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The Influence of Systolic Blood Pressure at the Time of Extubation on the Development of Postoperative Spinal Epidural Hematoma

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Background: The most common cause of neurological complications after a biportal endoscopic spine surgery (BESS) is postoperative spinal epidural hematomas (POSEH). The objective of this study was to determine the influence of systolic blood pressure at extubation (e-SBP) on POSEH.

Methods: A total of 352 patients who underwent single-level decompression surgery including laminectomy and/or discectomy with BESS under the diagnosis of spinal stenosis and herniated nucleus pulposus between August 1, 2018, and June 30, 2021, were reviewed retrospectively. The patients were divided into two, a POSEH group and a normal group without POSEH (no neurological complication). The e-SBP, demographic factors, and the preoperative and intraoperative factors suspected to influence the POSEH were analyzed. The e-SBP was converted to a categorical variable by the threshold level that was decided by maximum area under the curve (AUC) in receiver operating characteristic (ROC) curve analysis. Antiplatelet drugs (APDs) were taken in 21 patients (6.0%), discontinued in 24 patients (6.8%), and not taken in 307 patients (87.2%). Tranexamic acid (TXA) was used in 292 patients (83.0%) in the perioperative period.

Results: Of the 352 patients, 18 patients (5.1%) underwent revision surgery for the removal of POSEH. The POSEH and normal groups were homogenous in age, sex, diagnosis, operation segments, operation time, and lab findings that were related to blood clotting, whereas there were differences in e-SBP (163.7 ± 15.7 mmHg in POSEH group and 154.1 ± 18.3 mmHg in normal group), APD (4 takers, 2 stoppers, 12 non-takers in POSEH group and 16 takers, 22 stoppers, 296 non-takers in normal group), and TXA (12 use, 6 not use in POSEH group and 280 use, 54 not use in normal group) in single variable analysis. The highest AUC in the ROC curve analysis was 0.652 for 170 mmHg e-SBP ($p < 0.05$). There were 94 patients in the high e-SBP group (≥ 170 mmHg) and 258 patients in the low e-SBP group. In multivariable logistic regression analysis, only high e-SBP was a significant risk factor for POSEH ($p = 0.013$; odds ratio, 3.434).

Conclusions: High e-SBP (≥ 170 mmHg) can influence the development of POSEH in biportal endoscopic spine surgery.

Keywords: *Postoperative spinal epidural hematoma, Extubation systolic blood pressure, Biportal endoscopic spine surgery*

Postoperative spinal epidural hematomas (POSEH) are the most frequent cause of neurological complications after a spine surgery although the incidence is rare.[1] The most important thing to prevent permanent sequelae is early detection and evacuation.[2-6] The incidence of POSEH on magnetic resonance imaging (MRI) is as high as 15%–89%; however, symptomatic cases that need evacuation are only 0.1%–0.7%.[7-11] Symptomatic POSEH develop more frequently in biportal endoscopic spine surgery (BESS),[12]

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which may be attributable to bleeding masked due to the hydrostatic pressure and more difficult hemostasis than in a conventional open surgery. Awareness about the risk factors is pivotal to establish preventive measures. Although there have been many studies on the risk factors, their results are not consistent with each other. And suction drainage was useless to prevent POSEH.[1,13-17] In most cases POSEH developed within a few hours from the end of the surgery.[4,5] We conjectured that if intraoperative hemostasis was accomplished appropriately, massive bleeding during the short duration after wound closure would be necessary to develop POSEH under the presence of a vacuum drain. Sudden rising of systolic blood pressure at the time of extubation may contribute to such a condition. We hypothesized that high systolic blood pressure at extubation (e-SBP) would increase the incidence of POSEH and designed this study to prove it. The study participants were limited to those who underwent single-segment posterior lumbar decompression including laminectomy and/or discectomy with BESS to eliminate the influence of surgical factors (e.g., instrumented or uninstrumented, multiple or single segment).

METHODS

This study obtained approval of the public Institutional Review Board (No. POI-202012–21-017) and written informed consent from the patients was exempted. It was a retrospective single-center study. The patients who underwent lumbar single-level decompression surgery including laminectomy and/or discectomy under the diagnosis of spinal stenosis and herniated nucleus pulposus (HNP) with BESS technique in our institution between August 1, 2018, and June 30, 2021, were analyzed. Those who had a foraminal decompression only or those who underwent a surgery under spinal anesthesia were excluded. There were 352 eligible cases. The diagnosis was spinal stenosis in 247 cases (70.2%) and HNP in 105 cases (29.8%). There were 21 cases (6.0%) that had taken antiplatelet drugs (APDs) until the day before the operation, 24 cases (6.8%) that stopped them according to the individual guideline, and 307 cases (87.2%) that had not taken them. There were 292 cases (83.0%) that used tranexamic acid (TXA) intraoperatively and 60 cases (17.0%) did not due to contraindications to intravenous administration such as a medical history of deep vein thrombosis or pulmonary thromboembolism, acute myocardial infarction, heart failure, heart valve stenosis, ischemic stroke, coagulopathy, allergy to TXA, and severe liver or kidney disease (Fig. 1). The most commonly operated segment was L4–5 (214 cases, 60.8%), followed by L3–4 (66 cases, 18.8%) and L5–S1 (38 cases, 10.8%). The presence of POSEH was defined as the development of unprecedented neurological symptoms after operation, which was confirmed by MRI and improved immediately after revision surgery. All patients were divided into two groups, a POSEH group and a normal group who did not have POSEH, and their relevant variables were compared. Demographic factors such as age and sex, surgical factors such as diagnosis, operated segment, and operating time, and blood coagulation-related factors such as platelet count, prothrombin time, activated partial thromboplastin time, and epinephrine platelet function analysis, and medication factors such as whether taking APD or not and whether using a TXA during the operation were analyzed to ensure homogeneity. The e-SBP was also compared. All significant factors in single variable analysis proved their independency through multivariable logistic regression analysis. For the multivariable analysis, the e-SBP was converted to a categorical variable using the receiver operating characteristic curve. Among

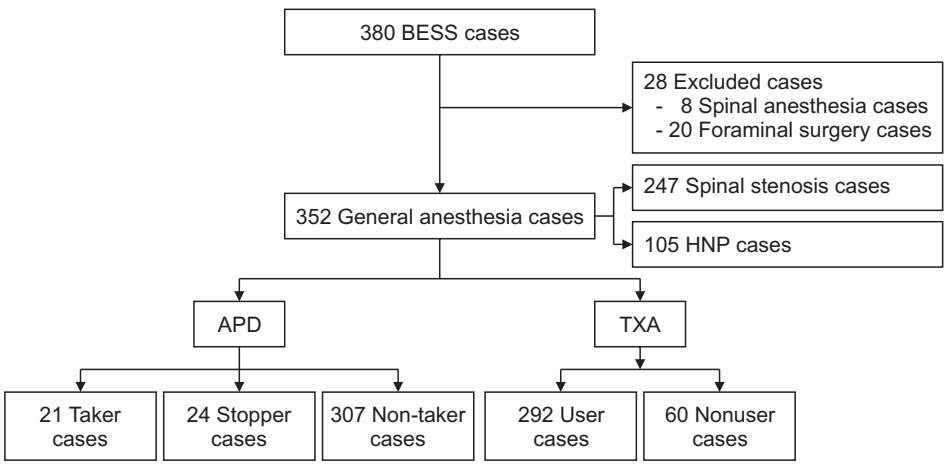

Fig. 1. Flowchart of study population. BESS: biportal endoscopic spine surgery, HNP: herniated nucleus pulposus, APD: antiplatelet drug, TXA: tranexamic acid.

150, 160, 170, and 180 mmHg, 170 mmHg had the highest area under the curve (Fig. 2). Finally, among all patients, those with high e-SBP (≥ 170 mmHg) were classified into the hypertension group and those with a normal e-SBP (< 170 mmHg) were classified into the normal group, and their relevant variables were compared.

Operation Method

Under general anesthesia with the patient placed in prone position, two portals were made over the target segment. Through the left side portal of the operator, an endoscope was inserted, and instruments were inserted through the right one. A saline infusion pump was used for continuous irrigation and the pressure was adjusted between 30 and 40 mmHg. The radiofrequency coagulator (ArthroCare) and the bipolar electrocautery (Valleylab; Medtronic) were used for soft-tissue hemostasis, and bone wax (Ethicon) was applied for hemostasis of the bone surface. TXA (10 mg/kg) was injected intravenously at the commencement of the operation as necessary. After finishing the decompression, thrombin-containing local hemostatic (Collastat; Dalim) was applied to control trivial bleeding. After compression for 4 minutes, the remaining particles that were not associated with the hemostatic clots were removed by irrigation. All cases had a drain line that was connected to a vacuum bag that had negative pressure of 120–140 mmHg (Ez-VAC). The target systolic blood pressure for all patients was 90 to 110 mmHg during surgery.

Evacuation of POSEH

The patients who developed neurological symptoms that had not been present before the operation such as radicular pain and had an MRI-confirmed thecal sac compressing more than 50% of the hematoma were indicated for evacuation of POSEH (Fig. 3). In all patients, the procedure was performed under local anesthesia using the BESS technique. The improvement of symptoms was verified on the spot during the procedure.

Statistical Analysis

Homogeneity between the two groups was analyzed with a *t*-test for continuous variables and a chi-square test or Fisher exact test for categorical variables. And those with a freedom degree less than 5 were done with linear by linear association. The level of significance was set as $p \leq 0.05$. The significance of the single variables for the multivariable analysis was set as $p < 0.1$. All *t*-tests get two-tailed values. SPSS ver. 12.0 (SPSS Inc., Chicago, IL, USA) was used.

RESULTS

Eighteen of the 352 patients (5.1%) underwent revision surgery due to POSEH. The homogeneity of the two groups is shown in Table 1. Regarding surgical and coagulation-related variables, there was no statistically significant difference. However, APD medication was more common and intraoperative TXA injection was less common in the POSEH group. There was statistically significant difference in the e-SBP (163.7 ± 15.7 mmHg in the POSEH group and 154.1 ± 18.3 mmHg in the normal group, $p = 0.021$). The hypertension group (≥ 170 mmHg) had significantly greater POSEH compared to the normal group (< 170 mmHg) (10 cases [10.6%] vs. 8 cases [3.1%], $p = 0.007$).

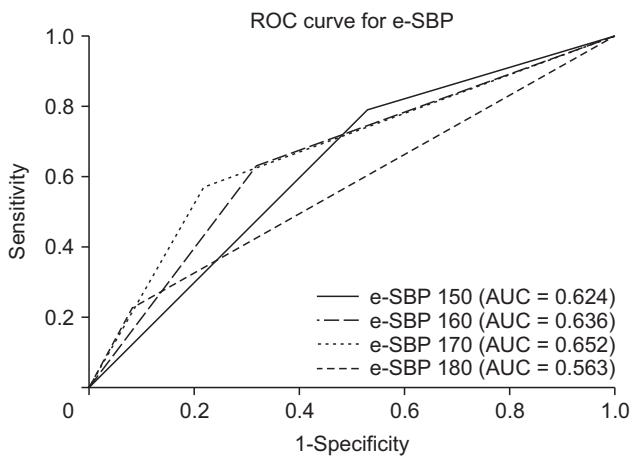

Fig. 2. The receiver operating characteristic (ROC) curves and area under the curve (AUC) values for systolic blood pressure at extubation (e-SBP), which was converted to a categorical variable. Among 150, 160, 170, and 180 mmHg, 170 mmHg had the highest AUC.

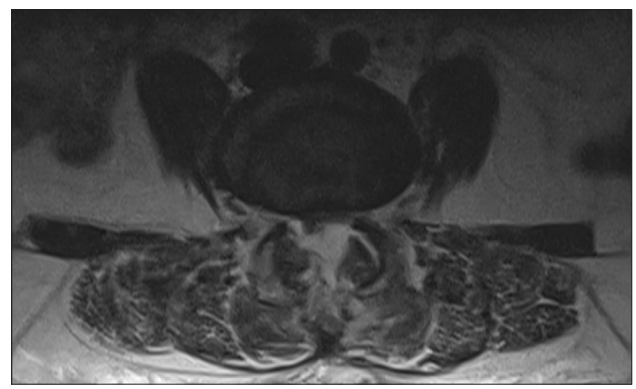

Fig. 3. T2-weighted axial image showing postoperative spinal epidural hematoma that compressed the thecal sac more than 50%.

Table 1. Data of the Patients

Variable	POSEH (n = 18)	Normal (n = 334)	*p*-value
Age (yr)	70.1 ± 7.7	67.4 ± 11.7	0.335
Sex (female : male)	9 : 9	191 : 143	0.628
Diagnosis			0.293
Herniated nucleus pulposus	3	102	
Spinal stenosis	15	232	
Operation segment			0.453
L1–2	2	7	
L2–3	1	24	
L3–4	4	62	
L4–5	9	205	
L5–S1	2	36	
Operation time (min)	126.7 ± 57.2	92.4 ± 45.0	0.205
Platelet count (μL)	23,630 ± 84,470	253,860 ± 67,274	0.184
PT	11.0 ± 0.4	11.0 ± 0.7	0.970
aPTT	28.3 ± 2.7	28.3 ± 3.2	0.973
PFA-epi	174.3 ± 87.6	157.6 ± 69.5	0.426
APD medication			0.038
Taker	4	16	
Stopper	2	22	
Non-taker	12	296	
TXA (use : not use)	12 : 6	280 : 54	0.066
e-SBP (mmHg)	163.7 ± 15.7	154.1 ± 18.3	0.021

Values are presented as mean ± standard deviation.
POSEH: postoperative spinal epidural hematoma, PT: prothrombin time, aPTT: activated partial thromboplastin time, PFA-epi: platelet function analysis-epinephrine, APD: antiplatelet drug, TXA: tranexamic acid, e-SBP: systolic blood pressure at extubation.

Table 2. The Association of APD Medication, TXA Use, and e-SBP with POSEH

Variable	Odds ratio	*p*-value
APD taker	0.243	0.070
APD stopper	0.439	0.393
TXA use	1.406	0.605
e-SBP ≥ 170 mmHg	3.434	0.013

APD: antiplatelet drug, TXA: tranexamic acid, e-SBP: systolic blood pressure at extubation, POSEH: postoperative spinal epidural hematoma.

Multivariable Analysis for Risk Factors

The variables that showed significant difference between the two groups ($p < 0.1$) were APD medication, use of TXA during operation, and e-SBP ≥ 170 mmHg (Table 2). Multivariable logistic regression analysis was applied for the above variables. The e-SBP ≥ 170 mmHg ($p = 0.013$; odds ratio, 3.434) was the only significant factor.

DISCUSSION

POSEH are the most common cause of neurological complications after a spinal surgery.[1-4] Though there are many studies about the risk factors of POSEH, their results were

not agreed upon from each other: old age, Rh+ blood type, alcohol drinking, revision surgery, coagulopathy, increased international normalized ratio, increased intraoperative blood loss, anemia, and obesity.[1-3,18] It is not quite practical to administer preventive measures because most of them are unavoidable factors.

In previous studies, Fujiwara et al.[19] reported that hypertensive illness itself was a risk factor, while Yamada et al.[20] and Tsuge et al.[21] reported that the great difference of blood pressure between intraoperative and at the time of extubation was a risk factor. Ohba et al.[22] noted that perioperative hypertension was a risk factor. We have experienced many cases where systolic blood pressure rises rapidly during extubation after surgery and thought that massive bleeding in short time after skin closure is a pivotal condition to form POSEH and high e-SBP would make such a condition. In our study, APD medication, TXA use, and e-SBP were statistically significantly associated with POSEH. In the multivariable logistic regression analysis, e-SBP ≥ 170 mmHg was the only risk factor for POSEH and the odds ratio was 3.434. Among the statistically significant factors, the APD and the use of TXA are patient factors that cannot be controlled during surgery, and only the e-SBP is considered a factor that can be controlled during surgery. In addition, the significant difference in the incidence of POSEH between the hypertension group (e-SBP ≥ 170 mmHg) and the normal group (e-SBP < 170 mmHg) was also considered to suggest the importance of e-SBP. Based on these findings, e-SBP control, as well as intraoperative meticulous hemostasis, is considered a strategy to reduce POSEH. Therefore, in order to reduce the occurrence of POSEH, it is considered to be important to properly maintain blood pressure not only intraoperatively but also during the perioperative period, especially during the extubation time.

In some studies, hypertension increased the viscosity of blood,[23,24] which may make a vacuum drain dysfunctional. However, in our cases, the POSEH developed while the vacuum drains functioned properly. In the study of Yamada et al.,[20] there was no difference in the amount of drained blood between the normal and POSEH groups. The increased blood viscosity in chronic hypertensive patients causes major circulatory pathologies,[25,26] but the influence in acute conditions as in the postoperative period would be limited. Furthermore, the fibrinogen and hematocrit that influence the viscosity of blood usually decrease after an operation due to intraoperative bleeding.

A vacuum drain was expected to prevent a POSEH; however, based on our literature review, there has been no study to prove that. Rather, most POSEH in previous studies developed in the presence of vacuum drains. We thought that to make a clotted hematoma mass that cannot be drained through vacuum drain lines, there should be a large amount of bleeding in short duration that cannot be drained completely. The vacuum drain was used in all cases in our study. In Mirzai's study on POSEH with MRI,[9] morphological POSEH was found in 89% without a vacuum drain and in 36% with a vacuum drain. However, in the case of symptomatic POSEH, there is no evidence that a vacuum drain can prevent POSEH yet.[1,3,13-17] Although POSEH mostly developed within several hours after operation with a vacuum drain placed, no authors presented their assumption why it could not prevent POSEH. We thought that the current study could give a clue on the reason.

The size of a POSEH matters to develop neurological symptoms.[18,27] The bigger the epidural dead space is, the greater the chance of having POSEH. The reason why a revision surgery is a risk factor is related to this.[28] The size of a potential epidural dead space is thought to be influenced by the instrumentation and the method of wound closure. To reduce the selection bias, we enrolled only the single-level decompression cases by BESS that had similar epidural dead space. In BESS, the detached muscles from the lamina cannot be repaired tightly over the dura mater. The working space is made by hydraulic pressure rather than the retractor. To make a working space, the muscles over the posterior arch are removed or shrunken by electrical cautery. So, the epidural dead space would be bigger than that in conventional open surgery. It has something to do with the reason the previous researchers reported that the incidence of POSEH in BESS was not low.[29,30] Therefore, in BESS with a relatively large potential epidural dead space, stricter blood pressure control is required at extubation time because bleeding can suddenly increase in a very short time.

The incidence of POSEH was higher in our study (5.1%) than that of other studies. The only way to reduce the neurological sequelae is an early evacuation of POSEH.[5,6,17] Although POSEH with mild symptoms could be treated conservatively, final satisfaction was relatively compromised and the authors thought that epidural fibrosis due to the POSEH might be the cause.[9] Hence, we had relatively wide indications of hematoma evacuation as follows: even though there was no motor weakness, if the lower extremity pain was not improved as expected or unprecedented leg pain developed, MRI was performed. And if the compression by POSEH was more than 50% of the thecal sac on MRI, we did hematoma evacuation. All cases were done with BESS under local anesthesia and the symptom improvement was verified at the operation the-

ater immediately. This was the reason why the incidence of POSEH was higher than that in other studies.

Based on the results, we could suggest preventive measures for POSEH as follows: the blood pressure of a patient should be normalized before finishing the operation and meticulous hemostasis should be done. Extubation should be done in a gentle manner and preemptive analgesic administration is recommended to prevent sudden elevation of e-SBP. Finally, e-SBP should be targeted at less than 170 mmHg, and more strict systolic blood pressure control is required in patients taking APD or who cannot use TXA.

There are several limitations of this study including the retrospective design and the relatively small number of study participants. First, although the first-year cases of BESS were not included, the effect of learning curve was not considered. Second, two surgeons performed the operations on the study participants, but the influence of the surgeon factors was not considered. Third, the heterogeneity between the two groups in terms of APD medication and TXA administration during the operation was close to the statistically significant level. However, we verified the independence of e-SBP through the multivariable analysis. Fourth, although we tried to make homogenous subject groups, the operated segment was not considered. Fifth, there was a concern about the increased viscosity of blood in hypertension patients that might hinder the vacuum drainage, but we did not consider the influence of viscosity.

In conclusion, the risk of symptomatic POSEH increased when the peak systolic blood pressure was elevated while extubating the endotracheal tube. It would be helpful to control e-SBP to prevent POSEH.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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