Delayed Onset Postoperative Spinal Epidural Hematoma After Lumbar Spinal Surgery: Incidence, Risk Factors and Clinical Outcomes

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Research article

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Abstract

Background: Posterior spinal epidural hematoma (PSEH) often develops after the surgery within 24 hours. On rare occasions, PSEH happened after 3 days, up to two weeks, which were classified as delayed onset PSEH. Due to its rarity, previous studies only described the clinical features, whereas risk factors cannot be able to assess.

Methods Patients who developed PSEH requiring hematoma evacuation between December 2013 and January 2020 were included and divided into early onset (Group A) and delayed onset group (Group B) based on the time of symptom onset (>72 hours). For each PSEH patients, 3 controls (Group C) who did not develop the PSEH in the same period were randomly selected. Clinical features were compared among three groups and multiple logistic regression analysis was performed to identify the risk factors for group A and B.

Results 32 patients (0.35%) were identified as the early onset PSEH (occurred at 10.68±11.5h) and 15 (0.16%) patients were the delayed onset ones (occurred at 130.60±61.78h). When compare the group A and B, group A showed higher rate of multilevel procedure (Group A: 75%, Group B: 40%, p=0.02), lower drainage (Group A: 239.69±245.70, Group B: 613.67±599.83, p=0.004), lower APTT (Group A: 31.55±4.07, Group B: 35.63±7.24, p=0.018) and higher JOA score at discharge (Group A: 20.68±4.72, Group B: 17.67±4.79, p=0.039). Multiple logistic regression analysis identified multilevel procedure (OR: 5.62, 95% CI: 1.84-17.25), postoperative systolic blood pressure (SBP)(OR: 1.10, 95% CI: 1.06-1.15) and abnormal coagulation (OR: 5.68, 95% CI: 1.74-18.52) as the independent risk factors for group A, whereas for group B, postoperative SBP (OR: 1.10, 95% CI: 1.04-1.16) and previous spinal surgery (OR: 4.74, 95% CI: 1.09-20.70) at the same level were the risk factors.

Conclusions Our study revealed the overall incidence of delayed onset PSEH was 0.16% in posterior lumbar spinal surgery and the risk for it was different from early onset PSEH. For the early onset PSEH, multilevel procedure, postoperative SBP and abnormal coagulation were the risk factors and for the delayed onset PSEH, the postoperative SBP and previous spinal surgery at the same level were the independent risk factors.

Background

Postoperative spinal epidural hematoma (PSEH) is a rare complication after spinal surgery, but can lead to devastating neurological deficits including sensory disturbance, lower extremities weakness, paralysis and bowel dysfunction[1, 2]. Since Jackson first described it as a clinical diagnosis in 1869, more than 1000 cases have been reported in the literature with the incidence, etiology, risk factors and outcomes. Incidence of PSEH was 0.1%-0.4%, which was proved to be increased in patients with age >60, high body mass index (BMI), previous spinal surgery, coagulopathy, use of non-steroidal drugs, intraoperative blood loss >1L, use of gelfoam and multilevel procedure[3–7]. In clinical practice, PSEH often develops after the surgery in a few days, especially in 24 hours. However, on rare occasions, PSEH happened after 3 days, up to two weeks, which were classified as delayed onset PSEH[8]. The cause of delayed onset PSEH is still unknown and because its rarity, previous studies only described its clinical features based on case reports or a small sample cohort, whereas risk factors cannot be able to assess. For example, Spanier DE et.al. first describes an epidural hematoma occurred at 16 days after index surgery in an elder patient who received heparin therapy[9]. Uribe Juan et al. reported 7 cases of PSEH happened with an average time of 5.7 days after original surgery over a 4-year period and observed high ratio of previous spinal surgery in such patients[8]. Additionally, surgeons may not always pay attention to such delayed onset disease which may lead to worse outcomes after the initial surgery.

Therefore, in this study, we aimed to investigate the incidence of delayed onset PSEH and identify the risk factors for it based on the patients who underwent posterior lumbar spinal surgery with instrumentation. Moreover, we enrolled early onset PSEH and compared the risk factors, clinical features and outcomes between two type of PSEH.

Methods
Subjects

This study was approved by the ethics board of our hospital and for this type of study, the informed consent was waived. Patients who underwent posterior lumbar decompression surgery for lumbar spinal stenosis caused by degenerative disease and disc herniation with instrumentation in our hospital between December 2013 and January 2020 were included in this study. The PSEH group patients were diagnosed by symptom (back pain at surgical level, radicular pain at lower limbs and/or neurological deterioration), radiological examination (MRI and/or CT), intraoperative finding (hematoma compressed the dura) and underwent hematoma evacuation. The PSEH group were divided into early onset (Group A) and delayed onset group (Group B) based on the time of symptom onset (>72 hours). For the control group (Group C), those who did not develop the PSEH in the same period were randomly selected using a random number table from the pool of patients. All patients were performed the surgery under the general anesthesia and drainage tube were routinely placed during the surgery. The drainage tube was withdrawn when the volume was less than 50 ml per 24 hours. The exclusion criteria were: (1) LSS caused by trauma, tumor, infectious, deformity and other diseases; (2) PSEH happened at thoracolumbar junction; (3) Initial surgeries were performed at other hospital; (4) incomplete clinical data.

Data Collection

Clinical data, comorbidities and possible risk factors for PSEH including preoperative factors, perioperative factors, postoperative factors, laboratory data, blood pressure at different time were reviewed.

Preoperative factors including the age, gender, body mass index (BMI), comorbidities, previous spinal surgery at the same level, smoking and drinking status, recent medication record, course of disease and radiographic parameters (lumbar lordosis and local lordosis angle) were recorded. Radiographic parameters were recorded from full-length spine lateral X-ray using the Surgimap software (Nemaris, USA). Perioperative factors including multilevel procedure, the length of surgery, estimated blood loss, dural tear, gelfoam dural coverage, number of drainage tube were recorded. Multilevel procedure was defined as a surgical procedure involved more than one intervertebral disc. Postoperative factors including increase of blood pressure after extubation, ratio of ≥ 50mmhg increase in blood pressure after extubation and drainage at evacuation surgery were recorded. Increase of blood pressure after extubation were calculated as difference between average intraoperative blood pressure and highest blood pressure after extubation before back to wards.

Laboratory data were collected including routine blood test (blood cell number, hemoglobin level, hematocrit, platelet count) and coagulation status (prothrombin time, activated partial thromboplastin time, thrombin time, fibrinogen, international standardization rate). Abnormal coagulation was evaluated by platelet count, prothrombin time and activated partial thromboplastin time according to our laboratory standards.

Blood pressure were measured at admission, intraoperative, after extubation and postoperative. The intraoperative blood pressure was measured every 10 minutes when general anesthesia begins, recording as an average level.

Literature review

We also conducted a brief review of published articles that reported delayed onset PSEH between 1998 to 2019 by using Pubmed. The database search was limited to publications enrolled delayed onset PSEH in English. The key words were “spinal epidural hematoma” and “delayed onset spinal epidural hematoma”.

Statistical analysis

Results were recorded and analyzed by SPSS software (version:24, IBM, Armonk, New York). Data are presented as mean ± standard deviation. Between each two group, continuous data were assessed by independent sample t-test and categorical data were assessed by X^2 test and Fisher’s exact test. Univariate analysis was carried out to identify the potential risk factors...
at first. Then multiple logistic regression analysis was applied to recognize the independent risk factors for each type of PSEH, and adjusted odds ratios with 95% confidence intervals were calculated. According to the results of the univariate analysis, factors with a P value less than 0.05 and significant clinical importance (whether P value was less than 0.05 or not) were selected into the multiple logistic regression. The P value < 0.05 was considered significant.

Results

From December 2013 to January 2020, 9258 patients underwent posterior lumbar decompression surgery for lumbar spinal stenosis at our hospital. 47 patients (0.51%) were diagnosed as the PSEH after the initial surgery and underwent the hematoma evacuation. Among them, 32 patients (68.09%) were identified as the early onset PSEH (occurred at 10.68 ± 11.5 h after initial surgery) and 15 patients (31.91%) were the delayed onset PSEH (occurred at 130.60 ± 61.78 h after initial surgery). Another 141 patients who were not develop PSEH were enrolled as control group.

Univariate Analysis

For preoperative factors, there was no significant difference in the ratio of males to females, age, comorbidities, smoking and drinking status, recent medication record, course of the disease and local lordosis angle between each two groups. When compared with group C, group A showed a higher BMI (26.31 ± 2.99 kg/m²), whereas group B showed a higher rate of previous spinal surgery at same level (26.67%) and larger lumbar lordosis (25.95 ± 27.99°). For perioperative factors, none of the estimated blood loss (395.00 ± 193.71 ml vs 506.67 ± 419.56 ml vs 446.92 ± 324.44 ml), duration of surgery (152.20 ± 35.53 min vs 159.64 ± 52.70 min vs 144.59 ± 44.46 min), dural tear and gelfoam dural coverage showed significant difference in group A, B and C, respectively. Only rate of multilevel procedure was significant higher in group A when compared with group B and C. For postoperative factors, increase of systolic blood pressure (SBP) in group C were significant lower than those in two type of PSEH. The drainage in group A were significant lower than group B and C. These data were listed in Table 1.
Table 1
Comparison of preoperative, perioperative and postoperative factors among three groups

|                        | Group A (Early onset) | Group B (Delayed onset) | Group C (Control group) | $P_{A-C}$ | $P_{B-C}$ | $P_{A-B}$ |
|------------------------|-----------------------|-------------------------|-------------------------|-----------|-----------|-----------|
| **Preoperative factors** |                       |                         |                         |           |           |           |
| Age (years)            | 56.65 ± 7.75          | 52.73 ± 13.84           | 55.72 ± 14.34           | 0.72      | 0.44      | 0.22      |
| Sex (Male/Female)      | 15/17                 | 8/7                     | 88/53                   | 0.11      | 0.49      | 0.68      |
| BMI (kg/m²)            | 26.31 ± 2.99          | 25.00 ± 3.10            | 24.32 ± 2.47            | <0.05     | 0.32      | 0.18      |
| Anticoagulation        | 4 (12.50%)            | 1 (6.67%)                | 6 (4.26%)               | 0.09      | 0.51      | 1.00      |
| Nonsteroidal drug      | 18 (56.25%)           | 10 (66.67%)              | 88 (62.41%)             | 0.52      | 0.50      | 0.27      |
| Hypertension           | 17 (53.13%)           | 6 (40%)                  | 50 (35.46%)             | 0.064     | 0.73      | 0.40      |
| Hypertension treatment | 10 (31.25%)           | 3 (20%)                  | 49 (34.75%)             | 0.71      | 0.25      | 0.42      |
| Diabetes (%)           | 6 (18.75%)            | 1 (6.67%)                | 13 (9.22%)              | 0.13      | 0.74      | 0.28      |
| Smoking or drinking    | 2                     | 0                       | 12                      | 1.00      | 0.61      | 1.00      |
| Previous spinal surgery at the same level (%) | 4 (12.50%) | 4 (26.67%) | 8 (5.67%) | 0.24 | **0.018** | 0.25 |
| Course of the disease (years) | 9.64 ± 8.74 | 7.91 ± 7.97 | 9.58 ± 6.41 | 0.96 | 0.36 | 0.53 |
| Lumbar lordosis (°)    | 33.37 ± 24.88         | 25.95 ± 27.99            | 34.76 ± 13.97           | 0.63      | **0.042** | 0.18      |
| Local lordosis angle (°) | 21.06 ± 12.39   | 19.60 ± 15.58            | 20.90 ± 6.27            | 0.92      | 0.55      | 0.75      |
| **Perioperative factors** |                       |                         |                         |           |           |           |
| Multilevel procedure (%) | 24 (75.00%) | 6 (40.00%) | 56 (39.72%) | <0.05 | 0.98 | **0.02** |
| Estimated Blood loss (ml) | 395.00 ± 193.71     | 506.67 ± 419.56          | 446.92 ± 324.44         | 0.39      | 0.51      | 0.22      |
| Duration of surgery (min) | 152.20 ± 35.53    | 159.64 ± 52.70           | 144.59 ± 44.46          | 0.37      | 0.24      | 0.58      |
| Dural tear (%)         | 4 (12.5%)            | 1 (6.67%)                | 8 (5.67%)               | 0.25      | 1.00      | 1.00      |
| Gelfoam dural coverage (%) | 21 (65.63%) | 11 (73.33%) | 72 (51.06%) | 0.14 | 0.10 | 0.74 |
| Number of Drainage tube (number) | 1.09 ± 0.29 | 1.07 ± 0.26 | 1.10 ± 0.30 | 0.93 | 0.69 | 0.76 |
| **Postoperative factors** |                       |                         |                         |           |           |           |
| Increase of SBP after extubation (mmhg) | 27.50 ± 16.11 | 30.00 ± 18.29 | 20.88 ± 13.22 | **0.015** | **0.019** | 0.64 |
| Increase of DBP after extubation (mmhg) | 23.23 ± 13.76 | 20.71 ± 13.84 | 18.11 ± 7.85 | **0.005** | 0.28 | 0.57 |

Values in Bold indicates $p$ value $<0.05$, which is considered as significance difference.

**BMI** body mass index.

Multilevel procedure was defined as a surgical procedure involved more than one intervertebral disc.

Increase of blood pressure after extubation were calculated as difference between average intraoperative blood pressure and highest blood pressure after extubation before back to wards.
|                              | Group A (Early onset) | Group B (Delayed onset) | Group C (Control group) | \(P_{A-C}\) | \(P_{B-C}\) | \(P_{A-B}\) |
|------------------------------|----------------------|------------------------|-------------------------|------------|------------|------------|
| \(\geq 50\) mmHg increase in SBP after extubation (%) | 6 (18.8%)            | 2 (13.3%)              | 15 (10.6%)              | 0.23       | 0.67       | 1.00       |
| Drainage (ml)               | 239.69 ± 245.70      | 613.67 ± 599.83        | 688.19 ± 295.81         | \(<0.05\)  | 0.41       | 0.004      |

Values in Bold indicates \(p\) value \(\leq 0.05\), which is considered as significance difference.

BMI body mass index.

Multilevel procedure was defined as a surgical procedure involved more than one intervertebral disc.

Increase of blood pressure after extubation were calculated as difference between average intraoperative blood pressure and highest blood pressure after extubation before back to wards.

Laboratory data was listed in Table 2. Only APTT and postoperative hemoglobin showed significant difference in group A, group B and group C. There was no significant difference in other laboratory data collected in this study among three groups. According to the coagulation status, 11 patients in group A, 4 patients in group B and 20 patients in group C were respectively classified as abnormal coagulation.
Table 2
Laboratory data

|                      | Group A (Early onset) | Group B (Delayed onset) | Group C (Control group) | \(P_{A-C}\) | \(P_{B-C}\) | \(P_{A-B}\) |
|----------------------|-----------------------|-------------------------|-------------------------|--------------|--------------|--------------|
| **Before surgery**   |                       |                         |                         |              |              |              |
| Red Blood cell \((-10^9/L)\) | 4.64 ± 0.49           | 4.63 ± 0.62             | 4.80 ± 0.58             | 0.16         | 0.31         | 0.96         |
| Hb (g/L)             | 140.71 ± 18.87        | 144.21 ± 17.30          | 146.70 ± 18.61          | 0.11         | 0.63         | 0.56         |
| HCT                  | 0.42 ± 0.05           | 0.43 ± 0.05             | 0.41 ± 0.03             | 0.38         | 0.075        | 0.51         |
| PLT \((-10^9/L)\)    | 237.90 ± 106.02       | 237.93 ± 69.72          | 227.09 ± 55.68          | 0.42         | 0.49         | 0.99         |
| PT (s)               | 10.45 ± 0.69          | 10.65 ± 0.98            | 10.54 ± 1.11            | 0.66         | 0.72         | 0.43         |
| APTT (s)             | 31.55 ± 4.07          | 35.63 ± 7.24            | 34.91 ± 4.21            | <0.05        | 0.56         | 0.018        |
| TT (s)               | 14.35 ± 1.38          | 13.63 ± 1.62            | 14.46 ± 1.58            | 0.72         | 0.06         | 0.13         |
| Fib (g/L)            | 2.89 ± 0.65           | 2.96 ± 0.61             | 2.96 ± 0.56             | 0.49         | 0.97         | 0.71         |
| INR                  | 0.98 ± 0.06           | 0.99 ± 0.08             | 1.01 ± 0.14             | 0.24         | 0.67         | 0.51         |
| Abnormal coagulation (%) | 11 (34.35%)       | 4 (26.7%)               | 20 (14.18%)             | **0.007**    | 0.25         | 0.74         |
| **After surgery**    |                       |                         |                         |              |              |              |
| Red Blood cell \((-10^9/L)\) | 3.52 ± 0.45           | 3.75 ± 0.45             | 3.70 ± 0.47             | 0.07         | 0.67         | 0.11         |
| Hb (g/L)             | 105.33 ± 16.68        | 115.72 ± 40.35          | 113.88 ± 5.98           | <0.05        | 0.62         | 0.28         |
| HCT                  | 0.32 ± 0.044          | 0.36 ± 0.032            | 0.35 ± 0.042            | 0.001        | 0.35         | 0.005        |
| PLT \((-10^9/L)\)    | 207.64 ± 210.72       | 209.38 ± 73.71          | 210.71 ± 50.44          | 0.81         | 0.93         | 0.95         |

Values in Bold indicates \(p \leq 0.05\), which is considered as significance difference.

Hb hemoglobin; HCT Hematocrit; PLT platelet count; PT prothrombin time; APTT activated partial thromboplastin time; TT thrombin time; Fib fibrinogen; INR international normalized ratio

Abnormal coagulation was evaluated by platelet count, prothrombin time and activated partial thromboplastin time according to our laboratory standards.

The comparison of clinical presentation between group A and B was shown in Table 3. The time from onset to evacuation were 24.72 ± 38.79 h in group A and 63.40 ± 57.87 h in group B, respectively. Symptoms were as follows: Group A: dysesthesias in 15 patients, pain in 5 patients, muscle weakness in 29 patients; Group B: dysesthesias in 5 patients, pain in 1 patients, muscle weakness in 15 patients. JOA Score were similar in two PSEH group prior to surgery, but were significantly worse in delayed onset PSEH group than in early onset group at discharge (Group A: 20.68 ± 4.72, Group B 17.67 ± 4.79, \(p = 0.039 < 0.05\)).
Table 3
Clinical presentation

|                      | **Group A** (Early onset) | **Group B** (Delayed onset) | **P**<sub>A-B</sub> |
|----------------------|---------------------------|----------------------------|---------------------|
| Onset (h)            | 10.68 ± 11.51             | 130.60 ± 61.78              | <0.05               |
| Time from onset to evacuation (h) | 24.72 ± 38.79                 | 63.40 ± 57.87               | 0.009               |

Symptoms

|                      | **Group A** (%) | **Group B** (%) | **P**  |
|----------------------|----------------|----------------|-------|
| Dysesthesias (%)     | 15 (30.6%)     | 5 (23.8%)      | 0.58  |
| Pain (%)             | 5 (10.2%)      | 1 (4.8%)       |       |
| Muscle weakness (%)  | 29 (59.2%)     | 15 (71.4%)     |       |

JOA Score

|                      | **Group A** | **Group B** | **P** |
|----------------------|-------------|-------------|-------|
| Admission            | 13.44 ± 5.39| 11.67 ± 5.54| 0.18  |
| Discharge            | 20.68 ± 4.72| 17.67 ± 4.79| 0.039 |

Values in Bold indicates p value < 0.05, which is considered as significance difference.

Blood pressure measured at different time point were listed Table 4. In control group, SBP at admission, after extubation and postoperative were significant lower than those in two type of PSEH, whereas DBP after extubation were significant lower than group A.

Table 4
Blood pressure at different time point

|                      | **Group A** (Early onset) | **Group B** (Delayed onset) | **Group C** (Control group) | **P**<sub>A-C</sub> | **P**<sub>B-C</sub> | **P**<sub>A-B</sub> |
|----------------------|---------------------------|-----------------------------|----------------------------|---------------------|--------------------|---------------------|
| SBP at admission (mmhg) | 138.15 ± 19.45             | 135.86 ± 19.46              | 124.38 ± 21.30             | 0.001               | 0.047              | 0.71               |
| DBP at admission (mmhg)  | 83.81 ± 11.22              | 81.80 ± 17.93               | 79.95 ± 10.80              | 0.07                | 0.56               | 0.64               |
| Intraoperative SBP (mmhg) | 123.34 ± 9.11              | 120.90 ± 10.53              | 121.35 ± 6.55              | 0.16                | 0.82               | 0.43               |
| Intraoperative DBP (mmhg) | 74.08 ± 15.14              | 75.40 ± 9.62                | 73.15 ± 6.80               | 0.60                | 0.26               | 0.77               |
| SBP after extubation (mmhg) | 148.13 ± 16.10             | 149.07 ± 16.65              | 139.95 ± 5.92              | <0.05               | <0.05              | 0.85               |
| DBP after extubation (mmhg) | 91.05 ± 13.72              | 86.00 ± 8.06                | 88.07 ± 4.58               | 0.016               | 0.13               | 0.16               |
| Postoperative SBP (mmhg)  | 151.75 ± 22.31             | 144.20 ± 14.24              | 129.89 ± 12.11             | <0.05               | <0.05              | 0.24               |
| Postoperative DBP (mmhg)  | 88.13 ± 12.90              | 83.33 ± 9.02                | 84.99 ± 9.02               | 0.11                | 0.50               | 0.20               |

Values in Bold indicates p value < 0.05, which is considered as significance difference.

SBP systolic blood pressure; DBP diastolic blood pressure
Table 5
Multiple logistic regression analysis

|                          | Adjusted OR | 95% CI      | p Value |
|--------------------------|-------------|-------------|---------|
| Group A (Early onset)    |             |             |         |
| Multilevel procedure     | 5.62        | 1.84–17.25  | 0.002   |
| postoperative SBP        | 1.10        | 1.06–1.15   | < 0.05  |
| Abnormal coagulation     | 5.68        | 1.74–18.52  | 0.004   |
| Group B (Delayed onset)  |             |             |         |
| postoperative SBP        | 1.10        | 1.04–1.16   | 0.001   |
| Previous spinal surgery at the same level | 4.74 | 1.09–20.70 | 0.038 |

OR odds ratio; CI confidence interval.

For group A, multiple logistic regression analysis identified multilevel procedure (adjusted odds ratio: 5.62, 95% confidence interval: 1.84–17.25), postoperative SBP (adjusted odds ratio: 1.10, 95% confidence interval: 1.06–1.15) and abnormal coagulation (adjusted odds ratio: 5.68, 95% confidence interval: 1.74–18.52) as the independent risk factors.

For group B, multiple logistic regression analysis identified postoperative SBP (adjusted odds ratio: 1.10, 95% confidence interval: 1.04–1.16) and previous spinal surgery at same level (adjusted odds ratio: 4.74, 95% confidence interval: 1.09–20.70) as the independent risk factors.

**Literature review** (Table 6)
Table 6
Literature review

| Author & Year | Number | Age (Years), Sex | Incidence | Disease Level | Surgical approach | Time to onset (days) | Recovery rate | Speculated contributing factors |
|---------------|--------|------------------|-----------|---------------|-------------------|---------------------|---------------|----------------------------------|
| Spanier DE et.al. 2000 | 1 | 80 F | N/A | L3-S1 | L3–S1 laminectomy and instrumented bilateral lateral fusion | 16 | N/A | Heparin therapy and thrombocytopenia |
| Uribe J et.al. 2003 | 7 | 62 3F/4M | 0.17% | 3C, 1CT, 2T, 1L | Laminectomy, Laminoplasty | 5.7 | 71.43% | Previous spinal surgery |
| Neo Masashi et.al. 2006 | 1 | 59 M | N/A | C3-T1 | C3–T1 laminoplasty | 9 | N/A | None |
| Sokolowski MJ et. al. 2006 | 4 | 73.5 2F/2M | N/A | 3L, 1CT | Posterior laminectomy, Anterior discectomy | 12.5 | N/A | Elderly patients underwent multilevel procedures |
| Parthiban et.al. 2008 | 1 | 34 M | N/A | T8 | T7 to T9 laminectomy | 3 | N/A | Paraspinal muscle stretching (arterial bleeding) |
| Kim Boram et.al. 2010 | 1 | 23 M | N/A | L3 | En bloc spondylectomy | 9 | N/A | Muscular branch of venous plexus |
| Tomii Masato et.al. 2018 | 1 | 56 M | N/A | C4-6 | Cervical laminoplasty | 7 | N/A | Hypertension |
| Anno Masato et.al. 2018 | 6 | 67.2 N/A | 0.18% | 1C, 2T, 3L | N/A | 5 | 80% | None |

Disease Level: C cervical; T thoracic; L lumbar; CT, cervicothoracic.

There were 22 delayed onset PSEH patients were reported in the literature during the past 21 years [8–15]. Among them, 5 studies were case reports and the other 3 were case series study. Only 2 studies reported the incidence and the recovery rate. The detailed information and speculated contributing factors were listed in Table 6.

Discussion
In the present study, over a 7-year period, we identified 47 of 9258 patients (0.51%) who developed PSEH after surgery and among them, 31.91% were the delayed onset hematoma (0.16%). Postoperative SBP and previous spinal surgery at the same level were identified as the independent risk factors for its development. Furthermore, we also found that the early and delayed onset PSEH had different risk factors. To the best of our knowledge, this is the first study that revealed the incidence of delayed onset PSEH in patients undergoing posterior lumbar spinal surgery and risk factors for it.

**Incidence**

Multiple studies have described delayed onset PSEH in patients with undergoing all level of spinal surgery[8, 11, 13-15]. However, because of its rarity, most studies on it were the case reports and cannot obtain the incidence. Based on our review, only three articles enrolled more than one cases in their studies and two of them estimate the incidence. Uribe J et.al. enrolled 7 patients, first defined the delayed PSEH as an uncommon cause of delayed neurological deterioration, which took more than three days, up to two weeks after the initial surgery and reported the incidence was 0.17%, whereas Anno Masato enrolled 6 patients and reported the incidence was 0.18%[8, 15]. In our practice, in order to avoid the influence of the anatomical characteristics of different region, we limited our study to the cases with posterior lumbar spinal surgery. 15 patients who enrolled in the study were asymptomatic at first 3 days after initial surgery and then developed neurological deterioration in an average duration of 134.6 hours. The prevalence was 0.16% which were close to the previous two studies, indicating that the incidence was similar regardless of the region.

**Risk factors**

The relationship between blood pressure and hematoma was widely studied in previous studies[4, 5, 16, 17]. According to our study, although univariate analysis revealed that SBP at different time point except for intraoperative were significant higher in delayed onset PSEH group, further multiple logistic regression analysis revealed patients with high postoperative SBP had a 1.10-fold increased risk to develop hematoma. Two possible explanations may account for it as follow: First, patients usually present an elevation in blood pressure after surgery because of wound pain, but the self-regulation mechanisms can rapidly adjust the vessels size to decrease the blood pressure. However, these poorly managed or undiscovered hypertension patients, owing to hardening vessels, self-regulation mechanism failed to regulate the vessel size and the high blood pressure may lead to hemorrhage again after surgery[16, 18]; Second, previous studies have reported the positive relationship between whole blood viscosity (WBV) and hypertension[19-21]. The high postoperative SBP may result in high WBV that could cause blood clots and block the drainage tube. Therefore, it should be noted that not only the preoperative hypertension, but also the postoperative hypertension need to be controlled immediately. It is coincidence with the previous studies. Ohba Tetsuro et. al. found that among the PSEH patients, 4 late-onset patients had obvious postoperative hypertension[18]. And another study from Japanese showed 83.3% of PSEH were in hypertensive state after surgery and development of PSEH can be prevented by controlling the blood pressure.

Another risk factors that is found to be independent associated with delayed onset PSEH is previous spinal surgery at the same level. Many previous studies investigated the role of this factor in PSEH[1, 4, 17]. However, only one study identified it as a risk factor[17]. Moreover, a study on delayed onset PSEH revealed that the rate of previous spinal surgery is much higher than control group[8]. But the samples were too small to conduct the statistical analysis. In our study, based on the information collected, we draw the similar conclusion with these two studies. It is possible because that the second surgery is more difficult and traumatic due to the scar tissues, increasing the risk of bleeding.

Interestingly, in our study, we first found that the risk factors were different for two type of PSEH, indicating that the mechanism of them were different. This may be one reason that why previous studies obtained the controversial results. Proportion of delayed onset PSEH in enrolled samples could influence the statistical analysis.

**Clinical features**
With regard to initial symptoms, our study was consistent with previous findings that lumbar PSEH often leads to paralysis and pain\cite{1, 15}. In our study, muscle weakness was the most common symptoms regardless of the time of onset, following the dysesthesias and pain. By comparing the two type of PSEH, although JOA Score were similar in two PSEH group prior to surgery, but were significantly worse in delayed onset PSEH group than in early onset group at discharge. Immediate surgical intervention seems to influence it. It is believed that patients with short symptom duration and rapidly surgical intervention are correlated with better outcomes\cite{22, 23}. However, the time from onset to evacuation in delayed onset PSEH is much longer than early one, indicating the spinal surgeons may ignore the possibility of PSEH happened after 3 days and treat it as nerve edema.

This study had some limitations. First, because of the retrospective study, missing data, bias and confounders are inevitable, which may affect the outcomes. Second, due to the rarity of delayed onset PSEH, the sample size was relatively small and cannot conduct a prospective study to verify the risk factors. Future multicenter studies are necessary to solve this problem. Third, because the spinal epidural plexus vein system is a valveless network, a sudden increase in abdominal pressure like a bad cough, sneezing may lead to rupture\cite{24}. Similar cause may affect the results.

Conclusions

In conclusion, our study revealed that among the PSEH patients, 31.91% were the delayed onset one and the overall incidence was 0.16% in posterior lumbar spinal surgery. Further study found that the postoperative SBP and previous spinal surgery at the same level were the independent risk factors for it. We also found that the risk factors for early and delayed onset PSEH were different. Our results remind surgeons should aware the possibility of delayed onset PSEH and if patients with such risk factors develop neurological deficit after 3 days, surgeons should make a timely diagnosis.

Declarations

Ethics approval and consent to participate: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this type of study, the informed consent was waived

This study was approved by Peking University Third Hospital Ethics Committee.

Consent for publication: Not applicable

Availability of data: The data used and analyzed during the current study was available from the corresponding author on reasonable request.

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Authors' contributions: LJ W conceived the project and analyzed the data. All authors contributed towards the interpretation and the collection of the data. All authors wrote and approved the final manuscript.

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