The Effect of Two Levels of Hypotension on Intraoperative Blood Loss During Total Hip Arthroplasty Performed Under Lumbar Epidural Anesthesia

Nigel E. Sharrock, MB, ChB, Robert Mineo, MS, Barbara Urquhart, RN, BSN, and Eduardo A. Salvati, MD

Departments of Anesthesiology and Orthopaedic Surgery, The Hospital for Special Surgery, New York, New York

The degree of induced hypotension necessary to achieve a significant reduction in intraoperative blood loss has never been defined. Forty patients undergoing primary total hip arthroplasty during epidural anesthesia by a single surgeon were randomly assigned to have mean arterial pressure maintained at 50 ± 5 mm Hg or 60 ± 5 mm Hg throughout surgery. Intraoperative blood loss was 179 ± 73 mL in the 50 mm Hg group and 263 ± 98 mL in the 60 mm Hg group (P = 0.004). Subjectively, there was more bleeding during surgery in the 60 mm Hg group during dissection of the hip joint (P = 0.0026) and while reaming the acetabulum (P = 0.0001) and femur (P = 0.0001). No difference in transfusion requirements, postoperative hematocrit, or duration of surgery was noted. A difference in mean arterial blood pressure of 10 mm Hg from 50 to 60 mm Hg during surgery for total hip arthroplasty under epidural anesthesia has a measurable effect on intraoperative blood loss.

(Anesth Analg 1993;76:580–4)

Induced hypotension is associated with less intraoperative blood loss during total hip arthroplasty (1–3), but the degree of hypotension necessary to achieve this reduction has never been defined. This is an important issue because there is little virtue in providing more profound intraoperative hypotension if a lesser degree will suffice.

We chose to study this question in a group of patients undergoing primary total hip arthroplasty by a single surgeon. Blood loss was assessed with target mean arterial pressure maintained at 50 or 60 mm Hg throughout surgery. These pressures were chosen because they constitute the range of induced hypotension used in clinical practice (4,5).

Methods

Following Institutional Review Board approval, 40 patients undergoing primary unilateral total hip arthroplasty by a single surgeon consented to be studied. All had hybrid total hip arthroplasty (noncemented acetabular and cemented femoral components) performed via the posterior approach in the lateral decubitus position. No patients received drugs to induce anticoagulation perioperatively. Exclusion criteria included bleeding disorder, aortic or mitral stenosis, carotid occlusion disease, ankylosing spondylitis, prior lumbar spinal surgery, operations involving cemented acetabulum, trochanteric osteotomy, or acetabular bone graft.

All patients received lumbar epidural anesthesia using 20–25 mL 0.75% bupivacaine injected via a Tuohy needle. Catheters were inserted, and each patient received 150 μg of epidural fentanyl plus additional 0.75% bupivacaine if necessary to extend the level to T-4 or above. All patients received nasal oxygen at 3 L/min and intravenous (IV) midazolam for sedation during surgery, 20-gauge ipsilateral radial artery cannulae, and central venous pressure monitoring.

Patients were randomly allocated to a mean arterial pressure (MAP) of between 45 to 54 mm Hg or 55 to 65 mm Hg to be maintained throughout surgery. Induced hypotension was achieved with the extensive epidural blockade. Hemodynamic stability was maintained by an IV infusion of low-dose epinephrine (1–5 μg/min) and IV lactated Ringer's solution. To facilitate achieving a disparity in pressures, upper lumbar interspaces (L1-2) were used preferentially in the lower pressure group (45–54 mm Hg); whereas lower lumbar interspaces (L3-4 or L4-5) were utilized in the 55–65 mm Hg group.

This paper was presented at The XI Annual European Society of Regional Anesthesia Congress, Brussels, Belgium, June 9-12, 1992.

Accepted for publication September 30, 1992.

Address correspondence and reprint requests to Nigel E. Sharrock, MB, ChB, Dept. of Anesthesiology, The Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021.

0003-2999/93/$5.00

Heart rate, MAP, central venous pressure (CVP), and oxygen saturation were measured before epidural injection (baseline), at the time of surgical incision, and every 15 min during surgery.

Intraoperative blood loss was measured by a nurse who was blinded to the degree of hypotension. Sponges were weighed as they were passed off the surgical field, and irrigation and suction volumes were measured. A qualitative assessment of the degree of bleeding in the wound was made by the surgeon after skin incision, during exposure of the hip joint, and during reaming of the acetabulum and the femur. The surgeon was unaware of the degree of hypotension and characterized the bleeding as normal, less or greater than normal. Total wound drainage via a closed low-suction system was also measured during the first 24 h postoperatively. Hematocrits were measured preoperatively and on the first and second postoperative days in all patients. All perioperative transfusions (homologous and autologous) were recorded.

Preoperative demographics, ASA status, comorbidities, serum creatinine, bilirubin, aspartate aminotransferase, activated partial thromboplastin time (aPTT), prothrombin time (PT), and platelet count were measured. The duration of surgery and the volume of lactated Ringer's solution administered during surgery were recorded.

Differences in blood loss, surgical time, and IV fluid administered between groups were analyzed using two-tailed unpaired Student's *t*-tests. Differences between qualitative assessment of bleeding at each stage of surgery was assessed using Mann-Whitney *U* test. Differences in hemodynamic variables between groups were assessed using one-way ANOVA with the Scheffé test applied for repeated measures. Relationships between bleeding and age, heart rate, and CVP were assessed by simple linear regression within each blood pressure group. The relationship between intraoperative blood loss and the average intraoperative systolic, diastolic, and mean arterial pressures was assessed in all 40 patients using simple linear regression. α was set at 0.05.

Results

There were no significant differences in patient characteristics between the groups. No patients had abnormal aPTT, PT, platelet count, liver function tests, or elevated serum creatinine preoperatively. The mean age was 69 ± 13 and 62 ± 11 in the 45–54 mm Hg and 55–65 mm Hg groups, respectively. Eight patients were ASA III in the 45–54 mm Hg group and three were ASA III in the 55–65 mm Hg group. The mean surgical duration was 79.4 ± 13.4 min in the 45–54 mm Hg group and 83.4 ± 14.2 min in the 55–65 mm Hg group (P = NS). The volume of crystalloid administered was 1032.5 ± 215.9 ml and 1220 ± 349.9 mL in the 45–54 and 55–65 mm Hg groups, respectively ($P = 0.05$) (Table 1). Intravenous hydralazine (5 or 10 mg) was necessary to augment the hypotension in four patients in the 45–54 mm Hg group and five patients in the 55–65 mm Hg group.

Table 1. Comparison of Demographics

	45–54 mm Hg group	55–65 mm Hg group	*P* value
Sex (M/F)	8/12	14/6	NS
Age (yr)	69 ± 13	62 ± 11	NS
Height (cm)	164 ± 10	169 ± 10	NS
Weight (kg)	70 ± 16	77 ± 13	NS
ASA			
I	4 (20%)	7 (35%)	NS
II	8 (40%)	10 (50%)	
III	8 (40%)	2 (15%)	
Fluid (mL)	1032.5 ± 215.9	1220 ± 349.9	0.05
Duration of surgery (min)	79.4 ± 13.4	83.4 ± 14.2	NS

Mean ± SD. NS, not significant.

Mean heart rate, CVP, MAP, and oxygen saturation are shown in Table 2. Mean target MAPs were achieved in both groups of patients at all observational points. CVP and oxygen saturation were similar between groups. Heart rate was significantly lower in the 45–54 mm Hg group at all observation points, but the change from baseline was not significantly different between groups (Table 2).

Measured intraoperative blood loss was 179 ± 73 mL in the 45–54 mm Hg group and 263 ± 98 mL in the 55–65 mm Hg group ($P = 0.004$). Postoperative drainage was 356 ± 150 mL and 313 ± 153 mL in the 45–54 and 55–65 mm Hg group, respectively (P = NS) (Table 3). Total measured blood loss was not different between groups.

Intraoperative blood loss was not significantly related to age ($r^2 = 0.02$ and $r^2 = 0.09$), to the average intraoperative CVP ($r^2 = 0.005$ and $r^2 = 0.001$), to the volume of lactated Ringer's solution infused during surgery ($r^2 = 0.1$ and $r^2 = 0.06$), or to the average intraoperative heart rate ($r^2 = 0.2$ and $r^2 = 0.001$) in either the 45–54 or 55–65 mm Hg groups, respectively. When all 40 patients were considered, intraoperative blood loss was significantly related to the average systolic pressure ($r = 0.101$ and $P = 0.0453$), diastolic pressure ($r = 0.506$ and $P = 0.0009$), and MAP ($r = 0.465$ and $P = 0.0025$) (Figure 1).

No significant differences in the qualitative assessment of bleeding were noted after skin incision. However, significantly less bleeding was noted in the lower blood pressure (45–54 mm Hg) group during exposure of the hip joint ($P = 0.0026$), reaming of the acetabulum ($P = 0.0001$), and the femur ($P = 0.0001$) (Table 4).

Table 2. Intraoperative Hemodynamic Comparisons

	mm Hg group	Baseline	Surgical incision	15 min	30 min	45 min	60 min	75 min
Heart rate	45–54	70.4 ± 12	65.7 ± 10.5**	63.1 ± 11**	61.7 ± 11.7**	61 ± 12.2**	62.9 ± 13.1**	65.2 ± 10.7**
	55–65	74.4 ± 10	74.9 ± 12.8	70.8 ± 12.2	72.8 ± 10	71 ± 8.9	72.4 ± 10.5	74.5 ± 8.7
Mean arterial pressure	45–54	104 ± 17	51 ± 6*	49 ± 4*	50 ± 4*	50 ± 4*	51 ± 5*	54 ± 9**
	55–65	102 ± 12	65 ± 8	61 ± 4	61 ± 5	62 ± 5	62 ± 5	62 ± 5
Central venous pressure	45–54	3.9 ± 2.2	3.8 ± 2.1	3.8 ± 1.9	3.7 ± 1.8	3.2 ± 1.7	3.2 ± 1.6	3.8 ± 1.2
	55–65	3.8 ± 1.8	4.9 ± 1.8	4.6 ± 2.2	4.2 ± 1.8	4.2 ± 2	4.2 ± 2	3.7 ± 1.2
Oxygen saturation	45–54	99	99	99	99	99	99	99
	55–65	99	99	99	99	99	99	99

Mean ± SD.
* $P = 0.0001$.
** $P < 0.05$.

Table 3. Blood Loss Comparison

	45–54 mm Hg group	55–65 mm Hg group	P value
Intraoperative (mL)	179 ± 73 (100–320)	263 ± 98 (130–500)	0.004
Postoperative (mL)	356 ± 150	313 ± 153	NS
Total blood loss (mL)	535 ± 175	576 ± 193	NS
Preoperative hematocrit (%)	39.0 ± 4.0	39.0 ± 4.0	NS
Postoperative day 1 hematocrit (%)	31.7 ± 3.4	32.9 ± 3.9	NS
Postoperative day 2 hematocrit (%)	31.5 ± 4.0	32.0 ± 3.8	NS
No. of patients transfused	13	13	

Mean ± SD. NS, not significant.

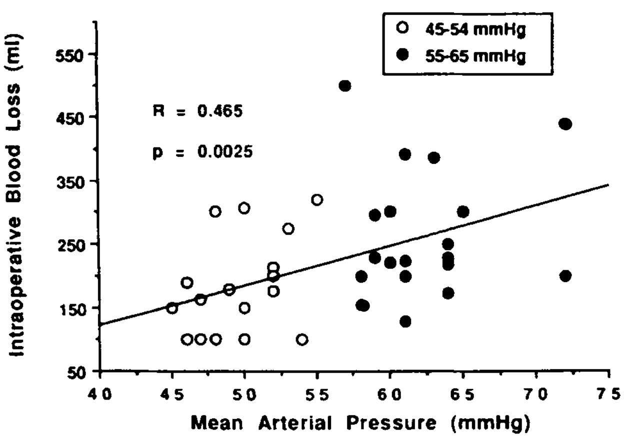

Figure 1. The relationship between intraoperative blood loss and the average intraoperative mean arterial pressure ($r = 0.465$, $P = 0.0025$).

Preoperative hematocrit was similar between groups (Table 3). Hematocrit decreases were similar postoperatively in both groups. No significant differences in transfusion requirements were observed. Thirteen patients in each group received transfusion: 20 received autologous and 6 received homologous blood (Table 3).

Table 4. Surgical Assessment of Bleeding

mm Hg group		Skin	Capsule	Acetabulum	Femur
45–54	Less	10[a]	11	11	13
(n = 20)	Moderate	5	5	8	6
	Excessive	5	4	1	1
55–65	Less	7	2	1	1
(n = 20)	Moderate	4	4	4	9
	Excessive	9	14	15	10
P value		NS	0.0026	0.0001	0.0001

NS, not significant.
[a] Each number represents number of patients.

Discussion

This study demonstrated a significant reduction in objective and subjective indices of blood loss between a MAP of 50 ± 5 and 60 ± 5 mm Hg during total hip arthroplasty. This 10 mm Hg difference in MAP was associated with a mean difference in intraoperative blood loss of 85 mL. Previous studies have demonstrated that blood loss is less with induced hypotension than with normotensive anesthesia (1–3,6–8), but no previous studies have examined the effect of different degrees of hypotension. Recommendations have suggested that MAP should be reduced to the point at which bleeding appears to be reduced (5,9). Although this is a reasonable recommendation, this study demonstrates that lower blood losses can be achieved by further reducing intraoperative arterial pressure.

Although this study demonstrates a difference in bleeding between two degrees of hypotension, it does not provide information about the relationship between blood loss and MAP over a wider range of pressures. Blood loss during total hip arthroplasty using normotensive anesthesia ranges from 500 to 1800 mL (10–17). This suggests a proportionately larger increase in blood loss with increasing MAP, but whether this relationship is linear or curvilinear is not clear.

It has been suggested that bleeding during surgery is, at least in part, dependent on venous pressure in the wound (9, 18–21). This is most apparent during general anesthesia where higher venous pressures occur, especially if ventilation is controlled (19,20). In the lateral decubitus position, the surgical wound is above the level of the right atrium. Venous pressure in the wound, therefore, tends to be lower than CVP. The lack of a relationship between CVP and blood loss in this study suggests that, at least with this anesthesia technique for this surgical procedure, bleeding is independent of venous pressure. This, however, may not apply to other surgical procedures or to total hip arthroplasty performed using controlled ventilation with general anesthesia.

There has been controversy in the literature regarding the mechanisms whereby blood loss is reduced using regional rather than general anesthesia (19,20). Several studies have implied that blood loss is less with regional anesthesia in spite of maintaining similar MAP (13,17,21–23). This has lead to the clinical practice of maintaining normal MAP using regional anesthesia (19–21). This study, however, supports the notion that further reductions in blood loss can be achieved by decreasing MAP during regional anesthesia.

One of the interesting observations in this study was the clear relationship between blood loss and MAP during reaming of the acetabulum and of the femur, whereas none was observed with skin incision. Perhaps bleeding from bone is more dependent on hypotension than bleeding from soft tissue. The reduction in bone bleeding may be particularly advantageous during cemented total hip arthroplasty because a dry bone surface facilitates the quality of the cement-bone microinterlock (24,25).

Induced hypotension improves the surgical field (18) and generally is believed to shorten the duration of surgery (1,7,8), but this has not been observed consistently (5,21). Surgical duration was 4 min longer in the 55–65 mm Hg group, but this was not statistically significant. It has been argued that with intraoperative hypotension it may be difficult to obtain complete hemostasis so that, with restoration of blood pressure at the end of surgery, excessive bleeding into the wound may occur. Previous studies have failed to show this (1,3,7,8,21); and, although we observed a slightly higher postoperative drainage in the 55–65 mm Hg group, this was not statistically significant.

Both subjective and objective means of measuring blood loss were utilized to provide a better overall assessment of potential differences. To avoid bias, all observers were blinded. The qualitative assessment by the surgeon was based on the usual level of blood loss experienced in the hospital wherein a MAP of 50–55 mm Hg is provided for the majority of patients undergoing total hip arthroplasty. In 15 of the cases with the higher pressure, the surgeon reported blood losses in excess of his expectations during reaming of the acetabulum, but only in one of the cases with the lower pressure.

In this study, we were unable to demonstrate any reduction in transfusion requirements, postoperative hematocrit, or in the duration of surgery between groups, even though intraoperative blood loss was reduced in the group with more profound hypotension. For this reason, it could be argued that lesser degrees of hypotension (e.g., mean of 60 mm Hg) are sufficient to minimize blood loss using epidural anesthesia. On the other hand, hypotensive anesthesia has been shown to improve the quality of cement-bone fixation of the acetabular component by plain x-ray (26). Other authors have shown that maintaining a blood-free bone surface improves the quality of the cement-bone microinterlock (25,27). In view of the low morbidity and mortality using this technique in elderly patients (26), a lower MAP is probably justified when inserting a cemented arthroplasty to improve the interdigitation of cement and bone (24,25).

References

1. Barbier-Böhm G, Desmonts JM, Couderc E, et al. Comparative effects of induced hypotension and normovolaemic haemodilution on blood loss in total hip arthroplasty. Br J Anaesth 1980; 52:1039–42.
2. Lawson NW, Thompson DS, Nelson CL, et al. Sodium nitroprusside-induced hypotension for supine total hip replacement. Anesth Analg 1976;55:654–62.
3. Keith I. Anaesthesia and blood loss in total hip replacement. Anaesthesia 1977;32:444–50.
4. Bernard J-M, Pinaud M, Francois T, et al. Deliberate hypotension with nicardipine or nitroprusside during total hip arthroplasty. Anesth Analg 1991;73:341–5.
5. Miller EDJ. Deliberate hypotension. In: Miller RD, ed. Anesthesia. New York: Churchill Livingstone, 1990:1347–67.
6. Davis NJ, Jennings JJ, Harris WH. Induced hypotensive anesthesia for total hip replacement. Clin Orthop 1974;93–8.
7. Thompson GE, Miller RD, Stevens WC, et al. Hypotensive anesthesia for total hip arthroplasty: a study of blood loss and organ function (brain, heart, liver, and kidney). Anesthesiology 1978;48:91–6.
8. Vazeery AK, Lunde O. Controlled hypotension in hip joint surgery: an assessment of surgical haemorrhage during sodium nitroprusside infusion. Acta Orthop Scand 1979;50:433–41.
9. Donald JR. Induced hypotension and blood loss during surgery [Editorial]. J R Soc Med 1982;75:149–51.
10. Eriksson BI, Kälebo P, Anthmyr BA, et al. Prevention of deep-vein thrombosis and pulmonary embolism after total hip replacement. J Bone Joint Surg [Am] 1991;73-A:484–93.
11. Maloney WJ, Krushell RJ, Jasty M, et al. Incidence of heterotopic ossification after total hip replacement: Effect of the type of fixation of the femoral component. J Bone Joint Surg [Am] 1991; 73-A:191–3.
12. McMurray MR, Birnbaum MA, Walter NE. Intraoperative autologous transfusion in primary and revision total hip arthroplasty. J Arthroplasty 1990;5:61–5.
13. Modig J, Maripuu E, Sahlstedt B. Thromboembolism following total hip replacement: a prospective investigation of 94 patients with emphasis on the efficacy of lumbar epidural anesthesia in prophylaxis. Reg Anesth 1986;11:72–9.

14. Paiement G, Wessinger S, Waltman A, et al. Low dose warfarin versus pneumatic compression for prophylaxis against venous thromboembolism following total hip replacement. J Arthroplasty 1987;2:23–6.
15. Planès A, Vochelle N, Fagola M, et al. Prevention of deep vein thrombosis after total hip replacement. The effect of low-molecular-weight heparin with spinal and general anaesthesia. J Bone Joint Surg [Br] 1991;73-B:418–22.
16. Torholm C, Broeng L, Jorgensen PS, et al. Thromboprophylaxis by low-molecular-weight heparin in elective hip surgery. J Bone Joint Surg [Br] 1991;73-B:434–8.
17. Twyman R, Kirwan T, Fennelly M. Blood loss reduced during hip arthroplasty by lumbar plexus block. J Bone Joint Surg [Br] 1990;72-B:770–1.
18. Eckenhoff JE. Deliberate hypotension. Anesthesiology 1978;48: 87–8.
19. Modig J. Beneficial effects on intraoperative and postoperative blood loss in total hip replacement when performed under lumbar epidural anesthesia. An explanatory study. Acta Chir Scand Suppl 1988;550:95–103.
20. Modig J. Regional anaesthesia and blood loss. Acta Anaesthesiol Scand Suppl 1988;32:44–8.
21. Rosberg B, Fredin H, Gustafson C. Anesthetic techniques and surgical blood loss in total hip arthroplasty. Acta Anaesthesiol Scand 1982;26:189–93.
22. Chin SP, Abou-Madi MN, Eurin B, et al. Blood loss in total hip replacement. Extradural v. phenoperidine analgesia. Br J Anaesth 1982;54:491–5.
23. Sculco TP, Ranawat C. The use of spinal anesthesia for total hip-replacement arthroplasty. J Bone Joint Surg [Am] 1975;57-A: 173–7.
24. Ranawat CS, Beaver WB, Sharrock NE, et al. Effect of hypotensive epidural anaesthesia on acetabular cement-bone fixation in total hip arthroplasty. J Bone Joint Surg [Br] 1991;73-B:779–82.
25. Bannister GC, Young SK, Baker AS, et al. Control of bleeding in cemented arthroplasty. J Bone Joint Surg [Br] 1990;72-B:444–6.
26. Sharrock NE, Mineo R, Urquhart B. Haemodynamic effects and outcome analysis of hypotensive extradural anaesthesia in controlled hypertensive patients undergoing total hip arthroplasty. Br J Anaesth 1991;67:17–25.
27. Eftekhar NS, Nercessian O. Incidence and mechanism of failure of cemented acetabular component in total hip arthroplasty. Orthop Clin North Am 1988;19:557–66.