The Effect of Induced Hypotension on Intraoperative Blood Loss during Spinal Surgery

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= Abstract =

Background: This study was performed to evaluate whether the degree of hypotension influences blood loss during spinal surgery.

Method: Fifty patients undergoing only one level spinal fusion were assigned to one of three groups. In group 1 (n = 14), the systolic blood pressure (SBP) was maintained at 100–120 mmHg with enflurane. In groups 2 (n = 18) and 3 (n = 18), the SBP were maintained at 80–100 and 60–80 mmHg, respectively. Hydralazine and esmolol were used in the hypotensive groups.

Results: Blood losses during operation in groups 2 (554 ± 287 ml) and 3 (456 ± 162 ml) were significantly lower than in group 1 (1141 ± 690 ml) ($P < 0.05$), although there was no significant difference between groups 2 and 3. The percentage of patients receiving transfusions during the operation in groups 1 and 2 were 57.1 and 5.6%, respectively.

Conclusions: The results show that a moderate reduction in SBP (80–100 mmHg) reduces blood loss by more than half in comparison to a mild reduction in SBP (100–120 mmHg). However, a severe reduction in SBP (60–80 mmHg) does not increase the reduction in blood loss in comparison to moderate hypotension. (Korean J Anesthesiol 2000; 38: S 6~S 12)

Key Words: Anesthetic technique: induced hypotension. Hemorrhage: blood loss. Pharmacology: esmolol; hydralazine.

INTRODUCTION

Spinal surgery may be associated with uncontrollable bleeding. To decrease blood loss, induced hypotension has been advocated for improving operative conditions or decreasing the need for blood transfusions. However, there have been different opinions among authors about the benefits of in-

duced hypotension on the reduction of blood loss, such as: 1) Does induced hypotension in fact reduce blood loss? 2) If so, at the least, how much blood pressure should be reduced? 3) Does the degree of hypotension influence blood loss?

Patel et al¹⁾ found improvement in blood loss by reducing 20 or 30 mmHg less than the preoperative systolic blood pressure (SBP), and McNeil et al,²⁾ by lowering SBP to at least 40 mmHg below preoperative blood pressure in scoliosis surgery. Amaranath et al³⁾ found a high correlation between blood loss and intraoperative SBP in total hip replacement. Sharrock et al⁴⁾ also showed that different degrees of hypotension significantly influenced blood loss under epidural anesthesia. But,

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they studied with only one level of induced hypotension,^{1,2)} used a variety of hypotensive agents,³⁾ did not include severe lowering of SBP,³⁾ and did not include a normotensive control group.⁴⁾

So, this study considered the following: 1) The number of vertebral levels for spinal fusion was limited to a single level to avoid the possibility of bias from multiple levels. 2) The hypotensive agents were restricted to hydralazine and esmolol in hypotensive groups. 3) Patients were divided into three groups, the control group, the moderate hypotensive group and the severe hypotensive group according to SBP. 4) The degree of hypotension at which a reduction in blood loss began to occur was analyzed. 5) Whether further levels of hypotension would result in proportionately further reductions in blood loss was analyzed. 6) And finally, as a secondary objective, the effect of induced hypotension upon urine output was analyzed.

METHODS

The author prospectively studied 50 ASA class I and II patients undergoing posterior lumbar spinal fusion for only one level. This study was approved by the institutional human investigation committee, and informed written consent was obtained from all patients. Patients who had hypertension, or central nervous system, cardiac, liver or renal disorders were excluded from this study. All patients were free of previous spinal surgery. Patients were randomly allocated to three groups, group 1 (SBP, 100–120 mmHg), group 2 (80–100 mmHg) and group 3 (60–80 mmHg). The characteristics of patients, such as sex, age, weight, and preoperative levels of hemoglobin and albumin, were recorded.

All patients were premedicated with glycopyrrolate 0.1 mg and midazolam 3 mg, IM, an hour before induction of anesthesia and pretreated with fentanyl 50 µg, IV, just before induction of anesthesia. Anesthesia was induced with thiopental sodium, 5 mg/kg, IV. All patients received pancuro-

nium, 0.08–0.1 mg/kg, IV, to facilitate endotracheal intubation. Anesthesia was maintained with nitrous oxide 50% in oxygen and enflurane 1 to 2%. Fentanyl, 50 µg, IV, was supplemented as needed. Ventilation was controlled to maintain PaCO₂ between 35 and 40 mmHg. A neuromuscular blockade was maintained with pancuronium, 1 mg, IV. Monitoring included electrocardiogram, central venous pressure (CVP), urine output, and arterial blood pressure and arterial blood gas analysis with a radial artery catheter. All patients received intravenous fluids consisting of lactated Ringer's solution at a rate of about 5 ml/kg/h. The patients were placed in a prone position on a Wilson supporting frame, allowing the patients' abdomens to hang freely to reduce intra-abdominal pressure during operation. The patients were placed in a 10° Trendelenburg position to improve venous drainage. An epinephrine mixture to minimize blood loss was not injected subcutaneously before skin incision.

Hypotension in groups 2 and 3 was induced by hydralazine, 10 to 20 mg, IV, before skin incision. After skin incision, an additional dosage of hydralazine, 5 to 10 mg, was added until the target range of SBP was obtained. Esmolol, 5 to 10 mg, IV, was given to keep pulse rate below 100 beats/min to assist the achievement of hypotension. It took 5–15 min. to reach the target SBP. Hypotension was maintained until the beginning of wound closure. When the closing began, the patient's SBP was reversed to the level before induced hypotension by reducing the concentration of enflurane. During operation, the SBP was kept in the middle of the target range of the SBP in each group. The CVP was maintained between + 1 and – 1 cmH₂O of initial CVP, which was measured before incision during prone position in each patient. The same surgeon performed all operations and the same anesthesiologist performed all anesthetics. The surgical team was blinded to the hypotensive anesthetic technique.

Intraoperative blood loss was measured by the

author by weighing the blood soaked gauzes and the contents of the suction bottle, deducting the irrigation fluid. Two milliliters of lactated Ringer's solution was infused for each ml of blood loss until the calculated "allowable blood loss (ABL)" was reached. Ten percent pentastarch was infused slowly when blood loss was expected to be more than 400 ml. The following formula for ABL was used:

$ABL = \text{Estimated blood volume} \times (\text{Initial Hct} - \text{Target Hct}) / \text{Initial Hct}$

EBV: 70 ml/kg in adult male, 65 ml/kg in adult female, Target Hct: 30%

When blood loss was more than ABL, a transfusion of packed red cells mixed with an equal amount of warm saline was begun according to the principle of an equivalent volume replacement for blood loss over ABL. A Hemovac (Zimmer, USA) evacuator was placed for 1 to 5 days postoperatively in all patients until the quantity of blood drained was markedly reduced. And the blood collected in the Hemovac was measured daily. Transfusions were ordered during the postoperative period whenever the level of hemoglobin fell below 8 g/dl. The amounts of packed red cells transfused during and after operation were recorded. Hourly urine output during the study period and postoperation was measured.

Data were analyzed with ANOVA. Differences were considered significant when $P < 0.05$.

RESULTS

There were no significant differences in sex, age, weight and preoperative SBP among the three groups (Table 1).

Intraoperative blood loss in groups 2 (554 ± 287 ml) and 3 (456 ± 162 ml) was significantly lower than that in group 1 (1141 ± 690 ml), respectively. Blood loss in groups 2 and 3 was decreased by 51.4 and 60.1%, respectively, as compared to that in group 1. However, the difference in blood loss during operation between groups 2 and 3 was not significant. No significant differences were seen in blood loss after operation among the three groups. There were no significant differences in operating time among the three groups (Table 2).

Table 1. Demographic Data of Patients

	Group 1 (n = 14)	Group 2 (n = 18)	Group 3 (n = 18)
Sex (M/F, n)	6/8	7/11	8/10
Age (yr)	48.4 ± 14.7	50.1 ± 14.1	46.8 ± 11.3
Weight (kg)	63.6 ± 7.3	62.3 ± 13.1	58.2 ± 9.1
Preop. SBP (mmHg)	119.0 ± 11.9	121.8 ± 13.6	118.4 ± 9.3

Values are mean $\pm$ SD unless otherwise indicated. Group 1: SBP 100–120 mmHg, Group 2: SBP 80–100 mmHg, Group 3: SBP 60–80 mmHg, Preop.: preoperative, SBP: systolic blood pressure.

Table 2. Blood Loss during and after Operation and Operating Time

	Group 1 (n = 14)	Group 2 (n = 18)	Group 3 (n = 18)
Blood loss during op. (ml)	1141 ± 690	$554 \pm 287^*$	$456 \pm 162^*$
Per operating time (ml/min)	8.2	4.3	3.6
Operating time (min)	139.8 ± 28.4	129.7 ± 22.7	127.8 ± 16.6
Blood loss after op. (ml)	624 ± 249	514 ± 263	603 ± 191

Values are mean $\pm$ SD. Group 1: SBP 100–120 mmHg, Group 2: SBP 80–100 mmHg, Group 3: SBP 60–80 mmHg, op.: operation, *: $P < 0.05$ compared with Group 1.

Table 3. Blood Transfusion Requirement and Fluid Replacement

	Group 1 (n = 14)	Group 2 (n = 18)	Group 3 (n = 18)
Number of units of PRBC during op. (percent of patients receiving transfusion)	2.5 (57.1)	2 (5.6)	0 (0)
Number of units of PRBC after op. (percent of patients receiving transfusion)	2 (7.1)	2.3 (16.7)	1.8 (27.8)
Fluid replacement during op. (ml)	2650 $\pm$ 815	2169 $\pm$ 574	2044 $\pm$ 408*

Number of units is mean value and fluid replacement is mean $\pm$ SD. Group 1: SBP 100–120 mmHg, Group 2: SBP 80–100 mmHg, Group 3: SBP 60–80 mmHg, PRBC: packed red blood cell, op.: operation, *: P < 0.05 compared with Group 1.

Table 4. Perioperative Data of Hemoglobin, Albumin and Urine Output

	Group 1 (n = 14)	Group 2 (n = 18)	Group 3 (n = 18)
Hb (g/dl)			
Before operation	13.0 $\pm$ 1.8	13.4 $\pm$ 1.3	13.5 $\pm$ 2.1
After operation	10.3 $\pm$ 0.9	10.8 $\pm$ 1.6	10.8 $\pm$ 1.9
Drop in Hb	2.7	2.6	2.7
Albumin (g/dl)			
Before operation	4.4 $\pm$ 0.3	4.3 $\pm$ 0.4	4.3 $\pm$ 0.4
After operation	2.9 $\pm$ 0.3	3.1 $\pm$ 0.5	3.1 $\pm$ 0.3
Drop in albumin	1.5	1.2	1.2
Urine output (ml/h)			
During operation	31.7 $\pm$ 41.1	16.4 $\pm$ 21.4	7.3 $\pm$ 10.8*
After operation	143.7 $\pm$ 104.8	159.6 $\pm$ 95.0	206.6 $\pm$ 132.7

Values are mean $\pm$ SD. Group 1: SBP 100–120 mmHg, Group 2: SBP 80–100 mmHg, Group 3: SBP 60–80 mmHg, Hb: hemoglobin, *: P < 0.05 compared with Group 1.

During operation, 57.1% of the patient in group 1 and 5.6% of the patient in group 2 received transfusions, but no transfusions were given in group 3. Postoperatively, the percentage of patients receiving transfusions in groups 1, 2 and 3 were 7.1, 16.7 and 27.8%, respectively (Table 3).

The differences in the levels of hemoglobin and albumin before and after operation among the three groups were not significant. The urine output in group 3 (7.3 $\pm$ 10.8 ml/h) during operation was significantly lower than in group 1 (31.7 $\pm$ 41.1 ml/h). No significant differences in the urine output after operation were seen among the three groups (Table 4).

The dosages of hydralazine administered during surgery were 17.5 $\pm$ 8.8 mg in group 2 and 21.9 $\pm$ 7.1 mg in group 3. The dosages of esmolol administered during surgery were 89.2 $\pm$ 109.7 mg in group 2 and 69.2 $\pm$ 62.4 mg in group 3.

DISCUSSION

There has been disagreement about which factor is more significant in determining arterial pressure and cardiac output in reducing blood loss during induced hypotension. Sivarajan et al⁵⁾ showed that blood pressure influenced blood loss, but cardiac output did not influence it. On the other hand,

Knight et al⁶⁾ demonstrated that LVSWI was the only hemodynamic index that showed a significant correlation with blood loss. So, an increase in cardiac output, even at hypotensive levels, would seem to increase LVSWI and blood loss.^{6,7)} In this study, a moderate reduction in SBP was associated with a significant reduction in blood loss. However, there was no significant difference in blood loss between the moderate and severe hypotensive groups.

The effects of induced hypotension in blood loss were varied among the authors because many factors were correlated, such as various kinds of hypotensive agents, mean circulatory filling pressure (MCFP), intra-abdominal pressure, the position of the patient and vasoconstriction of ruptured blood vessels.

It was suggested that different hypotensive agents with different pharmacological properties could have various effects on blood loss.⁸⁾ In this study, hydralazine with esmolol supplementation was given. Under the influence of hydralazine, the preferential dilation of arterioles compared with veins, and the reflex increase in the heart rate and contractility, promoted an increase in cardiac output.⁹⁻¹¹⁾ In contrast, the effect of esmolol was found to decrease cardiac output.¹²⁾ Consequently, concomitant administration with esmolol to limit the reflex increase in sympathetic nervous system activity induced by hydralazine was thought to reduce blood loss.

The MCFP is a measure of the degree of the filling of the circulatory system and is a major factor that determines cardiac output. Abdominal compression of the large venous reservoirs in the abdomen increases the MCFP, which increase venous return and cardiac output.¹³⁾ The patients in this study could not be completely free from abdominal compression during operation so that further reduction in blood loss in deep hypotension was hardly obtained.

When the patient is lying prone, the intra-abdominal pressure is increased, resulting in vena caval

compression that increases the pressure in the venous channels around the spine, which in turn may increase bleeding during exposure of the spine.⁷⁾ In this study, the author measured the shoulder width of each patient and adjusted the width of a Wilson frame to that width to avoid abdominal compression as much as possible in each patient. In Amaranath et al's and Sharrock et al's studies,^{3,4)} the patients were positioned laterally during hip surgery. Therefore, the operating site could be located higher above the level of the heart, and there was also less risk of abdominal compression than for those in the prone position during spinal surgery in this study. Therefore, the reduction in blood loss discovered according to the degree of induced hypotension in the former studies could be accounted for by the greater effect of gravity. But, in this study, deeper levels of hypotension compared to moderate hypotension did not yield any decrease in intraoperative blood loss.

Immediate vasoconstriction is the first stage of hemostasis when a blood vessel is ruptured. Boezaart et al¹⁴⁾ compared surgical conditions for functional endoscopic sinus surgery during induced hypotension, using SNP and esmolol. They concluded that poor surgical conditions in the SNP group were probably due to arteriolar vasodilatation. This suggests that blood vessels should not be dilated at the site of operation because this might counteract some of the benefits of low pressure.¹⁵⁾ A vasodilator like hydralazine itself might interfere with the benefits of both the vasoconstriction of ruptured blood vessels and the decrease in blood loss intraoperatively and/or postoperatively. In this study, a probable reason for observing no significant difference in blood loss between the moderate and severe hypotensive groups could be related to this factor.

Malcolm-smith and McMaster¹⁶⁾ removed the drains on the second postoperative day in all patients and showed that blood loss after operation in the hypotensive group (533 ml) was significantly lower

than that in the normotensive group (1014 ml). In this study, blood loss was measured from the drains until the draining almost stopped, anywhere between the first and fifth day, and there were no differences in blood loss among the groups. The reasons for disagreement in postoperative blood loss between Malcolm-smith and McMaster's study and this study may be related to following factors. First, the different residual vasodilative effect of agents after operation can affect the postoperative blood loss. In Malcolm-smith and McMaster's study, they used SNP and trimethaphan. But, in this study hydralazine was used. So, immediate vasoconstriction after operation cannot be anticipated. Second, the extent of operation may have affected postoperative blood loss. An average of 10.8 or 10.1 vertebrae were fused in Malcolm-smith and McMaster's study; whereas, only 2 vertebrae were fused in this study.

Park^{17,18)} studied the urine output and liver function under induced hypotension. Park¹⁷⁾ showed that oliguria was noted during induced hypotension (SBP: 65–75 mmHg), although renal failure did not occur after operation. In this study, all patients had recovered from oliguria after induced hypotension. Regarding liver function, Park¹⁸⁾ suggested that severe reduction in SBP (60–80 mmHg) could not exclude the possibility of liver damage. Furthermore, there was no difference in blood loss between moderate and severe hypotension in this study. Accordingly, it's better to avoid severe hypotension at the risk of oliguria and liver damage.

It might be surprising that the patients subjected to the greatest degree of hypotension (group 3) required a smaller mean dosage of esmolol than the patients in group 2. This was because the patients in group 3 were maintained with a bit larger dosage of hydralazine and deeper levels of anesthesia with enflurane than those in group 2.

The findings show that moderate and profound hypotension reduced blood loss to 50–60% of the normotensive group, and that there were fewer

transfusions required intraoperatively for the hypotensive patients. However, there was no significant difference in blood loss between the two hypotensive groups. This study has shown that it is not necessary to lower SBP excessively in order to reduce blood loss at the risk of oliguria.

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