The Effect of Patient Positioning on Intraabdominal Pressure and Blood Loss in Spinal Surgery

Chang Kil Park, MD

Department of Anesthesiology, Eulji University School of Medicine, Taejon, Korea

Intraabdominal pressure (IAP) can influence blood loss during spinal surgery. We examined the relationship of IAP changes to blood loss with a rectal balloon pressure catheter. Forty patients were randomly assigned to narrow (Group 1) or wide (Group 2) pad support widths of the Wilson frame. IAP was measured when the patient was supine after the induction of anesthesia, prone on a gurney, prone on the Wilson frame before and after incision, and then, again supine after tracheal extubation. IAP in the prone position on the Wilson frame before incision (3.6 cm H_2O) in Group 2 was significantly less than in Group 1 (8.8 cm H_2O) ($P < 0.05$). Intraoperative blood loss per vertebra in Group 2 (190 ± 65 mL) was significantly less than in Group 1 (381 ± 236 mL) ($P < 0.05$). The correlation between blood loss and IAP in the prone position on the Wilson frame in Group 1 was significant ($P = 0.0022$). In conclusion, IAP and intraoperative blood loss were significantly less in the wide, than in the narrow, pad support width of the Wilson frame. Blood loss tended to increase with an increase in IAP in the narrow pad support width of the Wilson frame.

(Anesth Analg 2000;91:552–7)

Spine surgeons are concerned about uncontrollable bleeding and have preferred induced hypotension during spinal surgery. However, despite induced hypotension, some patients continue to bleed. This might be related to inadequate positioning of the patient. Pressure on the abdominal contents would be transmitted to the inferior vena cava, and then, to the epidural venous system, thus causing increased bleeding (1). Any pressure on the anterior abdominal wall causes vertebral venous pressure to increase.

A Wilson spinal supporting frame (Fig. 1) has been used exclusively in spinal surgery in my hospital. The Wilson frame provides a convenient and stable method of maintaining patients in a flexed position for spinal surgery. It has two full-length pads which provide continuous support and adjust laterally to improve ventilation and relieve pressure on the abdomen. However, if the pad width is too narrow for the patient, the abdomen can be pressed and intraabdominal pressure (IAP) increases. In fact, an excessive pad may allow the patient to migrate down between the pads. It is necessary that the pad width of the Wilson frame be as wide as possible to decrease IAP, while preventing downward migration of the patient. This poses a unique problem for the Wilson frame compared with the Relton-Hall frame, which is constructed in such a manner that the upper pads support the upper part of the thorax and the lower pads support the pelvis, leaving the abdominal cavity pendulous and free from external pressure (2).

DisTefano et al. (3) and Lee et al. (4) monitored inferior vena cava pressure (IVCP) to indirectly detect the changes in the patient's vertebral venous pressure; however, they did not demonstrate the relationship between IVCP and blood loss. Bostman et al. (5) measured blood loss in two different positionings; however, they did not determine IVCP.

There have been no complete studies examining quantitative changes of IAP resulting from different positions in relation to blood loss. I decided to indirectly monitor changes in vertebral venous pressure by measuring IAP instead.

I considered the following variables: 1) the number of vertebral levels for spinal fusion was limited to one and two levels with the same number of patients between the groups; 2) narrow and wide pad support widths of the Wilson frame were used to determine the effect of pad width on IAP and blood loss; 3) hypotension was induced with hydralazine to a mean arterial pressure (MAP) of 55–65 mm Hg, in both groups; and 4) the correlation between IAP and blood loss was analyzed.

Accepted for publication May 8, 2000.

Address correspondence and reprint requests to Chang Kil Park, MD, Department of Anesthesiology, Eulji University School of Medicine, 24-14 Mok-dong Joong-ku, Taejon, 301-726, Korea. Address e-mail to pck@emc.eulji.ac.kr.

0003-2999/00

Figure 1. A Wilson spinal supporting frame.

Methods

This was a prospective study of 40 ASA physical status I and II patients undergoing posterior lumbar spinal fusion for one or two levels. The study was approved by the institutional human investigation committee and written informed consent was obtained from each patient. Patients who had hypertension, central nervous system, cardiac, liver, or renal disorders were excluded. No patient had previous spinal surgery. Patients entering the study were randomly allocated to either narrow (Group 1, $n = 20$) or wide (Group 2, $n = 20$) pad support widths of the Wilson frame. In Group 1, there were 14 one-level explorations and six two-level operations. In Group 2, the number of one-level explorations was 14, and six for two-level operations. The numbers of one- and two-level operations were the same between the groups.

All patients were premedicated IM with 0.1 mg of glycopyrrolate and 3 mg of midazolam 1 h before anesthesia. Anesthesia was induced with 5 mg/kg IV thiopental. All patients received 0.12 mg/kg IV vecuronium to facilitate endotracheal intubation. Anesthesia was maintained with 50% nitrous oxide in oxygen and 1% to 2% enflurane. Ventilation was controlled to maintain $Paco_2$ between 30 and 40 mm Hg. A neuromuscular block was maintained with 0.3 mg/kg IV vecuronium. Monitoring included electrocardiogram, central venous pressure (CVP), and analysis of arterial blood pressure and arterial blood gas with a radial artery catheter. All patients received IV fluids consisting of lactated Ringer's solution at a rate of approximately 5 $mL \cdot kg^{-1} \cdot h^{-1}$.

IAP was measured in the following positions in both groups: 1) supine after the induction; 2) prone on a gurney; 3) prone on the Wilson frame before and after incision; and 4) supine after tracheal extubation.

A 4.5F polyvinyl chloride, 2 m long, rectal balloon pressure (RBP) catheter (Mediplus; Albyn Medical, United Kingdom) (Fig. 2) was used to measure IAP. The tip is fitted with a preslit latex balloon protection device to ensure that the catheter does not become blocked by fecal matter during use. After induction while the patient was still on the gurney, the catheter was filled with saline and inserted into the rectum of the patient by the anesthesiologist. The catheter was advanced cephalad until the balloon of the catheter completely passed into the rectum. A three-way stopcock was connected to the RBP catheter, and an infusion set was installed longitudinally on the stopcock on a pole. A ruler was attached beside the longitudinal infusion set on the pole to measure IAP.

The zero point was set at the heart level of the patient during different positionings. The level of the heart was determined as follows: an anterior-posterior line that crossed with a lateral line passing both nipples was drawn on the lateral aspects of the patient's upper thoracic cage. The midpoint of the anterior-posterior line was regarded as the zero point for measuring IAP. This point was readjusted at every position with the same method. The longitudinal infusion set was filled with saline to a point above an anticipated level of IAP. Refilling the longitudinal infusion set with saline above the expected level of IAP was repeatedly performed before every measurement in each position. The stopcock was then turned on to allow saline in the longitudinal infusion set to go through the RBP catheter. The upper level of saline slowly dropped and was nearly stabilized, after which the measurements of IAP were started. IAP measurements were made four times with intervals of 3 min during each positioning. The average of these four measurements was regarded as the patient's IAP in that position.

The shoulder width of the patient was measured by a lateral line passing the suprasternal notch, whereas the upper extremities were maintained alongside the patient's flank. The distance of both lateral borders of the pad supports were adjusted to 3 cm shorter than the patient's shoulder width in Group 1 and 3 cm longer in Group 2. The pad support width in Group 2 was thought to be a full width, but not such an excessive width that it might allow the patient to slip down between the pads. The pad supports in each patient were slid into the desired location on the crossbar in parallel. The patients were transferred onto the Wilson frame by lifting the prone patient from the gurney into the prone position atop the frame. The patients were placed in a horizontal position, not the Trendelenburg

ANESTH ANALG
2000;91:552–7

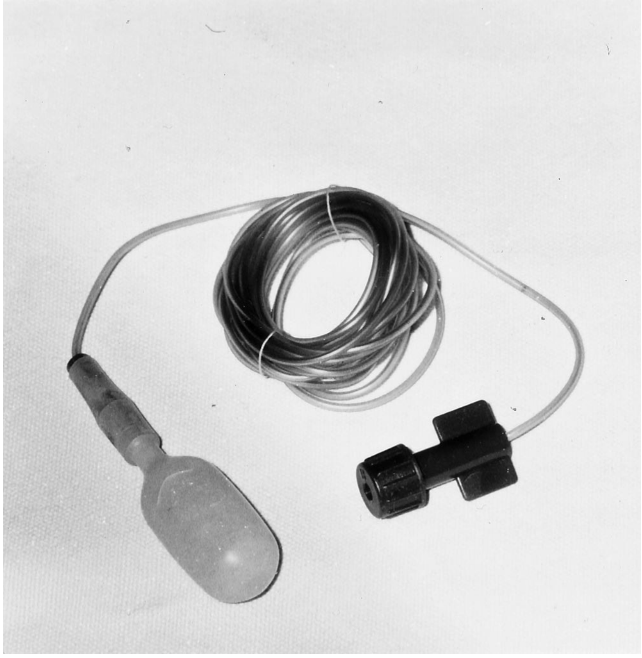

Figure 2. A rectal balloon pressure catheter with a preslit latex balloon protection device at the tip (4.5F polyvinyl chloride catheter, 2 m long, Mediplus; Albyn Medical, United Kingdom).

position. The skin of the abdomen was drawn downward just enough to eliminate any skin folds, thus avoiding anterior abdominal wall tension and allowing the abdomen to hang freely as much as possible. Female breasts were positioned in a comfortable and natural position. The pads of the Wilson frame were fully flexed to decrease lumbar lordosis and to open disk spaces for improved access at the surgical site until screw fixation was started. The pads were completely extended just before the beginning of screw fixation.

Hypotension was induced after IAP measurements and after incision in the prone position on the Wilson frame in both groups. Hypotension was induced by 10 to 20 mg IV hydralazine until the target range of 55–65 mm Hg MAP was obtained. Hypotension was then maintained until the beginning of wound closure. CVP was maintained between +1 and −1 cm H_2O of initial CVP, which was measured before incision during the prone position on the Wilson frame in each patient. When the closing began, the patient's MAP was reversed to the level before hypotension by reducing the concentration of enflurane. All operations were performed by the same surgeon, and the same anesthesiologist performed all anesthesias. The surgical team was blinded to the type of group.

Intraoperative blood loss was measured by weighing blood-soaked gauzes as they were passed off the surgical field. The suction bottle was completely evacuated before operation. Blood contents of the suction

Table 1. Demographic Data of Patients

	Group 1 (n = 20)	Group 2 (n = 20)
Age (yr)	58.6 ± 6.8	50.2 ± 11.4*
Sex (m/f)	5/15	9/11
Weight (kg)	59.9 ± 7.7	62.1 ± 7.2
Height (cm)	157.0 ± 5.5	160.9 ± 10.8
Shoulder width (cm)	39.6 ± 1.2	40.8 ± 1.2
Pad support width of Wilson frame (cm)	36.6 ± 1.2	43.8 ± 1.2*
Preoperative MAP (mm Hg)	89.9 ± 8.1	91.7 ± 9.9

Values are mean ± SD except sex.
* $P < 0.05$ compared with Group 1.

bottle were measured with a measuring cylinder calibrated up to 1 L, just before the irrigation began. Once irrigation was finished, irrigation solution was emptied, and the suctioned blood was collected in the suction bottle. Blood on the drapes in the surgical field was negligible. Total blood loss in one-level (two vertebrae) and two-level (three vertebrae) operations was calculated into blood loss per one vertebra in each patient. Two milliliters of lactated Ringer's solution was infused for each mL of blood loss until calculated "allowable blood loss" (ABL) was reached. Pentastarch (10%) was infused slowly when blood loss was expected to be more than 400 mL. The following formula for ABL was used:

ABL = Estimated blood volume × (Initial hematocrit − Target hematocrit)/Initial hematocrit

where estimated blood volume is 70 mL/kg in adult men and 65 mL/kg in adult women and target hematocrit is 30%.

When blood loss was more than ABL and the level of hemoglobin decreased to <8 g/dL, transfusions of packed red cells mixed with an equal amount of warm saline was begun. The amounts of packed red cells transfused during operation were recorded.

Data were analyzed with Student's paired *t*-test within groups and two sample *t*-tests between groups. However, we used Wilcoxon's two-sample test to compare total blood loss and blood loss per vertebra, and the number of patients transfused was compared with a Fisher's exact test. Differences of $P < 0.05$ were considered significant. Correlation analysis was performed between blood loss and IAP in each group.

Results

There were no significant differences between the groups in sex, weight, height, shoulder width, and preoperative MAP, except for age and pad support width of the Wilson frame (Table 1).

IAP in the prone position on the gurney was not different from that in the supine position in each

Table 2. The Changes of Intraabdominal Pressure of Patients (cm H_2O)

		Prone			
			On Wilson frame		
	Supine after induction	Without frame	Preincision	Postincision	Supine after extubation
Group 1 ($n = 20$)	6.9 ± 2.5	6.7 ± 2.6	8.8 ± 3.1*	10.6 ± 4.0†	13.3 ± 4.6*
Group 2 ($n = 20$)	7.0 ± 3.3	7.8 ± 3.3	3.6 ± 3.2*‡	4.7 ± 3.6*†‡	13.0 ± 5.0*

Values are mean ± SD.
* $P < 0.05$ compared with supine after induction.
† $P < 0.05$ compared with preincision.
‡ $P < 0.05$ compared with Group 1.

group. IAP in the prone position on the Wilson frame before incision (8.8 cm H_2O) was significantly more than that in the supine position after the induction (6.9 cm H_2O) in Group 1 ($P < 0.05$). However, in Group 2, IAP in the prone position on the Wilson frame before incision (3.6 cm H_2O) was significantly less than that in the supine position after the induction (7.0 cm H_2O) ($P < 0.05$). IAP in the prone position on the Wilson frame after incision was 10.6 cm H_2O in Group 1 and 4.7 cm H_2O in Group 2 and was higher than that of preincision in each group ($P < 0.05$). IAP in the supine position after tracheal extubation was the most in each group. In a comparison between the groups, IAPs in the prone position on the Wilson frame before and after incision in Group 2 were significantly less than those in Group 1 ($P < 0.05$) (Table 2).

Intraoperative blood loss in Group 2 (436 ± 159 mL) was significantly less than in Group 1 (878 ± 521 mL) ($P < 0.05$). Blood loss per vertebra in Group 2 (190 ± 65 mL) was also significantly less than that in Group 1 (381 ± 236 mL) ($P < 0.05$). There were no significant differences in operating, hypotensive, and anesthetic time between the groups. During operation, five patients in Group 1 and one patient in Group 2 received transfusions. The differences in the level of hemoglobin before and after operation between the groups were not significant (Table 3). The dosage of hydralazine administered during surgery was 16.3 ± 5.3 mg in Group 1 and 16.4 ± 4.8 mg in Group 2. Correlation between blood loss per vertebra and IAP in the prone position on the Wilson frame after incision was significant in Group 1 ($P = 0.0022$) (Fig. 3), but not significant in Group 2 ($P = 0.5313$) (Fig. 4).

Table 3. Blood Loss and Fluid Replacement During Spinal Surgery

	Group 1 ($n = 20$)	Group 2 ($n = 20$)
Total blood loss (mL)	878 ± 521	436 ± 159*
Blood loss/vertebra (mL)	381 ± 236	190 ± 65*
Number of patients transfused	5	1
Mean units of packed red cells	2.2	2
Fluid replacement (mL)	2175 ± 611	1685 ± 406*
Preoperative Hb (gm/dL)	13.1 ± 1.0	13.1 ± 1.4
Postoperative Hb (gm/dL)	10.6 ± 1.1	11.3 ± 1.1
Operating time (min)	136.8 ± 23.7	134.0 ± 27.8
Hypotensive time (min)	103.0 ± 25.7	101.5 ± 22.0
Anesthetic time (min)	219.3 ± 34.3	203.3 ± 33.6

Values are mean ± SD.
* $P < 0.05$ compared with Group 1.
Hb = hemoglobin.

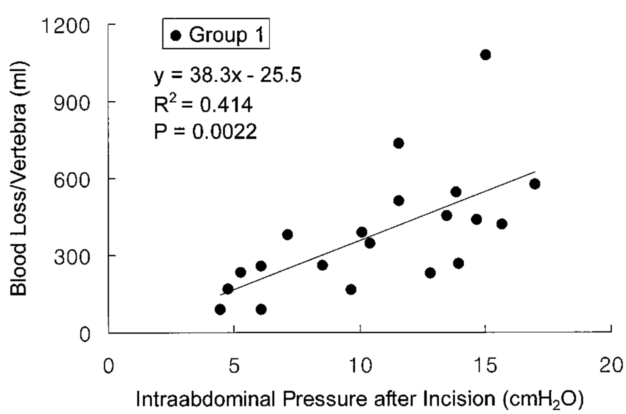

Figure 3. Correlation of blood loss per vertebra with intraabdominal pressure in the prone position on the Wilson frame after incision in Group 1. There was a significant correlation. y = blood loss/vertebra.

Discussion

Some patients continue to bleed during spinal surgery despite deliberate hypotension. Whether this circumstance can be ascribed to position and other factors is unknown. This study sought to identify any effect of abdominal compression on intraoperative blood loss.

Batson (6) demonstrated a valveless communication between the vertebral veins and inferior vena cava. When a patient is lying prone, IAP increases, resulting in vena cava compression that increases pressure in the venous channels around the spine. This, in turn, can cause increased bleeding during spinal exposure.

Many efforts have been made to avoid abdominal compression during spinal surgery (2–5,7). Bostman et al. (5) showed that blood loss in a frame-supported kneeling position was much less than in the prone position on bolsters. They supposed that this result

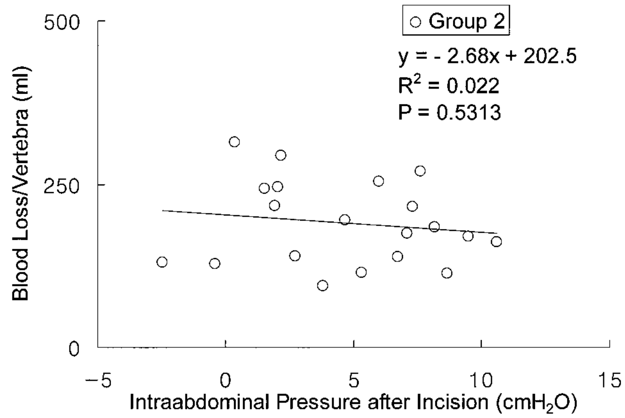

Figure 4. Correlation of blood loss per vertebra with intraabdominal pressure in the prone position on the Wilson frame after incision in Group 2. The regression plot does not show a significant correlation. y = blood loss/vertebra.

was because of decreased IVCP in the kneeling position; however, they did not measure IVCP or IAP. Lee et al. (4) studied changes of IVCP when the same patient was prone on a conventional pad and on a Relton-Hall frame. In their study, many kinds of surgery were included and there was no control group. Therefore, they could not evaluate the efficacy of improved patient positioning for the reduction of blood loss. Sunden et al. (7) used the Wilson spinal frame and found that increased pressure occurred in lumbar epidural veins with the frame. They demonstrated that the amount of blood loss was significantly less by using a vacuum pillow than a Wilson spinal frame; however, they did not measure IAP.

In the narrow type of the Wilson frame in the current study, IAP in the prone position on the frame was significantly greater than in the supine position after the induction. This suggests that flexed pads in narrow pad support width could compress the patient's abdomen instead of relieving abdominal compression. However, in the wide type of the Wilson frame, the patient was positioned carefully in the wide pad support width, so that IAP in the prone position on the Wilson frame was significantly decreased compared with that in the supine position after the induction. IAP in the prone position on the Wilson frame after incision was greater than that before incision in both groups because of continuous downward pressure during surgery. IAP on supine position after tracheal extubation was the highest among all positionings in both groups, because of self-respiration of the patient and abdominal straining because of surgical pain. This means that full relaxation of abdominal muscle is necessary to relieve IAP during operation.

Blood loss in the wide pad support width of the Wilson frame was much less than that in the narrow pad support width. Blood loss per vertebra tended to increase with an increase in IAP in the narrow pad support width of the Wilson frame. These results show that every effort should be made to give adequate support without allowing external pressure on the anterior abdominal wall to decrease IAP during spinal surgery.

Spinal surgeons usually prefer a position that decreases lordosis of the lumbar spine and opens the posterior intervertebral spaces, thus facilitating entrance into the spinal canal. This can be achieved by the Wilson frame with fully flexed pads which allows extreme kyphosis of the lumbar spine. However, if the pad width is too narrow for the patient, there is not enough space between the pads to allow the abdominal contents to be pendulous. Fully lifted narrow pads should compress the abdomen and increase IAP. On the contrary, if the pad is too wide it is difficult for the surgeon to approach the intervertebral space because excessive kyphosis of the lumbar spine cannot be achieved, and the patient could slip down between the pads, although more abdominal compression is relieved. Accordingly, it is difficult to simultaneously satisfy the two goals of lumbar kyphosis and abdominal decompression with the Wilson frame.

IAP after incision did not show all of the changes in IAP which occur during spinal surgery. After initiation of induced hypotension, another set of measurements for IAP were attempted; however, they were frequently interrupted during the middle of operation as the fully flexed pads had to be fully released before the start of screw fixation. Therefore, the baseline for IAP measurement was shifted downward, after which it could not be measured. In the current study, the pad support width was narrow in Group 1 and wide in Group 2. IAP readings of the same patient in the narrow and wide pad support widths could not be made because of a busy operating room schedule.

Bhatia et al. (8) demonstrated a significant correlation between bladder and rectal pressure recordings ($r = 0.91$). Al-Taher et al. (9) showed excellent correlation between vesical and rectal pressures in response to changes in abdominal pressure. It appears that rectal pressure recording is a reliable method for IAP measurement. It can be realized by observing the immediate response of a conductive fluid column when surgeons press the surgical site and when there is abdominal straining because of surgical pain after tracheal extubation. In this study, the measurements changed from minute to minute. Accordingly, I measured IAP four times with three-minute intervals during each positioning and then, I took an average. The fluid column in the longitudinal IV infusion set oscillated simultaneously with patient inspiration and expiration. If the oscillation did not show, the RBP catheter was considered to have become blocked by fecal matter, and the measurements were discontinued in that patient.

In conclusion, IAP and intraoperative blood loss were less in the wide than in the narrow pad support width of the Wilson frame. In a correlation between IAP and blood loss, blood loss per vertebra tended to increase with an increase in IAP in the narrow pad support width of the Wilson frame.

References

1. Sleath GW, Archer LT. Halothane for controlled hypotension in back surgery. Can Anaesth Soc J 1967;14:407–11.
2. Relton JES, Hall JE. An operation frame for spinal fusion: A new apparatus designed to reduce hemorrhage during operation. J Bone Joint Surg Br 1967;49:327–32.
3. DisTefano VJ, Klein KS, Nixon JE, Andrews ET. Intraoperative analysis of the effects of position and body habitus on surgery of the low back: A preliminary report. Clin Orthop 1974;99:51–6.
4. Lee TC, Yang LC, Chen HJ. Effect of patient position and hypotensive anesthesia on inferior vena caval pressure. Spine 1998;23:941–8.
5. Bostman O, Hyrkas J, Hirvensalo E, Kallio E. Blood loss, operating time and positioning of the patient in lumbar disc surgery. Spine 1990;15:360–3.
6. Batson OV. The function of vertebral veins and their role in the spread of metastases. Ann Surg 1940;112:138–49.
7. Sunden G, Walloe A, Wingstrand H. A new device to reduce intra-abdominal pressure during lumbar surgery. Spine 1986; 11:635–6.
8. Bhatia NN, Bergman A. Urodynamic appraisal of vaginal versus rectal pressure recordings as indication of intra-abdominal pressure changes. Urology 1986;27:482–5.
9. Al-Taher H, Sutherst JR, Richmond DH, Brown MC. Vaginal pressure as an index of intra-abdominal pressure during urodynamic evaluation. Br J Urol 1987;59:529–32.