty utilizing a minimal invasive posterior approach with hypotensive spinal-epidural anesthesia were evaluated retrospectively. The effect of fluid loading under hypotensive anesthesia was investigated by calculating the blood loss that corresponds to patients' preoperative and postoperative hemoglobin levels, as well as calculating the hemoglobin levels expected for known volumes of blood loss.

Results: There was a large discrepancy between the calculated blood loss (1358 mL) and the actual measured blood loss (212 mL). Patients received an average of 4488 (SD 1209) mL of intravenous fluid within 24 hours of surgery. There was also a large difference between the calculated hemoglobin level based on the measured blood loss (13.6 g/dL) and the actual measured mean hemoglobin (10.8 g/dL).

Conclusion: Blood volume expansion and hemodilution with hypotensive epidural anesthesia leads to decreased hemoglobin levels in the early postoperative period and likely impacts on transfusion requirements. Hypotensive anesthesia might have a detrimental effect on transfusion requirements in procedures with relatively low blood loss.

Keywords: Total hip arthroplasty; Spinal-epidural; Hypotensive anesthesia; Blood management; Allogeneic blood transfusion; Anemia

Introduction

Hypotensive epidural anesthesia is a readily available and effective method to reduce intraoperative blood loss in total hip arthroplasty (THA) [1]. The technique is performed at an upper thoracic level such as T4, effectively blocking the thoracic sympathetic chain. This achieves extensive vasodilation and hypotension without reflex tachycardia as the cardiac sympathetic innervation is also blocked. Continuous intravenous infusion of a low-dose epinephrine solution is used to stabilize heart rate, CVP and cardiac output during hypotension. This results in arterial hypotension with preservation of central venous pressure, heart rate, stroke volume, cardiac output, and an augmentation of blood flow to the lower extremity [2]. Lowering the mean arterial pressure (MAP) to 50 mmHg has been found to decrease intraoperative blood loss by up to 40% [3] and reduce postoperative wound drainage [4]. The technique does not appear to adversely affect cardiac, renal, or cerebral function and is used safely in patients with hypertension, ischemic heart disease, and in the elderly. It has been associated not only with reduced intraoperative blood loss, but also with fewer perioperative blood transfusions [5,6], a lower rate of deep vein thrombosis [7,8], and a low perioperative mortality rate [9].

It has been established that the relative reduction in pressure and not cardiac output is the primary determinant of intraoperative blood loss [5,10]. lntraoperative blood losses during primary total hip replacement have been reported in the range between 100 and 300 mL with this technique, as opposed to the average 500 ml to 1700 ml with general anesthesia [6,11]. Most patients undergoing primary THA require on average 1,000-1,500 mL of lactated Ringer's solution to maintain blood pressure (80 or 90 mm Hg systolic and 50 to 65 mm Hg diastolic blood pressure) and heart rate during surgery using hypotensive epidural anesthesia [2]. The infusion of crystalloids or colloids in the setting of even moderate epidural-induced hypotension has been associated with a degree of blood dilution much greater than that usually resulting from crystalloid fluid supplementation [12,13]. While the blood volume increases by between 25 and 35% of the amount of crystalloid solution given by intravenous infusion to normotensive patients, double the amount is retained when the patient develops hypotension [14]. As such, the increased hemodilution in the setting of epidural anesthesia in joint replacement procedures lowers the postoperative hemoglobin (Hb) levels. Therefore, relying on hemoglobin levels in the acute postoperative phase might lead to diagnosing false anemia and overutilization of blood transfusions in the early postoperative period. The current study evaluates: (1) whether there is a difference between the calculated blood and the measured blood loss, (2) how much fluid do patient receive during hypotensive anesthesia, (3) what blood loss is necessary to explain the postoperative drop in hemoglobin, (4) what percentage of nonanemic patients received blood transfusions within the first 24 hours after surgery suggesting aggressive perioperative hemodilution as the main reason for the transfusion.

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Materials and Methods

The charts of 293 patients who had primary unilateral total hip arthroplasty between October 2009 and October 2011 were retrospectively reviewed. 233 patients had preoperative hemoglobin greater than or equal to 12.5 and did not donate any autologous blood. All hip arthroplasty procedures were performed by the principle investigator utilizing a minimal invasive posterior approach (incision length less than 10 cm) with hypotensive spinal-epidural anesthesia. Two patients who underwent general anesthesia and 20 patients who received allogeneic blood throughout their hospital stay were excluded. Blood transfusion was indicated after a failed attempt of a fluid bolus, but strict transfusion guidelines were not enforced. The 211 patients registered an average drop of 50 mmHg in systolic blood pressure (SBP) and 25 mmHg in diastolic blood pressure (DBP) intraoperatively. The study was approved by the Institutional Review Board at Hospital for Special Surgery.

Gender, age, BMI, preoperative Hb, date of preoperative Hb measurement, number of transfusions, time of transfusion, intraoperative blood loss, postoperative blood loss, postoperative Hb levels until date of discharge, preoperative as well as intraoperative blood mean arterial blood pressure, fluid intake and output, and in-house complications were recorded.

Calculating blood loss relies on a formula incorporating pre- and postoperative hemoglobin levels and the patient's blood volume (BV) which is derived from the body mass index (BMI). Therefore, if Hb is measured before and after surgery, the volume of blood lost during surgery $V = BV \times \ln Hb_{preop}/Hb_{postop}$. If a patient loses a volume of blood V, the hemoglobin falls according to the formula $Hb_{postop} = Hb_{preop} \times e^{-V/BV}$, where BV is the blood volume [15]. Therefore, it is possible to calculate the hemoglobin level expected for a known amount of blood loss. The blood volume was estimated according to the formula described by Nadler taking into account gender, body mass, and height [16]:

For Males=0.3669* Ht (m^3)+0.03219 * Wt (kg)+0.6041

For Females=0.3561* Ht (m^3)+0.03308 x Wt (kg)+0.1833

This value is affected by blood loss as well as fluid administration, and has been shown to equilibrate back to its preoperative value on the third postoperative day in total hip surgery [17].

Data were analyzed using a standard two-tailed *t* test (Microsoft Excel, Microsoft Corporation, Redmond, WA, USA, Microsoft Office Professional Plus 2010 Version 14.0.6 for Windows 7). A *p* value of less than 0.05 was considered statistically significant (Table 1).

Results

The patients in this study were preoperatively non-anemic with an average preoperative Hb of 14.5 g/dl in males and 13.5 g/dl in females and similar mean American Society of Anesthesiologist (ASA) score of 2 (range: 1 to 3). The estimated volume of blood lost intraoperatively and the blood volume recovered from drains add up to a mean measured

Number of patients	211
Males/Females	108/103
Mean age (years)	61.0 (28-85)
Mean BMI (kg.m^{-2})	26.4 (14.1-44.5)
Mean SBP drop (mmHg)	51 (10-113)
Mean DBP drop (mmHg)	25 (0-50)

Table 1: Demographics of primary total hip arthroplasty cases.

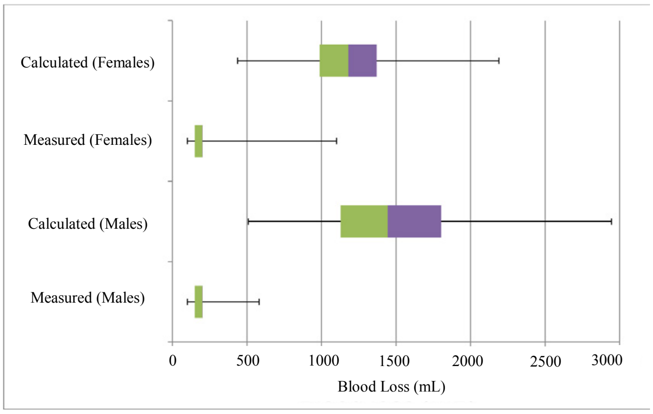

Figure 1: The calculated blood loss was 1291 ml more than measured blood loss in males and 991 ml in females. ($p<0.001$) (Green=25th percentile, Median, Purple=75th percentile).

blood loss of 212 ml (range: 100 to 1100). Patients were discharged on average 3 days postoperatively (range: 1 to 10). The average discharge Hb level of 10.8 g/dl reflects a calculated blood loss of 1358 ml (range: 437 to 2946), a difference of 1146 ml from the measured value of 212 ml ($p<0.001$). The patients were given on average 2567 ml (range: 320 to 4400) of fluids on the day of the surgery, and 1941 ml (range: 90 to 4500) on the first postoperative day (Figure 1).

Substituting the measured volume of blood lost in $Hb_{postop} = Hb_{preop} \times e^{-V/BV}$ allows us to calculate the expected postoperative hemoglobin level that corresponds to it. Assuming that BV has reached its preoperative value on patient discharge on POD #3, the expected mean hemoglobin level would be 13.5 g/dl ± 1.1 (range: 10.0 to 16.5). This value is significantly higher than the measured mean Hb of 10.8 g/dl (range: 7.6 to 13.9) ($p<0.001$).

Subgroup analysis revealed that none of the 56 patients who were discharged with a measured hemoglobin level of 10 g/dl or less had a corrected hemoglobin level below 10 g/dl. It is worth noting that among the 20 patients who received allogeneic blood, 55% were transfused in the first 24 hours postoperatively.

Discussion

An overview of controlled trials in the last 2 decades including 636 patients revealed that deliberate hypotension to a range of 48-78mmHg reduces blood loss most effectively for total hip arthroplasty (503 mL), followed by spine fusion (318 mL) [18]. Hypotensive anesthesia has been shown to significantly reduce transfusion requirements as well as the rates of postoperative deep vein thrombosis compared to general anesthesia after hip surgery [2,19,20]. It is proposed that the epinephrine-induced increase in low extremity skeletal muscle blood flow prevents stasis, and potentially prevents endothelial disruption [8,21]. The main concern with this technique is the risk of tissue hypoxia by reducing end-organ perfusion. The auto-regulatory function of the arteriolar bed in end-organ tissues is responsible to maintain perfusion and blood flow over the auto-regulatory limits of the tissue during the drop in MAP [22]. Hypotensive anesthesia has been associated with a morbidity rate of 2.5% and mortality between 0.02% and 0.60% [18]. A previous study at our institution reported no deaths in 392 patients undergoing one-stage bilateral THR performed under hypotensive epidural anesthesia upon its introduction in 1987 to 1991 [9]. Although it is contraindicated in patients with severe aortic or mitral stenosis, the procedure does not appear to increase the rate of cardiac complications in high-risk patients [2].

The circulatory effects of this technique are due to both the extensive sympathetic block and the intravenous epinephrine infusion. The epidural anesthesia dilates the arterioles and veins and suppresses both the heart rate and contractility [23]. Unopposed, this causes hypotension, bradycardia, and a significant reduction in cardiac output [24]. Epinephrine is used to maintain heart rate and stroke volume and to preserve central venous pressure as well as cardiac output [24]. Employing epidural anesthesia in total hip arthroplasty preserves or even augments lower extremity blood flow during surgery, potentially decreasing stasis and the risk of deep venous thrombosis [8]. It has been observed that the physiologic handling of infused crystalloid solutions is altered with the onset of neural blocks, achieving twice as much fluid retention when hypotension is induced [12,25,26]. Crystalloid volume loading (10 ml/kg) in hypotensive patients was associated with twice the decrease in hemoglobin that was seen in normotensive patients [12]. This correlates to an increase in blood volume proportional to the degree of hypotension, causing significant hemodilution. While colloids increase blood volume more significantly and show a more profound hemodilution effect, both crystalloids and colloids boost preload temporarily and are then redistributed from the blood volume [27].

The difference between the calculated and measured blood loss reveals a discrepancy of 1146 ml. This could in part be explained by the hidden blood loss into the thigh. The effect of hidden blood loss has been shown to be more pronounced in primary total knee than total hip arthroplasty [28,29] with ranges reported in the literature varying from 471 ml (26% of the total loss) with epidural anesthesia [28] to 1050 ml (up to 60% of the total loss) in THA with general anesthesia [30]. While some hidden blood loss is expected, possibly up to double the estimated loss [28], hidden blood loss is not very significant in THA. The discrepancy in blood volume lost in our study was more than 5-fold the measured blood loss. Very likely this is not just hidden blood loss but the result of hemodilution and increase in blood volume. Figure 2 depicts the progression of blood loss corresponding to the measured hemoglobin levels assuming a constant BV without hemodilution suggesting continued significant blood loss until postoperative day 2 (Figure 2).

This is also reflected by the difference between the calculated drops in hemoglobin levels from 14.1 g/dl to 13.5 g/dl, compared to the actually measured hemoglobin levels of 10.8 g/dl ($p<0.001$)

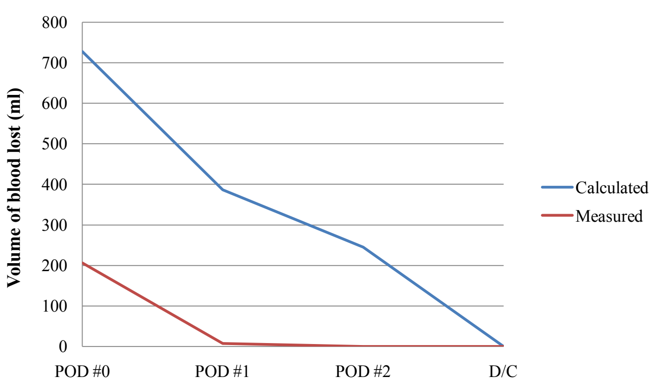

Figure 2: The progression of calculated blood loss correlating to hemoglobin measurements compared to measured blood loss (intraoperative+drains). Blood volume is assumed to be constant.

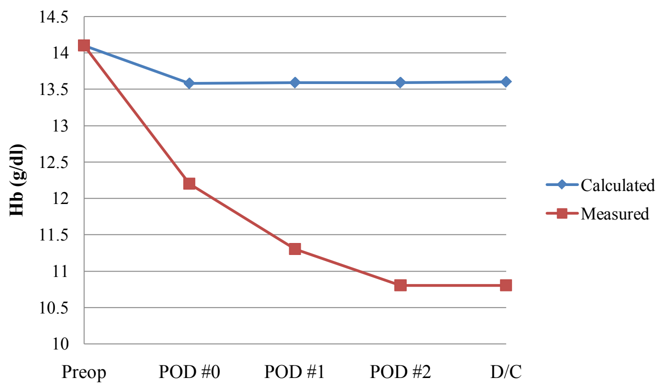

Figure 3: The calculated hemoglobin level corresponding to the measured blood loss values were significantly higher than the measured hemoglobin. Blood volume is assumed to be constant.

(Figure 3). The authors do not believe that the difference in the drop in hemoglobin of 2.7 g/dl is due to hidden blood loss. The theoretical loss of blood volume that is expected to give such Hb levels would have to be 2850 ml in the first 24 hours postoperatively, and 100 ml over the following 24 hours, more than 50% of the preoperative BV in males and 65% of females. The authors believe that hemodilution in the setting of hypotension results in postoperative anemia. Because of the hemodilution, postoperative hemoglobin levels are not a reliable indicator or anemia and unlikely represent a true need for transfusion in the acute postoperative phase after hypotensive anesthesia (Figure 3).

While blood loss decreases proportionally to mean arterial pressure, more profound hypotension does not reduce transfusion requirements [5,31]. A meta-analysis studying the effects of deliberate hypotension reveals reduced transfusion requirements for patients undergoing total hip and total knee arthroplasty [18]. However, only 3 of the 17 randomized trials mentioned transfusion rates, and only one study reports transfusion rates in patients undergoing total hip arthroplasty. Data from another meta-analysis reported a reduction in measured blood loss by 275 mL in elective THA with neuraxial block versus general anesthesia [32]. The literature lacks comprehensive data on transfusion rates in anemic and non-anemic patients undergoing hypotensive anesthesia. Existing studies do not follow standardized transfusion triggers or protocols. The transfusion rate of 8.5% in this series of non-anemic patients appears high and the drop in perioperative hemoglobin does not mirror the minimal invasive nature of the surgery and measured blood loss. Hypotensive anesthesia might prove detrimental in this patient subgroup in terms of assessing transfusion requirements.

In summary, hypotensive anesthesia has undisputed benefits for procedures with a large intraoperative blood loss [2,18]. However with the current advent of less invasive surgical techniques and local measures to reduce blood loss (fibrin sealants, coagulation, tranexamic acid), it is likely less beneficial for primary total hip replacement. The significant amount of fluid given to stabilize the blood pressure results in hemodilution and probably increases exposure to allogeneic blood transfusions. Further research with accurate tracking of the perioperative changes in patients' blood volumes could provide further insight into the impact of hypotensive anesthesia on postoperative transfusion requirements in total hiparthroplasty.

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