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Review Article

Perspective: Postoperative spinal epidural hematomas (pSEH) should be treated, not ignored

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ABSTRACT

Background: Patients with postoperative spinal epidural hematomas (pSEH) typically require emergency treatment to avoid paralysis; these hematomas should not be ignored. pSEH patients need to undergo immediate MR studies to document the location/extent of their hematomas, and emergent surgical decompression with/without fusion if warranted.

Methods: The frequencies of symptomatic pSEH ranged in various series from 0.1%-4.46%. Major predisposing factors included; perioperative/postoperative coagulation abnormalities/disorders, multilevel spine surgeries, previous spine surgery, and intraoperative cerebrospinal fluid (CSF) leaks. For surgery at all spinal levels, one study observed pSEH developed within an average of 2.7 postoperative hours. Another series found 100% of cervical/thoracic, and 50% of lumbar pSEH were symptomatic within 24 postoperative hrs., while a third series noted a 24-48 postoperative window for pSEH to develop.

Results: Early recognition of postoperative symptoms/signs of pSEH, warrant immediate MR examinations to diagnose the local/extent of hemorrhages. Subsequent emergent spinal decompressions/fusions are critical to limit/avert permanent postoperative neurological deficits. Additionally, patients undergoing open or minimally invasive spinal procedures where pSEH are suspected, warrant immediate postoperative MR studies.

Conclusion: Patients undergoing spinal surgery at any level typically become symptomatic from pSEH within 2.7 to 24 postoperative hours. Early recognition of new neurological deficits, immediate MR studies, and emergent surgery (i.e., if indicated) should limit/minimize postoperative neurological sequelae. Thus, pSEH should be treated, not ignored.

Keywords: Emergency, Diagnosis, Surgery, Postoperative spinal epidiural hematomas (pSEH), Not ignored, Avoid delays, Paralysis, Early diagnosis, Early surgery

INTRODUCTION

The incidence of symptomatic postoperative spinal epidural hematomas (pSEH) occurring at varying spinal levels ranged in 7 series from 0.1% to 1%,[1,2,4,8,9,15,16] in 5 studies it ranged from < 1% up to 2.9%,[11,12,15,17,18] and in 3 papers from 3%-4.46% [Tables 1 and 2].[2,6,17] Major predisposing factors for pSEH included; perioperative/postoperative coagulation disorders, multilevel spinal surgery, prior spine surgery, and intraoperative cerebrospinal fluid leaks (CSF) [Tables 1 and 3].[1-18] The times to onset of symptomatic postoperative pSEH following

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all-level spine surgery ranged from an average of 2.7 postoperative hours,[1] to less than 24,[2] to between 24-48 postoperative hrs.[5] [Tables 1-4].[1,2,5] Notably, minimally invasive surgery increased the risk of pSEH 5-fold vs. open procedures.[4] The most critical factors to limit/avert permanent neurological sequelae of pSEH included; early recognition of new postoperative neurological deficits, obtaining immediate magnetic resonance imaging (MR) studies, and performing emergency spine surgery where indicated [Tables 1-4].[1-18]

Incidence of pSEH

The incidence of symptomatic postoperative spinal epidural hematomas (pSEH) involving all spinal levels ranged in 7 studies from 0.1% to 1%,[1,2,4,8,9,15,16] in 5 series from <1% to 2.9%,[11,12,15,17,18] and in 3 series between 3%-4.46% (i.e., the 1 of 10 patients with a 10% incidence of pSEH was considered an outlier)[2,6,17] [Tables 1 and 2].[1-18]

Multiple Risk Factors Associated with pSEH

The most common risk factors predisposing patients to pSEH included; perioperative/postoperative coagulopathy,[5,8,9,11,12,16,18] multilevel surgery,[1,5,8,11,12] prior spine surgery,[1,18] intraoperative CSF leaks,[18] advanced age,[5,11] and minimally invasive surgery (i.e. 5-fold increase in pSEH) [Tables 1 and 3].[1-18] Other studies mentioned less frequently encountered risk factors [Table 3]. In Kou *et al*. (2002) series involving 12 (2.9%) pSEH of 416 patients undergoing lumbar laminectomy/decompressions, the 2 major risk factors included multilevel surgery, and perioperative coagulopathies.[12] Amiri *et al*. (2013) found a 0.22% incidence of pSEH out of 4568 all-level spinal procedures with alcohol abuse (i.e. >10 units/week), prior spine surgery, and multilevel surgery predisposing to pSEH.[1] For Guodong *et al*. (2014) series of 12 (0.5%) cervical pSEH out of 2338 patients undergoing cervical surgery, risk factors included hypertension in 2/3 of patients, and multilevel surgery; notably, none had coagulopathies.[8] Following 310 biportal endoscopic procedures, immediate postoperative MR scans in Kim *et al*. (2019) series documented a 1.9% incidence of symptomatic pSEH; here major risk factors included age over 70, more extensive surgery/more bone work (laminectomy/interbody fusion), and anticoagulation therapy.[11] Eguchi *et al*. (2019) observed a 3.7% rate of pSEH out of 133 patients undergoing thoracolumbar posterior spinous process splitting procedures/fusions (PSPS), and risk factors here included; surgery at/above the L2/3 level, and reduced postoperative drainage.[6] Risk factors in Hohenberger *et al*. (2020) 42 (0.69%) of 6024 patients undergoing all-level spine surgery included preoperative anticoagulation/coagulopathy, and smoking.[9] For Wang *et al*. (2022) 24 (1.49%) pSEH of 1612 patients undergoing thoracic surgery, major predisposing risk factors included an intraoperative cerebrospinal fluid (CSF) leak, a kyphotic angle of greater than 8.77 degrees, a cross-section/axial occupancy ratio of > 49.58%, coagulopathy, and a history of prior spine surgery.[18] For 37 (0.39%) pSEH of 9307 patients undergoing thoracolumbar surgery, Saitta *et al*. (2022) major risk factors included hypertension and coagulopathies; they also recommended careful monitoring of drain output for those on antiplatelet regimens.[16] Chen *et al*. (2022) meta-analysis of 40 studies (i.e., noting 0.52% frequency of pSEH for all-level surgery) concluded that pSEH were not increased by perioperative anticoagulation; rather, minimally invasive (MI) spinal procedures increased the risk of pSEH 5-fold (1.94%) vs. open surgery (i.e., 0.425%).[4] Djurasovic *et al*. (2022) quoted a range of 0.1-0.69% in the literature for pSEH occurring in all spinal proceudres; their identiifed risk factors included older age, anticoagulation, and multilevel laminectomy.[5]

Controversy Regarding Correlation of Perioperative/Postoperative Coagulation Disorders with pSEH

Perioperative/Postoperative Coagulation Disorders Increased Risk of pSEH

In 6 spinal series, authors determined that preoperative/perioperative coagulation disorders/coagulation abnormalities increased the risk of pSEH [Tables 1 and 3].[5,9,11,12,16,18] Kou *et al*. (2002) found that coagulation abnormalities increased the risk of pSEH following lumbar surgery (i.e., 12 (2.9%) pSEH of 416 patients)).[12] Kim *et al*. (2019) determined that for the 1.9% of patients developing pSEH out of a series of 310 patients undergoing biportal endoscopic spine surgery, anticoagulation was a major risk factor.[11] In Hohenberger *et al*. (2020) (0.69% or 42 of 6024 patients undergoing all level surgeyr), in Wang *et al*. (2022) (1.49% or 24 pSEH of 1612 thoracic procedures), in Saitta *et al*. (2022) (0.39% or 117 pSEH of 9307 having thoracolumbar surgery), and Djurasovic *et al*. (2022) (0.1-0.6% all level surgery), the multiple authors considered anticoagulation to be a significant risk factor for pSEH.[5,9,16,18]

Perioperative Chemoprophylaxis for Deep Venous Thrombosis (DVT)/Pulmonary Embolism (PE) "May" Increase the Risk for pSEH

Two studies determined that chemoprophylaxis for Deep Venous Thrombosis (DVT)/Pulmonary Embolism (PE) "may" increase the risk for pSEH.[3,7] Butler *et al*. (2022) specifically acknowledged that DVT/PE prophylaxis "may" increase the

Table 1: Incidence and treatment of postoperative spinal epidural hematomas (pSEH).

Author Journal Years	Patient Population Study Design	Results	Results	Results	Outcomes
Kou[12] **Spine** **2002**	Incidence of Sx pSEH Suspect with New Postop Deficit RiskFac	416 L LAM Decomp 12 (2.9%) pSEH 404 No Clot (Control Gp)	RiskFac pSEH Preop Coag Multilevel	Not RiskFac Age BMI CSF Leak Postop Drains	Pts with Preop Coag or Multilevel Proc Sig Higher Risk pSEH
Kebaish[10] **Neurosurg Focus** **2004**	Spine Surg Rate Cause pSEH/CES Most Spinal Epidural Clots Due to Trauma, Anticoag, Vascular Lesions, Epidural Procedures	Sx pSEH 0.1-3% Reported	Critical Early Diagnosis Clinical Eval MR Imaging	**"Once the disease is suspected clinically and confirmed on diagnostic imaging, emergency evacuation of the lesion should be performed"**	**"Prognosis depends on the rate of development of symptoms, interval to surgery, level of spinal involvement, and degree of neurological deficit".**
Glotzbecker[7] **Spine** **2010**	Incidence pSEH Effect of Chemo Proph RiskFac	Risk Sx pSEH vs. DVT/PE Proph Medline Search-16 Article Used	Incidence pSEH 0%-0.7% Chem Prophy v 0%-1% All Studies	**"...insufficient published data. to precisely define the safety of postop chemoproph**	**"...evidence. suggest that use of therapeutic doses of heparin in postop spinal patients who sustain a PE may have a higher incidence of bleeding complications"**
Martin[13] **Spine J** **2010**	Case Report pSEH Distant Site from Main Surg	57 yo F Adult Scoliosis Junctional Kyphosis Fusion T3-Sacrum	3 hrs Postop Paraplegia Distant Level Myelo-CT pSEH Compression Cord Upper Thoracic Spine	Immediate LAM Clot Removal Near Full Recovery 5 mos Postop "If...deficit...site distant from the original surgery... reimaging (MR/Myelo-CT)... indicated"	"**A neurological examination should always be conducted in the operating room immediately after surgery; it is abnormal pSEH should be suspected"**
Aono[2] **J Neurosurg Spine** **2011**	Postop Sx pSEH Frequency 0.1-3% pSEH **Most After Th Lam and Reco C/Th** **Sx of pSEH C/TH Noted in 24 hrs**	**Most Severe Paralysis** **½ Sx L pSEH After Drain Removal** 26 Pts pSEH Total 6356 Spinal Decomp Surg 1986-2005	Frequency Time to pSEH Surg Comorbid Neuro Recovery Frequency pSEH 0.41% (26/6356 Pts) 0% L Disk Surg 0.5% (8/1614) L LAM	Frequency pSEH 0.41% (26/6356 Pts) 0.67% PLIF 4.46% (5/112) Th LAM 0.44% C LOP 0.21% C ACDF 9 Postop Clots pSEH Removed 4 hrs-8 Days postop	Severe Paralysis <24 Hrs Most with C/TH Surg ½ After L Surg with Sx Leg Pain BB DysFx (After Drain Removal) "**The shorter the period to evacuation, the better were the results of neurological recovery"**
Amiri[1] **Spine J** **2013**	Postop pSEH Incidence RiskFac Onset Treatment Open Spine Surg 1999-2006 .22% of 4568 Pts Sx pSEH Spine Surgery	0 Postop RiskFac ETOH >10 U/wk Prior Spine Surg Multilevel Onset Sx avg 2.7 hrs Postop	Evacuation < 6 hrs Onset Improved Avg 2 FG Surgery > 6 Hours Onset Sx Improved 1 FG Sx pSEH Rate 0.22% This Series	RiskFac ETOH >10 U/wk Multilevel Prior Spine Surg Present Early Postop < 2.7 hrs-Import Close RR Monitoring Min 4 hrs	**"This study suggests that earlier surgical intervention may result in greater neurological recovery"**

(Contd...)

Table 1: *(Continued).*

Author Journal Years	Patient Population Study Design	Results	Results	Results	Outcomes
Guodong[8] **Acta Orthop Traumatol Turc** **2014**	Acute Postop C pSEH Clinical RiskFac Treatment Outcomes	2338 C Spine Surgery 2004-2008	12 (0.5%) Sx pSEH 2/3 HTN Disease or Postop None Abnl Coagulation	All pSEH removed within 2 hrs of Diagnosis Acute pSEH Rare RiskFac Clot HTN, Multilevel Surg	**"Early diagnosis and evacuation of the hematoma can result in resolution of the neurological** deficit"
Minato[14] **Case Rep Orthop** **2016**	pSEH Case Report TL PostF Th Vert Fx 42 y9o M CT T12 Disloc Fx Type B2	4 Days Later TL PostF Without Decomp 3 hrs Postop Acute Pain Severe Wk pSEH	STAT Revision OR Postop Ambulatory 1 mo Later	Future Concern Possible Preop SEH Without Deficits	Future Concern Possible Periop Coag with Trauma
Moufarrij[15] **J Neurosurg** **2016**	Case Report pSEH After Placing Thoracic Paddle SCS	Compared with Controls Postoperative pSEH	4 (2.6%) of 154 SCS Placed 2002-2015 Resulted in pSEH/LE Wk-3 of 4 pts Delay Onset	Controls pSEH 1 (0.84%) of 119 new Postop Motor Wk-SSEP Non SCS LAM	Concluded **"pSEH after Th Paddle SCS may be under-reported"** Incidence 3X More pSEH with Th SCS Placement vs. Non SCS Lam
Shin[17] **Word Neurosurg** **2017**	Eval EDH STAT Postop MR Th PSF 10 Pts-(2013 yr) vs. 3 Postop MR of 260 Control Pts 2000-2013	MR 9/10 Pts Neuro Intact MR No Clot Preserved CSF Space Metal Artifact PS	1 Pt Poor Outcome MR EDH Mild Cord Comp Less CSF Space	3 of 260 Controls with pSEH-Motor Deficits-MR Showed pSEH Comp Cord/Less CSF Space	Conclusion STAT Postop MR Detect Postop EDH Th PSF OR Despite Metal Artifact-Critical Loss CSF Space
Kim[11] **World Neurosurg** **2019**	RiskFac pSEH After Biportal Endoscopic Spine Surg Th/L	310 Pts 2015-2017 MR All Pts Preop and Postop **23.6% (94) pSEH on MR No Sx** **1.9% Sx pSEH Here**	No Clot 76.4% (304 Levels/398 Levels) 6 Reop Clot Removal	RiskFac F, Age >70, > Surgery -Bone Work LAM/IBF Anticoag Rx, Intraop Use of "Water Infusion Pump"	**Rare Sx pSEH 1.9% Here** **Confirmed on Postop MR** 23.6% Seen on Postop MR Periop RiskFac F, > 70 yo, Lam/IBF,
Eguchi[6] **Spine Surg Relat Res** **2019**	**History pSEH Rate 1.9%** Th/L Spine Surg here 3.7% Postop Clots-New Deficits	3.7% of 133 Pts/137 Levels New Postop Deficit-Reop Avg 72.4 yrs 68 M	All 4 Postop Clots 1-Level LAM: T9/10 (1 Pt) L2/3 (3 Pts) >M Clots (100% Clots vs. 48% Control)	P that SEP A.OR Level At/Above L23 B.Less Drain Output	RiskFac P SPSL Less Decompress Higher Risk Sx Clot Due Less Room
Hohenberger[9] **J Neurol Surg A Cent Eur Neurosurg** **2020**	Sx pSEH Postop RiskFac Outcome Sx Comp **« Delayed evacuation may result in severe neurological impairment »**	Prevalence RiskFac Recovery 15 yrs 42/6024 pSEH Revision Surg Neuro Worse or Rad Pain MR pSEH F/O-avg 3 mos	0.69% (42) pSEH 7 (0.54%: 1284 Pts C 1 (0.12%: 774) TH 34 (0.85%: 3966) L Etiology of pSEH Anticoag Preop Coag Abnl Smoking	RiskFac Surgery >1 Level Trend Increased Risk pSEH Pts Preop Paraplegic (0.026) Sig Higher Risk Poor Outcome-No Full Neuro Recovery	"Functional outcome was related to the duration between hematoma evacuation and the clinical presentation of symptomatic pSEH"

(Contd...)

Table 1: *(Continued).*

Author Journal Years	Patient Population Study Design	Results	Results	Results	Outcomes
Wang[18] **Global Spine J 2022**	Sx/RiskFac Th Surg pSEH 24 (1.49%) of 1612 pts V Control 53 Pts	2010-2019 pSEH Th Surg Clot Evac v For Each PSEH Patient Matched with 2-3 Controls (No Clots)	pSEH Pts Sig High APTT High INR Prior Surg CSF Leak Th Kyph Occ Ratio SEVPG	3 RiskFac pSEH CSF Leak Kyph Angle (> 8.77%) Occ Ratio/Cross Section (> 49.58%)	Frequency pSEH 1.49% Post TH Surg Large Local Kyphosis Angle High Occ Ratio CSF Leak
Saitta[16] **Global Spine J 2022**	Sx pSEH Time to Discontinue ASA Preop TL Surgery 2009-2020 Conclusion Preop ASA	Increased Risk pSEH Even Stop Correct Preop Postop Anticoag-Not Increase Risk pSEH	Preop + Postop Anticoag (AC)+ APM (Antiplatelet Medication) I & D Sx pSEH AC+APM 14 d Preop-Postop	9307 TL Surg 117 (1.9%) Return to OR in 30 d 37 (0.39%) due to pSEH7 AC or APM Preop 16 AC or APM Postop 5 ASA Preop Risk Not > Multiple Rx	No AC or APM > Risk pSEH postop (Trend with Multiple Rx) Increased Risk pSEH: HTN, Drain Carefully Monitor those on Preop Antiplatelet Meds for pSEH
Chen[4] **Eur Spine J 2022**	Postop Sx pSEH Need Reop Meta-Anal 40 Studies Pooled Incidence pSEH 0.52%	Frequency Sx pSEH Postop Search Databases PubMed Embase Cochrane Library to 3/22	More pSEH Deformity More Than Degen/Tumor Location pSEH 0.32% C 0.84% Th 0.63% L	Ant 0.24% Post 0.70% **5X MORE pSEH with MI Surg** 1.94% v Open Surg 0.42%	More 0.16% Delayed vs Early Onset No Increase pSEH with Periop Anticoag
Butler[3] **Clin Spine Surg 2022**	Sx pSEH Lumbar Spine Variable Clinical Findings ". potential to rapidly cause an irrecoverable neurological injury"	Literature not Support efficacy Subfascial Drains to Decrease Risk pSEH Suggest DVT/PE Proph may Increase Risk pSEH	Sx of pSEH Include Acute LBP Increased LE Wk MR for Diagnosis	"if not acutely available (MR) an immediate return to the operative theater for exploration without advanced imaging is justified"	"Treatment of pSEH consists of emergent hematoma evacuation as a delay in repeat surgery has a deleterious effect on neurological recovery"
Djurasovic[5] **Orthop Clin North Am 2022**	Sx pSEH Rare 0.1-0.69% Risks-Older Age, Coag (Preop/Postop), Multiple Level Lam	Proph Drains Not Reduce pSEH **Most Present 24-48 hrs Postop-Some Later**	Diagnosis Clinical/MR Sx: Marked Pain-Rad, Wk, BB DysFx	Recommend MR Emergent Confirms Clot "...surgical evacuation should be carried out as quickly as possible""	"The prognosis for neurologic improvement after evacuation depends on the time delays and the degree of neurologic impairment before evacuation"

Sx=Symptomatic, pSEH=Symptomatic Spinal Epidural Hematoma, M=Males, F=Females, avg=Average, MR=Magnetic Resonance Imaging, CT=Cat Scan, d=days, mos=months, wk=Week Pt (s)=Patient/Patients, CSF=Cerebrospinal Fluid, Rad=Radiculopathy, Myelop=Myelopathy, SS=Spinal Stenosis, DDD=Degenerative Disk Disease, Th=Thoracic, Surg=Surgery, RiskFac=Risk Factors, Ant=Anterior, Post=Posterior, Evac=Evacuation, v=Versus, Kyph=Kyphosis, Occ=Occupying SEVPG=Spinal Epidural Venous Plexus Grade, L=Lumbar, SS Spinal Stenosis, LAM=Laminectomy, SPSL=Spinous Process-Splitting Laminectomy, yrs=Years Old, Postop=Postoperative, Reop=Reoperation, OR=Operations, Decomp=Decompressed, Sig=Significantly, EDH=Epidural Hematoma, PSF=Posterior Screw Fixation, Neuro=Neurological, Rec=Recovery, PS=Pedicle Screws, Comp=Compression, TL=Thoracolumbar, PostF=Posterior Fusion Vert=Vertebral, Fx=Fracture, Disloc=Dislocation, Decomp=Decompression, Wk=Weakness, wk=Week, SEH=Spinal Epidural Hematoma, Periop=Perioperative, Coag=Coagulopathy, Meta-Anal=Meta Analysis Degen=Degeneration, L=Lumbar, C=Cervical, MI=Minimally Invasive, Anticoag=Anticoagulation Therapy, SCS=Spinal Cord Stimulator, LBP=Low Back Pain, LE=Lower Extremity, Myelo-CT=Myelogram Cat Scan, Comorbid=Comorbidities, Neuro=Neurological, PLIF=Posterior Lumbar Interbody Fusion, LOP=Laminoplasty, BB=Bowel and Bladder, DysFx=Dysfunction, pSEH=Postoperative Spinal Epidural Hematoma, F/O=Follow-Up, Coag=Coagulation/Coagulopathy, Proph=Prophylactic, Chem=Chemoprophylaxis, DVT=Deep Venous Thrombosis, PE=Pulmonary Embolism, Rx=Treatment, IBF=Interbody Fusion, ETOH=Alcohol, U=Units, Wk=Weakness, FG=Frankel Grade, RR=Recovery Room Monitoring. Min=Minimum, Abnl=Abnormal, HTN=Hypertension, AC=Preoperative and Postoperative Anticoagulation, APM=Antiplatelet Medication, CES=Cauda Equina Syndrome, Gp=Group, BMI=Body Mass Index, AAPTT=Partial Thromboplastin Time, ASA= Aspirin, Th Lam=Thoracic Laminectomy, C LOP=Cervical Laminoplasty, C ACDF=Cervical Anterior Diskectomy and Fusion, C/Th=Cervical/Thoracic, Th vert=Thoracic Vertebra

Table 2: Incidence of postoperative spinal epidural hematomas (PSEH).

Author Journal Year	Spine OR	0.1-1% pSEH	>1 – 2.9% pSEH	> 3.0% pSEH	0.1-3% Historical Data/Other
Kou[12] **Spine** **2002**	L		**2.9%** 12/416		
Kebaish[10] **Neurosurg Focus** **2004**	G				0.1-3.0%
Glotzbecker[7] **Spine** **2010**	G				0.1-0.7% 0.1-1.0%
Aono[2] **J Neurosurg Spine** **2011**	G	**0.41% Total** TH 26/6356 0% LD 0.21 C ACDF 0.44% C LOP 0.5% LAMST 0.67% PLIF		4.46% Th LAM	0.1-3%
Amiri[1] **Spine J** **2013**	G	**0.22%** 1/4568			
Guodong[8] **Acta Orthop Traumatol Turc** **2014**	C	**0.5%** 12/2338			
Moufarrij[15] **J Neurosurg** **2016**	TH	**0.84%** TH No SCS Controls	**2.6%** TH SCS		
Shin[17] **Word Neurosurg** **2017**	TH		**1.15%** 3/260 Control TH LAM	**10%** 1/10 TH LAM Postop MR	Postop MR Study
Eguchi[6] **Spine Surg Relat Res** **2019**	TL			**3.7%** 5/133	1.9%
Kim[11] **World Neurosurg 2019**	TL		**1.94%** 6/310 Symptoms Postop MR		23.6% No Symptoms Postop MR Study
Hohenberger[9] **J Neurol Surg A Cent Eur Neurosurg** **2020**	G	**0.69%** **42/6024** 7 C (0.54%) 1 Th (0.128%) 34/3966 L (0.85%)			
Wang[18] **Global Spine J** **2022**	TH		**1.49%** 24/1612		
Saitta[16] **Global Spine J** **2022**	TL	**0.39%** 37/9307			

(Contd...)

Table 2: *(Continued).*

Author Journal Year	Spine OR	0.1-1% pSEH	>1 – 2.9% pSEH	> 3.0% pSEH	0.1-3% Historical Data/Other
Chen[4] **Eur Spine J** **2022**	G	**0.52%** 0.32% C 0.63% L 0.84% Th			**MI 1.94% 5-Fold Greater Rate pSEH** **v Open 0.42% OR**
Djurasovic[5] **Orthop Clin North Am** **2022**	G				0.1-0.69%

G=General/Including All Spine Level Surgery, C=Cervical, Th=Thoracic L=Lumbar, SCS=Spinal Cord Stimulator Placement, LAM=Laminectomy, LD=Lumbar Disk, ST=Stenosis, PLIF=Posterior Lumbar Interbody Fusion, C-LOP=Cervical Laminoplasty, C-ACDF=Cervical ACDF, Postop=Postoperative MI=Minimally Invasive, Open=Open Surgery OR=Operations, v=Versus

risk of lumbar pSEH.[3] Glotzbecker *et al.* (2010) evaluated 16 articles dealing with all-level spine surgery, and found the frequency of pSEH was 0-0.7% with chemoprophylaxis vs. a nearly comparable 0-1% without such treatment.[7] They concluded that; "...evidence suggests that use of therapeutic doses of heparin in postop spinal patients who sustain a PE may have a higher incidence of bleeding complications".

Perioperative/Postoperative Coagulation Disorders/ Chemoprophylaxis Did Not Increase the Risk of pSEH

Two studies documented no increased risk of pSEH in patients with perioperative and/or postoperative coagulation abnormalities/disorders/chemoprophylaxis [Tables 1-4].[4,8] Guodong *et al.* (2014) determined that coagulation disorders did not contribute to the frequency of cervical pSEH (i.e., 0.5% or 12 pSEH of 2338 patients).[8] In a meta-analysis of 40 studies, Chen *et al.* (2022) similarly found a 0.52% incidence of pSEH after all-level spine surgery; they, too concluded that coagulation disorders did not contribute to the frequency of pSEH.[4]

Minimally Invasive Surgery Increases Risk of pSEH 5-Fold

In Chen *et al.* (2022) meta-analysis of 40 studies, showing an overall 0.52% frequency of pSEH for all-level spinal procedures, they very specifically noted that minimally invasive (MI) operations increased the risk of pSEH 5-fold (1.94%) vs. open surgery (i.e. a lesser 0.425%) [Tables 1-4].[4]

Placement of Thoracic Spinal Cord Stimulators (SCS) Increased Risk of pSEH 3-Fold

Moufarrij *et al.* (2016) found a 3-fold higher rate of pSEH for 4 (2.6%) of 154 patients undergoing SCS (i.e., placement of thoracic paddle leads for thoracic spinal cord stimulators through laminectomies); for the 119 control patients undergoing thoracic laminectomies without SCS placement, the frequency was a much lower 0.84% (i.e., 1 case of pSEH) [Tables 1and 4].[15]

Controversy Regarding Utility of Drains in Spinal Surgery to Avoid pSEH

Use of Drains to Monitor Output and Predict Onset of pSEH

Two studies advocated monitoring postoperative drainage following spine surgery to anticipate an increased risk for pSEH [Tables 1 and 3].[6,16] For Eguchi *et al.* 3.7% of 133 patients who developed pSEH following posterior thoracolumbar surgery, reduced postoperative drainage potentially signaled the onset/presence of a pSEH.[6] Further, when Saitta *et al.* (2022) diagnosed 37 (0.39%) of 9307 patients with symptomatic pSEH following thoracolumbar surgery, monitoring significant changes in postoperative drainage, especially in those on antiplatelet therapy, helped identify those at risk for pSEH.[16]

Drains In Spine Surgery Did Not Reduce the Incidence of pSEH

Three series concluded that placing drains during spine surgery did not reduce the frequency of pSEH [Tables 1 and 3].[1,3,5] Kou *et al.* (2002) found that drains did not influence the 2.9% incidence (i.e., 12 pSEH of 416 patients) of pSEH occurring following lumbar laminectomies.[12] Looking at the incidence of pSEH following lumbar surgery, Butler *et al.* (2022) found no support regarding the efficacy of subfascial drains in reducing pSEH.[3] Further, when Djurasovic *et al.* (2022) evaluated the frequency of pSEH following all-level spine surgery, drains did not effectively decrease the incidence of pSEH.[5]

Table 3: Risk factors predisposing to postoperative spinal epidural hematomas (pSEH).

Author Year	Population Levels	Risk Factors AA, PSS, HTN, OA, RDO, SM, PreopPP, CSF Leak, CrO, Kyph, DSurg	Risk Factors Preop Coag Abnormal	Risk Factors Multilevel SS	Not Risk Factors
Kou[12] **Spine 2002**	12 (2.9%) of 416 L LAM		Y	Y	OA, High BMI Postop Drains CSF Leak
Amiri[1] **Spine J 2013**	0.22% of 4568 SS	AA		Y	
Guodong[8] **Acta Orthop Traumatol Turc 2014**	12 (0.5%) of 2338 C pSEH	HTN	N	Y	No Coag Abnormalities
Kim[11] **World Neurosurg 2019**	BESS 310 Pt 1.9% Sx pSEH 23.6% ASx	OA>70	Y	Y	
Eguchi[6] **Spine Surg Relat Res 2019**	3.7% 133 Pt TL Post SS	RDO		Reduced Extent Decompress Above L23	
Hohenberger[9] **J Neurol Surg A Cent Eur Neurosurg 2020**	42 (0.69%) of 6024 Sx pSEH	SM PreopPP	Y		
Wang[18] **Global Spine J 2022**	24 (1.49%) of 1612 Th Sx pSEH	CSF Leak Kyph, PSS CrO >49.58%,	Y		
Saitta[16] **Global Spine J 2022**	37 (0.39%) of 9307 TL Surg pSEH Return to OR	HTN, Changes Drain Output	Y		
Chen[4] **Eur Spine J 2022**	Meta-A 40 studies 0.52% pSEH Various SS	MISS Increased Risks 5X (1.94%) Risk Open Surg 0.42% DSurg			No Impact Preop Anticoag
Butler[3] **Clin Spine Surg 2022**	Lumbar pSEH	No Support in Literature For Subfascial Drains	Y		
Djurasovic[5] **Orthop Clin North Am 2022**	All S Rate pSEH 0.1-0.69% All	OA Drains Did Not Reduce pSEH	Y	Y	

pSEH=Postoperative Spinal Epidural Hematoma, BMI=Body Mass Index, , Y=Yes, CSF=Cerebrospinal Fluid, Postop=Postoperative, AA=Alcohol Abuse, PSS=Prior Spine Surgery, HTN=Hypertension, Coag=Coagulation, BESS=Biportal Endoscopic Spine Surgery, Sx=Symptomatic, ASx=Asymptomatic, Pt=Patient (s), OA=Older Age, TL=Thoracolumbar, SS=Spine Surgery, Post=Posterior, Decompress=Decompress/Decompression, RDO=Reduced Drain Output, SM=Smoking, PreopPP=Preoperative Paraplegia, Kyph=Kyphosis, CrO=Cross Section Occupancy Ratio, Surg=Surgery, OR=Operating Room, Meta-A=Meta-Analysis, Anticoag=Anticoagulation, MIS=Minimally Invasive Spine Surgery, X=Times, DSurg=Delayed Surgery, *P*=Preop, Coag=Coagulopathy, Abnormal=Abnormality, C=Cervical, Th=Thoracic, SS=Spine Surgery

Symptoms and Signs of pSEH

Several common symptoms and signs (i.e., acute increased postoperative pain, radiculopathy, weakness (i.e. including paraplegia), and sphincter dysfunction) signaled the presence/onset of pSEH following spinal surgery [Table 1].[3,5,10] In Kebaish *et al.* (2004) series, the multiple etiologies of postoperative spinal hematomas included; trauma, anticoagulation, vascular lesions, and postoperative

Table 4: Spinal Levels of pSEH.

Author Year	Population Levels	All SS	Cervical	Thoracic	Thoraco-lumbar	Lumbar
Kou[12] **Spine 2002**	12 (2.9%) 416 L LAM					12 (2.9%) 416 L LAM
Aono[2] **J Neurosurg Spine 2011**	26 (0.41%) of 6356 All SS	26 (0.41%) of 6356 All SS	0.21% ACDF 0.44% C-LOP	4.46% Th Lam (5/112)		0% L-Disk 0.5% L LAM 0.67% PLIF
Amiri[1] **Spine J 2013**	100 (0.22%) of 4568 All SS	100 (0.22%) of 4568 All SS				
Guodong[8] **Acta Orthop Traumatol Turc 2014**	12 (0.5%) of 2338 C		12 (0.5%) of 2338 C			
Moufarrij[15] **J Neurosurg 2016**	4 (2.6%) of 154 Th SCS			4 (2.6%) of 154 Th SCS		
Shin[17] **Word Neurosurg 2017**	1 (10%) of 10 vs. 3 of 260 Th PF			1 (10%) of 10 -Older Series 3 (1.15%) of 260 Th PF		
Kim[11] **World Neurosurg 2019**	1.9% of 310 TL BESS				6 (1.9%) of 310 TL BESS	
Eguchi[6] **Spine Surg Relat Res 2019**	3.7% of 133 TL SS				5 (3.7%) of 133 TL SS	
Hohenberger[9] **J Neurol Surg A Cent Eur Neurosurg 2020**	42 (0.69%) of 6024 SS	42 (0.69%) of 6024 SS	7 (0.54%) of 1284 C	1 (0.12%) of 774 Th		34 (0.85%) of 3966 L
Wang[18] **Global Spine J 2022**	24 (1.49%) of 1612 Th SS			24 (1.49%) of 1612 Th		
Saitta[16] **Global Spine J 2022**	117 (1.9%) of 9307 TL SS				117 (1.9%) of 9307 TL SS	
Chen[4] **Eur Spine J**	0.52% All SS	0.52% All SS	0.32% C	0.84% Th		0.63% Lumbar
Summary of Cases of pSEH/Total Cases		168 pSEH of 16,948 Total Pts	17 Of 3622 Pts	38 pSEH of 2883 Pts	128 pSEH of 9750 Pts	46 of 4382 Pts
Summary of Range of %		0.22%-0.41% -0.52% -0.69%	0.21%-0.32% -0.44% -0.5%-0.54%	1.9%-2.6%-3.7% 4.46%-10%	1.9%-1.9%-3.7%	0.5%, 0.63%-0.67%-0.85% 2.9%

LAM=Laminectomies, L=Lumbar, C=Cervical, Th=Thoracic, TL=Thoracolumbar, SS=Spine Surgery, SCS=Spinal Cord Stimulator, Th PF=Thoracic Posterior Fusion, BES=Biportal Endoscopic Spine Surgery, pSEH=Postoperative Spinal Epidural Hematoma, ACDF=Anterior Cervical Diskectomy/Fusion, C-LOP=Cervical Laminoplasty, PLIF=Posterior Lumbar Interbody Fusion, L-Disc=Lumbar Diskectomy, LAM=Laminectomy %=Percentages

epidural hemorrhages (i.e., quoted the incidence of pSEH in the literature between 0.1 to 3%).[10] For Butler *et al*. (2022) patients undergoing lumbar surgery, symptoms/signs of postoperative cauda equina syndromes included acute worsening or excruciating low back pain, and weakness; patients typically warranted immediate postoperative MR scans, and emergent decompressive surgery with/without fusions.[3] Symptoms/signs for those with pSEH in Djurasovic *et al*. (2022) all-level spine series included; postoperative back/leg pain, new radicular deficits, significant weakness, and/or compromise/loss of sphincter function.[5]

Acute pSEH can be Diagnosed on Immediate Postoperative MR Scans Despite Metal Artifact

MR scans are the "gold standard" for diagnosing immediate pSEH despite metallic artifact from instrumentation [Table 1].[11,17] In 2013, Shin *et al*. (2017), immediate postoperative MR scans in 10 patients undergoing thoracic posterior spinal fusions yielded one patient (10%) with a pSEH; this was readily identified by the clear loss of cerebrospinal fluid around the cord, and was readily diagnosed despite artifact from instrumentation.[17] These same authors also similarly diagnosed 3 (1.15%) of 260 pSEH from a comparable prior series of patients undergoing thoracic instrumented fusions. Kim *et al*. (2019), following biportal endoscopic thoracolumbar spine surgery, also readily diagnosed pSEH on immediate postoperative MR scans in 1.9% symptomatic patients (i.e, out of a total of 310 patients); however, they also found that an additional 23.6% (94 patients) of patients had asymptomatic pSEH.[11]

Gelfoam and/or Surgiflo If not Removed During Spinal Decompressions/Laminectomy May Swell/ Contribute to pSEH

Package inserts for both Gelfoam (i.e., Pharmacia and Upjohn Company 7000 Portage Road, Kalamazoo, Michigan 49001 USA), and Surgiflow Hemostatic Matrix (i.e. Ethicon, Johnson and Johnson 507 Mount Wellington Hwy, Penrose, New Jersey 1060, NZ) warn that these products should be removed if applied during spinal decompressions/laminectomies due to marked swelling (i.e., easily up to 20%). Although significant pSEH due to Gelfoam or Surgiflo can be readily diagnosed based on postoperative MR studies, spinal surgeons need to order these scans and perform definitive surgery in a timely fashion so that these products can be removed.

Gelfoam

The package insert for Gelfoam states; "...it (Gelfoam) should be removed after use in laminectomy procedures and from foramina in bone, once hemostasis is achieved. This is because GELFOAM may swell to its original size on absorbing fluids and produce nerve damage by pressure within confined bony spaces." They further noted; "When GELFOAM was used in laminectomy operations, multiple neurologic events were reported, including but not limited to cauda equina syndrome, spinal stenosis, meningitis, arachnoiditis, headaches, paresthesias, pain, bladder and bowel dysfunction, and impotence".

Surgiflo

The warnings for Surgiflo are simlar to those for Gelfoam; "SURGIFLO® should be removed from the site of application when used in, around, or in proximity to foramina in bone...". "That is; "...because it may swell resulting in nerve damage". Notably; "Safe and effective use in neurosurgery has not been proven..." Also; "SURGIFLO® may swell up to 20% upon contact with additional fluid...", and; "...should be removed if possible once hemostasis has been achieved because of the possibility of dislodgment of the device or compression of other nearby anatomic structures."

MR-Documentation of Spinal Levels of pSEH

MR studies documented that most pSEH occurred in the thoracic spine, followed by the thoracolumbar spine, and cervical spine [Tables 1, 2, 4].[1,2,4,6,8,9,11,12,15-18] Four studies focused on the 0.22% - 0.69% frequencies of pSEH that followed spine surgery performed at all levels.[1,2,4,9] Four other series cited 0.21% - 0.54% frequencies of pSEH after cervical surgery that included; 0.21% for Anterior Diskectomy/Fusion (ACDF) and 0.44% for C-LOP (Cervical Laminoplasty).[2] [Table 4].[2,4,8,9] Six thoracic series (i.e., including thoracic laminectomies, posterior decompressions/ fusions, and one spinal cord stimulator) cited frequencies of pSEH ranging from 0.12% to 4.46% (i.e., one study was an outlier and cited a 10% rate (i.e., just for 1 of 10 patients)).[2,4,9,15,17,18] Three thoracolumbar studies (i.e., involving largely instrumented fusions) cited frequencies of pSEH ranging from 1.9%-3.7%.[6,11,16] For 4 lumbar series, the pSEH rate ranged from 0.5% to 2.9%.[2,4,9,12] Notably, for Aono *et al*. patients undergoing lumbar procedures, there were no pSEH for those undergoing diskecotmy; however, there was a 0.5% incidence of pSEH following lumbar laminectomy, and an even higher 0.67% frequency of pSEH after posterior lumbar interbody fusions (PLIF).[2]

Timing to Onset of Symptoms from pSEH Following All-Level, Cervical, Thoracic, and Lumbar Surgery

Time to Onset of Postoperative Symptoms for pSEH After All-Level Spine Surgery

Four studies defined the times to onset of pSEH as ranging from 2.7 hrs., to < 24 hrs, to 24-48 hrs. after all-level spine

surgery.[1,2,5] Aono *et al.* (2011) found that (i.e., in 26 (0.41%) pSEH of 6356 patients undergoing spinal surgery at all levels) 100% of patients undergoing cervicothoracic surgery were symptomatic from pSEH within < 24 postoperative hrs. vs. a lesser 50% rate for those undergoing lumbar procedures [Tables 1 and 4].[2] In Amiri *et al.* (2013), the average time to the onset of postoperative symptomatic pSEH was just 2.7 postoperative hrs. (i.e., in 100 (0.22%) of 4568 all-level spine operations); therefore, minimal 4-hour postoperative observation windows were critical for patients undergoing ambulatory spine surgery.[1] Subsequently, in 2022, Djurasovic *et al.* observed that patients with pSEH typically presented within 24-48 postoperative hours (i.e., incidence 0.1%-0.69% for those undergoing all-level spine surgery).[5]

Time to Onset of Postoperative Symptoms for Cervical pSEH

For patients undergoing cervical surgery, pSEH were typically symptomatic within < 24 postoperative hours.[2,8] Aono *et al.* (2011) found pSEH in 0.44% patients following cervical laminoplasties, and 0.21% after cervical ACDF; all patients were typically severely symptomatic in less than 24 postoperative hrs.[2] Of interest, out of the 2338 cervical operations in Guodong *et al.* (2014) series, the 12 (0.5%) patients diagnosed with cervical pSEH underwent surgical removed within 2 postoperative hours and, therefore, did well.[8]

Time to Onset of Postoperative Symptoms for Thoracic/ Thoracolumbar pSEH

The following 3 series focused on the incidence of pSEH for patients undergoing thoracic/thoracolumbar surgery; patients became symptomatic from postoperative pSEH within 3 postoperative hrs. (i.e., 2 case reports), or within 24 hrs. postoperatively [Tables 1 and 4].[2,13,14] In Aono *et al.* (2011) 5 (4.46%) of 112 patients undergoing thoracic laminectomies developed symptomatic pSEH within 24 postoperative hrs.[2] Martin *et al.* (2010) 57-year-old female undergoing a T3-sacrum scoliosis procedure was paraplegic from a pSEH within 3 postoperative hours.[13] Minato *et al.* (2016) 42-year-old male with a CT-documented T12 Fracture/Dislocation (Type B) who underwent a posterior thoracolumbar fusion without decompression 4 days later, was also symptomatic within 3 postoperative hours from a pSEH (i.e., he developed severe pain and weakness); he also underwent an emergent secondary decompression.[14]

Time to Onset of Postoperative Symptoms for Lumbar pSEH

In Aono *et al.* (2011) series. 0.5% of patients undergoing lumbar laminectomies and 0.67% of those having PLIF became symptomatic from pSEH within 24 postoperative hrs. [Tables 1 and 4].[2]

Early Diagnosis and Emergent Surgery Yielded the Best Outcomes for Patients with pSEH

This perspective emphasizes that early diagnosis and emergent surgery for patients with pSEH yielded the best neurological outcomes [Tables 1-4].[1-3,5,8-10,13] Kebaish *et al.* (2004) confirmed that patients with clinical evidence of pSEH should undergo immediate postoperative MR scans to diagnose/confirm their location, and this should be followed by emergent surgical decompressions; "Prognosis depends on the rate of development of symptoms, interval to surgery, level of spinal involvement, and degree of neurological deficit".[10] Martin *et al.* (2010), also noted that early diagnosis of pSEH was critical and stated; "A neurological examination should always be conducted in the operating room immediately after surgery..."[13] Aono (2011) also noted that; "The shorter the period to evacuation, the better were the results of neurological recovery".[2] Amiri *et al.* (2013) found the best outcomes occurred for surgery performed within </= 6 postoperative hrs. from the onset of symptoms; these patients improved an average of 2 Frankel Grades.[1] Alternatively, those operated more than 6 hrs. after the onset of symptoms, had poorer outcomes; they just improved 1 Frankel Grade.[1] They concluded; "This study suggests that earlier surgical intervention may result in greater neurological recovery"[1] In Guodong *et al.* (2014) series, involvling 12 (0.5%) pSEH of 2338 cervical operations, surgery was performed within 2 hours of diagnosing pSEH, leading them to also conclude; "Early diagnosis and evacuation of the hematoma can result in resolution of the neurological deficit."[8] Hohenberger *et al.* (2020) also observed for symptomatic pSEH; "Functional outcome was related to the duration between hematoma evacuation and the clinical presentation of symptomatic pSEH".[9] They also emphasized: "Delayed evacuation may result in severe neurological impairment."[9] Djurasovic *et al.* (2022) similarly recommended; "...surgical evacuation should be carried out as quickly as possible", and; "The prognosis for neurologic improvement after evacuation depends on the time delays and the degree of neurologic impairment before evacuation."[5] When Butler *et al.* (2022) evaluated the frequency of lumbar pSEH, they further concluded; "Treatment of pSEH consists of emergent hematoma evacuation as a delay in repeat surgery has a deleterious effect on neurological recovery."[3] In short, this perspective presents the consensus opinion that for pSEH, early diagnosis and emergent surgery are essential to optimize neurological outcomes [Tables 1-4].[1-3,5,8-10,13]

CONCLUSION

Symptomatic pSEH occur following 0.1%-4.46% of all spinal operations within an average of 2.7, to < 24 hrs (i.e., nearly 100% for cervical/thoracic, and 50% for lumbar lesions),

to between 24-48 postoperative hrs. [Tables 1-4].[1-18] The most critical factors to limit/avert permanent neurological sequelae of pSEH included; early recognition of new postoperative neurological deficits within these time frames, obtaining immediate/timely postoperative MR studies, and performing emergency spine surgery where indicated [Tables 1-4].[1-18]

Declaration of patient consent

Patients' consent not required as patients' identities were not disclosed or compromised.

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