Eastern Green Neurosurgery Original Article

egneuro,05(01):17-26,2024

Comparative Efficacy of Wound Drainage and Non-Drainage in Posterior Spinal Surgery

Bikram Shakya[1], Bidur K C[1]

[1] Department of Neurosurgery, Kathmandu Medical College Teaching Hospital, Sinamangal, Kathmandu

Correspondence:
Dr. Bikram Shakya
Department of Neurosurgery
Kathmandu Medical College Teaching Hospital, Sinamangal, Kathmandu
Email: drsbikram@gmail.com

Background: The recent trend has been toward recommendation of nondrainage in spinal surgery. However, the use of drains following posterior spinal surgery is still controversial. It has been claimed that wound drainage confers no significant advantages, increases the risk of infection and the need for blood transfusion with the attendant risks of this therapy. Suction drainage is used to minimize infection, prevention of wound swelling, improvement of the local wound environment, prevent hematoma and /or seroma formation. The aim of this study was to determine the incidence of post-operative complications after posterior lumbar instrumentation with and without a subfascial drain. **Methods:** This is prospective analysis of 32 adult (≥18 years old) spine patients that underwent elective and emergency posterior lumbar instrumentation at Kathmandu Medical College Teaching Hospital, from January to December 2023. There were randomly assigned 16 (50%) patients who had a post-operative drain and 16 (50%) patients who did not have a postoperative drain (No-Drain: n=16; Drain-Use: n=16). Patient demographics, comorbidities, intra- and post-operative complication rates were collected for each patient. The primary outcome investigated in this study was pain, the need for post-operative transfusion, dressing changes, surgery – discharge interval, the rate of post-operative complications, specifically surgical site infections (SSI) and hematoma formation. Data was analyzed using SPSS statistics version 29 (IBM Corp., New York). **Results:** Our study revealed that no significant differences regarding wound infection ($P = 1$), hematoma, neurological injury, estimated blood loss ($P = 0.3$), or dry and moderate dressing drainage between the groups. There were no 30-day hospital readmission or incidence of 30-day wound dehiscence, draining wound or bleeding between both patient groups. **Conclusions:** There is no obvious advantage of the application of suction drains for spinal surgery. There was no significant difference in the rate of infection or wound healing and no patient developed a postoperative neurologic deficit. However, a decision of wound drainage or wound non-drainage should be individualized for each patient because many factors affect the outcomes.

Key Words: Spine Surgery, Wound Drainage, Wound Non-Drainage, Complications

Date submitted: 20/04/2024
Date accepted: 08/05/2024

Since its publication in 1971 by neurosurgeon Jackson-Pratt, detailing the preventive benefits of drainage for subdural hematomas in injured brains, various drain types, including closed-suction and simple conduits, have been thought to deter blood and fluid accumulation post-spinal surgery.[1] The occurrence of postoperative hematomas typically falls within a range of 0.2 to 2.9%.[2] Guided by the longstanding belief in drain necessity and the potential severity of complications like epidural hematomas leading to neural compression, neurological deficits, or the need for hematoma evacuation reoperation, drains have routinely featured in spinal surgeries, including minimally invasive procedures (MIS).[3] Particularly in conventional open posterior spine surgeries with instrumentation, which entail more extensive procedures compared to simple decompression, drain insertion has been deemed a vital and customary final step.[4] However, a thorough literature review reveals a lack of definitive scientific evidence supporting the routine use of drains in aseptic spine surgeries. The surgeon stands at a dilemma of whether to use or not to use wound drains.

Closed suction drainage is commonly used in spine surgery. The drainage tube is inserted at the time of surgery directly into the wound or through a small separate incision site. The aim of using closed suction drainage is the prevention of the formation of hematomas.[5] Postoperative hematoma in the operative field can increase tension on incisions, delay wound healing, and lead to wound infection.[6] Moreover, epidural hematoma can lead to spinal cord compression and even paralysis in spinal surgery.[7] Among patient demographics, comorbidities and obesity are known to be significant risk factors for increasing perioperative blood loss.[8]

Hematoma associated with both muscle and epidural space fibrosis is the reason of postoperative pain syndrome, according to several authors.[9, 10] A few studies have demonstrated that closed suction drainage has no benefit in spinal surgery.[11] In contrast, closed suction drainage could cause retrograde infection, increase post- operative blood loss, and the need for transfusion.[12] Thus, it is unclear which procedures benefit from postoperative drainage. Contrary to the long-standing belief in the need for the drain, the risk of surgical site infection (SSI) or hematoma was not influenced using a drain, and a systematic review concluded that spine surgeons should not routinely rely on the closed suction drain without a higher level of evidence.[13] These reports addressed the efficacy of a drain after decompression alone, and only a few studies dealt with extensive spine surgery.[14] To our best knowledge, there have been no studies dealing with the usefulness of a drain that included conventional spine surgery alone. The use of closed suction drainage in posterior spinal surgery remains controversial.[15] Therefore, we realized a need for study to provide evidence-based judgment regarding the use of closed suction drainage in posterior spinal surgery.

Aims and objectives

The study aimed to document wound and systemic factors in two treatment groups and determine whether prophylactic drainage of operative wounds confers any significant advantages. Specifically, it sought to compare postoperative complications among patients undergoing posterior lumbar spinal surgery, with and without drains on the operated wound, with the aim of assessing whether drains could be avoided. The objectives included; assessing the effect on wound infection rates with and without the use of drains in posterior spine instrumentation surgeries, determining the incidence of hematoma-related complications after posterior spine instrumentation surgery without drainage, evaluating the clinical necessity and usefulness of routine insertion of a subfascial drain following posterior spine surgery based on comparative analysis, exploring the age and sex distribution of patients undergoing posterior spine surgery and comparing the study outcomes with other standard institutional studies.

Method

After obtaining institutional review board (IRB) approval, prospective observational descriptive analysis of clinical outcomes of 32 patients were carried out, who underwent elective and emergency posterior spine injuries stabilized with various instrumentation techniques, from January to December 2023.

The study population comprised patients who presented at the Emergency Room (ER) and Neurosurgery Outpatient Department (OPD) and were subsequently admitted for routine or emergency posterior lumbar spine instrumentation surgery in the Department of Neurological Surgery at KMCTH. All patients admitted during the study period for needful neurosurgical intervention in spine surgery, whether routine or emergent, were included. Exclusion criteria encompassed patients with polytrauma admitted under other departments, those under 18 years of age,

Date submitted: 20/04/2024
Date accepted: 08/05/2024

individuals with medical comorbidities such as diabetes mellitus (DM), hypertension (HTN), hypo/hyperthyroidism, etc., those with open or infected wounds, and those with incidental dural injury. Additionally, patients with neoplastic conditions (e.g., metastasis or myeloma), infections, severe osteoporosis, metal sensitivity, or mental illness were also excluded from the study.

In this prospective study, 37 consecutive patients undergoing different instrumentation techniques for lumbar spinal cord stabilization and decompression were included. All patients received intravenous antibiotic prophylaxis immediately before surgery.

These patients were randomly assigned into 2 Cohort groups.

1. Post op, wound closure with closed suction drain,
2. Post op, wound closure without closed suction drain.

Randomization took place during the surgical procedure, following completion of the decompression, through the selection of a card from an envelope indicating the assigned group. Five patients (3 in the drain group, 2 in the no-drain group) were unavailable for follow-up and were therefore excluded, resulting in a total of 32 patients included in the study.

Surgery was performed with the patient in prone position, following the administration of general anesthesia and endotracheal intubation. As part of anesthesia induction, systemic prophylactic antibiotic therapy using Inj Cephazolin 1000 mg was administered intravenously.[16] The required instrumentation surgery was carried out in the standard manner by two experienced consultant neurosurgeons. A midline skin incision was made to expose the posterior elements. The surgery was performed under hypotensive anesthesia, maintaining systolic blood pressure below 90 mm Hg. Blood pressure was restored to normotension before wound closure. Hemostasis was achieved using bipolar electrocoagulation and gel foam when necessary.

In our standardized technique, for the drainage group, closed drainage was initially placed under the deep fascia before wound closure. The tube was connected to a closed suction reservoir, and negative suction was generated by fully compressing the reservoir to create negative pressure. Drain removal was determined either when the drainage volume fell below 50 ml/day or after a maximum of 48 hours, with ongoing monitoring for the possibility of cerebrospinal fluid leak if larger drainage volumes persisted.[17]

In both the drainage and non-drainage groups, wound closure involved five layers: the paraspinal muscles, fascia, and supraspinal ligament were closed in three separate layers using interrupted-X stitches with 0 or 1-0 Vicryl sutures[18]. Subcutaneous tissues were closed with inverted Vicryl 2-0 in two planes for tissues deeper than 25 mm[19]. Skin closure was accomplished with prolene 3-0, continuous suture. [20, 21, 22]

Both groups underwent closure using identical techniques, and hemostasis was ensured in all patients before the surgeon was aware of the patient's group assignment. All participants or their relatives provided informed consent before undergoing various instrumentation surgeries. 16 patients, constituting the drain group, underwent placement of a closed wound suction drain deep to the lumbar fascia before wound closure. Conversely, 16 patients categorized as the no-drain group did not have a drain placed. All patients received intravenous antibiotic prophylaxis immediately before surgery.

Post-operative care

A complete neurological examination was done in all patients following recovery from anesthesia. As per our departmental protocol Systemic antibiotics were not given. Appropriate analgesics were given for the first week post-operatively. There was no administration of aspirin or other anti-inflammatory medications during the postoperative period. On the 2nd post operative day, all drains were removed, and the drainage volume was recorded (average 50ml). Patients were discharged on the 14th postoperative day and scheduled for follow-up appointments between 8-10 days after discharge. Throughout this period, surgery wounds were regularly assessed for hematoma and/or wound infection. In cases where a suspected infection was detected, wound cultures were obtained, and intravenous antibiotic therapy was initiated. If patients failed to respond to antibiotic treatment within 2 days, incision and drainage of the wound was performed.

Thromboprophylaxis drugs were not administered during the postoperative period, as all patients commenced mobilization on the first day after surgery. Furthermore, none of the patients included in the study were prescribed anti-platelet agents requiring cessation prior to surgery, and no antifibrinolytic agents were administered. Additionally, there was no need for blood transfusions in any of the patients.

Follow up

Clinical and radiological follow up of patients was done immediately postoperatively. Patients were followed up for a total duration of one month.

Post op complication as indicated by presence of at least one of the following.

- Hematoma
- Pain
- Tenderness
- Swelling
- Need of re-exploration due to above reasons or others

Statistical analysis

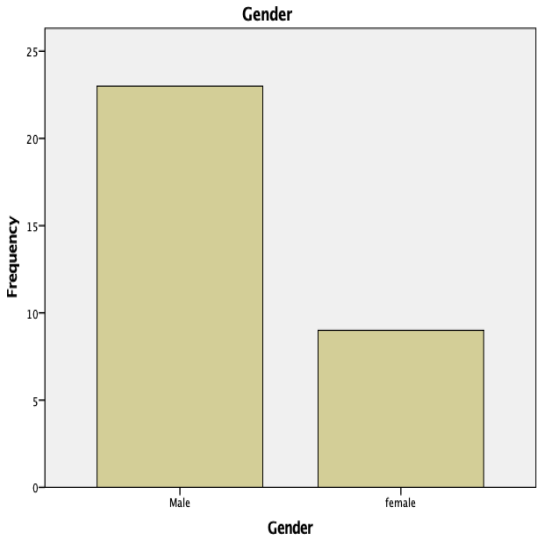
Data had been collected and recorded using a designed questionnaire. The following data were recorded: age, gender, the drainage volume, postoperative temperature, hemoglobin, total drainage days, and postoperative complications. Continuous data are presented as mean ± standard deviation. These collected data were entered in SPSS data sheet, subjected for descriptive statistics, diagrams and the needful z test. Statistical analysis would be done using SPSS computer software version 29.0.

Differences between cohorts were analyzed in a univariate manner, continuous variables- Student's t-test for normally distributed data. Associations between categorical variables were tested with Chi-square test ($\chi 2$ test). The p value of < 0.05 was considered as statistically significant.

Results

There were 16 (50%) who had a post-operative drain and 16 (50%) who did not have a postoperative drain (No-Drain: n=16; Drain-Use: n=16). Patient

Figure 1 Gender distribution

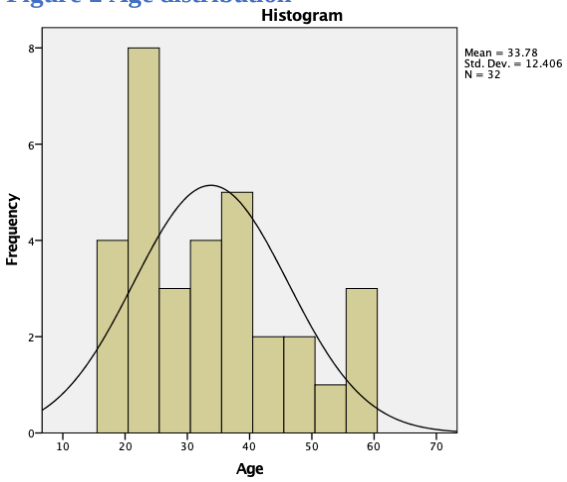


demographics, comorbidities, intra- and post-operative complication rates were collected for each patient. Wound healed by primary intension. The primary outcome investigated in this study was the rate of post-operative complications, specifically surgical site infections (SSI) and hematoma formation.16 (50%) post- operative drain; 16 (50%) did not have postoperative drain.

S.N	Characteristics		Withdrain (N=16)	Withoutdrain (N=16)	P value
1)	Mean Age		35.81±14.237	31.75±10.325	0.333
2)	Sex	Male	12 (75%)	11 (68.8%)	0.694
		Female	4 (25%)	5 (31.3%)	
3)	Weight (Kg)		67.13 ± 7.667*	68.56 ± 5.876*	0.270
4)	Operation time		130.50 ± 37.888*	116.25 ± 16.591*	0.424
5)	Blood loss, ml		286.25 ± 91.788*	282.81 ± 45.386*	0.310
6)	Wound length, mm		93.75 ± 10.878*	99.37 ± 12.366*	0.577
7)	Postoperative in patient stay, days		14.81 ± 1.377	15.50 ± 2.221*	0.689

* Significance of difference between subgroups (drains used or not used) according to Student's t-test, $p < 0.05$

Figure 2 Age distribution



Complications

Patients both with drains and without them did not have any neurologic complications due to epidural hematoma.

Total blood loss calculated was almost similar in patients with and without drains. Total blood loss weakly correlated both with the duration of inpatient stay and arterial hypertension in patients with and without drains.

	With drain	Without drain	P-value
Superficial wound infection	2	1	1
Deep wound infection	0	0	0
Symptomatic hematoma	1	0	0.310
Post operative neurological injury	0	0	0
Estimate blood loss	286.25 (mean)	282.81 (mean)	0.310

More patients with saturated dressings in the no drainage group (P = 0.002).

No significant differences in the 30-day hospital readmission rate or incidence of 30-day wound dehiscence, draining wound or bleeding between both patient groups

Two patients who underwent drain placement were documented to have superficial wound infections. One patient was diagnosed with a Staphylococcus aureus infection, while the other had a Streptococcus infection. Both patients exhibited wound drainage immediately following surgery upon diagnosis of the condition. Treatment for both cases involved the administration of Injection Flucloxacin 500 mg IV q.i.d. for a 10-day course, resulting in successful resolution of the infection.

In the group without drains, one patient developed an infection. This patient was presented with a moderate amount of purulent drainage on the seventh day after surgery. Cultures confirmed the presence of S. aureus. The infection was superficial and located above the lumbodorsal fascia. It was effectively managed with surgical debridement followed by 10 days of intravenous antibiotics and an additional 2 weeks of oral antibiotics.

Neither group experienced postoperative neurological deficits, and there were no significant hematoma or seroma occurrences requiring drainage in either group.

Discussion:

The conceptual benefits of employing prophylactic drains in straightforward spine procedures stem from the premise that the development of a postoperative hematoma increases the likelihood of tissue compression, potentially leading to wound infections or neurological issues. The placement of drains is intended to mitigate these risks, by facilitating the evacuation of the hematoma. In spinal surgery, the primary objective of keeping drains is to evacuate postoperative hematomas and preempt complications linked to their persistence. Areas for discussion is related to wound healing, infectious complications, symptomatic epidural hematomas, and the necessity for blood transfusions during the postoperative phase.

In a meta-analysis, Liu Y., Li Y., and Miao J. (2016); with data from both randomized and non-randomized controlled trials, revealed no substantial contrast between the drainage and non-drainage cohorts. Their study was on the occurrence of infectious complications, symptomatic epidural hematoma, and

the need for blood transfusions. Infectious complications manifested in 1.68% of cases with drain compared to 1.32% in groups without drains.[23]

The proliferation of bacteria within enclosed drainage systems has been well documented. The incidence of infection is contingent upon the initial level of wound contamination. Single-channel drains elevate the risk of bacterial proliferation by 75-90% within 72 hours. Closed suction drainage systems pose a 20% higher risk of contamination compared to not using drains at all.[24] Despite being employed to prevent infection, a prior investigation into drain utilization for orthopedic procedures revealed that 15% of patients with a suction drain exhibited culture- positive wound contamination.[25] Previous research suggests that the presence of a drain increases the risk of infection by 5 to 12%.[26]

Our study did not reveal any disparity in infection rates based on the utilization of postoperative drains. These results align with prior research, which similarly concluded that the absence of drains did not affect infection rates or wound healing outcomes among patients undergoing vascular reconstruction or total hip arthroplasty.[27, 28, 29]

Based on existing literature, the incidence of infectious complications in spinal surgery ranges from 0.7% to 6%, with an increase in incidence when fixation devices were used.[30] The efficacy of utilizing drains to mitigate infectious complications associated with spinal instrumentation remains a subject of debate.[31] One drawback with drain usage is the creation of a potential entry point at the location where the drainage tube is inserted, along with the introduction of an extra foreign object into the surgical site that communicates with the external environment.

In their systematic review analyzing five studies investigating the efficacy of drainage in surgeries for lumbar spine degenerative diseases, Waly F. et al. (2015) found no significant difference in the rates of infectious complications and postoperative hematomas between patients who underwent wound drainage and those who did not. Nevertheless, the relatively small sample sizes and the lack of data on other concurrent and exacerbating factors may potentially impact the conclusions drawn from these investigations.[32]

In our study, infectious complications of postoperative wounds were superficial and were noted in patients with one to three-level decompression-stabilizing interventions in the lumbar spine with drainage, in 2 of cases and without drainage, in one. Deep inflammation was not diagnosed.

It has been documented that symptomatic epidural hematomas can lead to spinal cord compression and potential paralysis, following posterior lumbar spine surgery.[33] The incidence of symptomatic epidural hematomas, which may result in neurological impairment such as motor deficiency, sensory disorders, and pelvic organ dysfunction, is reported to range from 0.1% to 2.9%. In some cases, surgical intervention is necessary.[34] Initially, drainage was associated with concerns regarding significant blood loss and the need for transfusions. However, studies have shown similar transfusion requirements between groups.[35] There is an increased incidence of allogeneic blood transfusion observed in cases of post-hemorrhagic anemia and drain utilization.[36]

Postoperative MRI studies revealed a notably reduced hematoma volume in the intervention zone when drains were kept.[37] Conversely, alternative research indicated a larger amount of hemorrhagic discharge on dressings, suggesting independent evacuation of hematomas if present.[35] Several studies indicated that drainage does not increase blood loss during the postoperative period, consequently not increasing the need for blood transfusions.[38] Our study did not diagnose any symptomatic epidural hematomas in either patient group.

A comparative study conducted by Blank J., Flynn J.M., Bronson W., and Ellman P. (2003), on posterior instrumental fixation, in idiopathic scoliosis patients aged 11- 18 years revealed that the insertion of drains can decrease the incidence of wound complications without significantly increasing the requirement for blood transfusions. In the cohort with wound drainage, blood transfusions were more prevalent, although without statistical significance. Conversely, among patients without drains, 58% required hematoma evacuation through the wound, leading to compromised healing, with three out of 12 patients exhibiting superficial inflammation.[35]

The patients were discharged from the hospital as their general condition stabilized, the neurological manifestations of the disease subsided, and the postoperative wound healed. In the group of patients with multilevel fixation of the spine in the presence of drainage, the stay in the hospital after the operation significantly increased. This group had a greater total blood loss and more blood transfusion occasions that required a longer period to stabilize the condition and

the increase in their inpatient stay.

With the changes in health care, cost-conscious behavior must be in the minds and actions of surgeons. Although the cost of a closed suction drain could be minimal, as it's paid once, this becomes compounded when a large volume of operations is performed. Use of a closed Romovac drain in posterior lumbar instrumentation cannot be justified by the scientific data presented. As the number of patients in this study is relatively small, it is not possible to draw conclusions regarding rare events such as epidural hematomas.

Limitation of the Study:

1. In this analysis, we encompassed all routine and emergency surgical cases. It's conceivable that patient-related factors, indications, and diagnoses may have influenced the risk of infection or postoperative complications, despite the mentioned exclusion criteria.

2. The study aimed to offer a comprehensive evaluation of compliance with guidelines regarding drain placement. Future investigations should concentrate on a detailed examination of patient factors specific to neurospine surgical indications, followed by prospective trials.

3. Although the cohorts analyzed for cost were well-defined, it's important to note that the primary cost drivers in healthcare are surgeries or repeat surgeries for surgical site infections (SSI), along with prolonged length of hospital stays (LOS) associated with hospital admissions. We believe that the observed increased costs likely reflect trends linked to preventable complications, at least within the institution under study.

4. It is worth acknowledging that we hadn't initially considered the significant investment made by society and hospitals in acquiring a high level of expertise and skill in these procedures by the respective surgical teams.

Conclusion:

Our study revealed a predominance of males among patients with lumbar spine injuries who underwent instrumentation. The majority of these individuals belonged to the productive age group. Falls were identified as the primary cause of spinal injuries.

Regarding posterior spinal surgery, the use of drainage led to a reduction in the volume of saturated dressing drainage. However, it did not result in a decrease in postoperative occurrences of wound infection, hematoma, neurological injury, or estimated blood loss. Notably, there were no instances of hematoma-related neurological deficits or reoperations due to epidural hematoma or surgical site infection (SSI) in the group that did not use drains. Furthermore, the no-drain group did not exhibit a significantly higher incidence of postoperative complications compared to the group that utilized drains. Consequently, the routine insertion of drains following posterior spinal surgery warrants careful reconsideration. The application of suction drains for spinal surgery does not appear to offer any obvious advantages. The approach to surgical wound care and drainage always remains the decision of the surgeon, influenced by their training and practice. However, there is a need for more high-quality randomized controlled trials (RCTs) with improved experimental designs and larger patient cohorts to further inform clinical practice.

References:

1. Jackson FE, Pratt 3rd RA. Technical report: a silicone rubber suction drain for drainage of subdural hematomas. Surgery. 1971; 70(4):578-579. PMID: 5099446
2. Kou J., Fischgrund J., Biddinger A., et al. Risk factors for spinal epidural hematoma after spinal surgery. *Spine (Phila Pa 1976)* 2002;27(15):1670–1673.
3. Ali Y, Roux FX, Meder JF, Pallud J. Symptomatic extensive thoracolumbar epidural hematoma following lumbar disc surgery treated by single level laminectomy. *Asian Spine J*. 2012;6(2):152–155. doi:10.4184/asj.2012.6.2.152
4. Ohba T, Ebata S, Haro H. Comparison of serum markers for muscle damage, surgical blood loss, postoperative recovery, and surgical site pain after extreme lateral interbody fusion with percutaneous pedicle screws or traditional open posterior lumbar interbody fusion. BMC Musculoskelet

Disord. 2017;18(1):415. doi:10.1186/s12891-017-1775-y

5. Holt BT, Parks NL, Engh GA, Lawrence JM. Comparison of closed-suction drainage and no drainage after primary total knee arthroplasty. Orthopedics. 1997; 20(12):1121–4. discussion 24-5. PMID: 9415907;

   DOI: 10.3928/0147-7447-19971201-05
6. Kim YH, Cho SH, Kim RS. Drainage versus nondrainage in simultaneous bilateral total knee arthroplasties. Clin Orthop Relat Res. 1998; Feb (347):188–93. PMID: 9526208; DOI: 10.1016/s0883-5403(98)90093-6
7. Li ZJ, Fu X, Xing D, Zhang HF, Zang JC, Ma XL. Is tranexamic acid effective and safe in spinal surgery? A meta-analysis of randomized controlled trials. Eur Spine J. 2013;22(9):1950– PMID: 236576; PMCID: PMC3777050; DOI: 10.1007/s00586-013-2774-9
8. Villavicencio A, Lee Nelson E, Rajpal S, Vivek N, Burneikiene S. The impact of BMI on operating room time, blood loss, and hospital stay in patients undergoing spinal fusion. Clin Neurol Neurosurg. 2019; 179:19-22. doi:10.1016/j.clineuro.2019.02.012 ; PMID: 30784895;

   DOI: 10.1016/j.clineuro.2019.02.012
9. Mirzai H., Eminoglu M., Orguc S. Are drains useful for lumbar disc surgery? A prospective, randomized clinical study. J. Spinal Disord. Tech., 2006, vol. 19, no. 3, pp. 171-177.
10. Sen O., Kizilkilic O., Aydin M.V., Yalcin O., Erdogan B., Cekinmez M., Caner H., Altinors N. The role of closed- suction drainage in preventing epidural fibrosis and its correlation with a new grading system of epidural fibrosis on the basis of MRI. Eur. Spine J., 2005, vol. 14, no. 4, pp. 409-414.
11. Scuderi GJ, Brusovanik GV, Fitzhenry LN, Vaccaro AR. Is wound drainage necessary after lumbar spinal fusion surgery? Med Sci Monit. 2005; 11(2): CR64–6.
12. Chen ZY, Gao Y, Chen W, Li X, Zhang YZ. Is wound drainage necessary in hip arthroplasty? A meta-analysis of randomized controlled trials. Eur J Orthop Surg Traumatol. 2014; 24(6):939–46.
13. Kelly EG, Cashman JP, Imran FH, Conroy R, O'Byrne J. Sys- tematic review and meta-analysis of closed suction drainage ver- sus non-drainage in primary hip arthroplasty. Surg Technol Int. 2014; 24:295-301.
14. Kotil K. Closed drainage versus non-drainage for single-level lumbar disc surgery: relationship between epidural hematoma and fibrosis. Asian SpineJ. 2016; 10(6):1072-1078. doi: 10.4184/asj. 2016.10.6.1072
15. Kanayama M, Oha F, Togawa D, Shigenobu K, Hashimoto T. Is closed-suction drainage necessary for single-level lumbar decompression?: review of 560 cases. Clin Orthop Relat Res. 2010; 468(10):2690–4.
16. Bryson D.J., Morris D.L.J., Shivji F.S., et al. Antibiotic prophylaxis in orthopaedic Surgery. Difficult decisions in an era of evolving antibiotic resistance. Bone Joint Lett. J. 2016;98-B:1014. –19.
17. Buser Z, Chang K, Kall R, Formanek B, Arakelyan A, Pak S, et al. Lumbar surgical drains do not increase the risk of infections in patients undergoing spine surgery. Eur Spine J. 2022;31:1775–83.
18. Haupt S, Cornaz F, Falkowski AL, Widmer J, Farshad M. Biomechanical considerations of the posterior surgical approach to the lumbar spine. Spine J. 2022 doi: 10.1016/j.spinee.2022.08.006.
19. Mehta A, Babu R, Karikari I, Grunch B, Agarwal V, Owens T, et al. 2012 young investigator award winner: The distribution of body mass as a significant risk factor for lumbar spinal fusion postoperativeinfections. Spine (Phila Pa 1976) 2012;37:1652–6.
20. Shani A, Poliansky V, Mulla H, Rahamimov N. Nylon skin sutures carry a lower risk of post-operative infection than metal staples in open posterior spine surgery: A retrospective case-control study

of 270 patients. Surg Infect (Larchmt) 2020;21:440–4.

21. Suter A, Spirig J, Fornaciari P, Bachmann E, Götschi T, Klein K, et al. Watertightness of wound closure in lumbar spine-a comparison of different techniques. J Spine Surg. 2019;5:358–64.
22. Yilmaz E, Blecher R, Moisi M, Ankush C, O'Lynnger T, Abdul-Jabbar A, et al. Is there an optimal wound closure technique for major posterior spine surgery? A systematic review. Global Spine J. 2018;8:535–44.
23. Liu Y., Li Y., Miao J. Wound drains in posterior spinal surgery: a meta-analysis. J. Orthop. Surg. Res., 2016, vol. 11, p. 16. doi: 10.1186/s13018-016-0351-8.
24. Ra, Slifkin M, Diamond DL: A bacteriological study comparing closed suction and simple conduit drainage. Am J Surg 148:618-620, 1984.
25. Waugh TR, Stinchfield FE: Suction drainage oforthopaedic wounds: Suction drainage wounds. J Bone Joini Surg [Am] 43:939-946, 1961.
26. Barker WF: Postoperative wound infections: The influence of ultraviolet irradiation of the operating room and of other vari- ous factors. Ann Surg 160(suppl 2):32-81, 1964.
27. Beer KJ, Lombardi AV, Mallory TH, Vaughn BK: The effica- cy of suction drains after routine total joint arthroplasty. J Bone Joint Surg [Am] 73:584- 587, 1991.
28. Ritter MA, Keating EM, Faris PM: Closed wound drainage in total hip or total knee replacement. J Bone Joint Surg [Am] 76:35-38, 1994.
29. Healy DA, Keyser J, Holcomb GW, Dean RH, Smith BM: Pro- phylactic closed suction drainage offemoral wounds in patients undergoing vascular reconstruction. J Vase Surg 10:166-168, 1989.
30. Walid M.S., Abbara M., Tolaymat A., Davis J.R., Waits K.D., Robinson J.S. 3rd, Robinson J.S. Jr. The role of drains in lumbar spine fusion. World Neurosurg., 2012, vol. 77, no. 3-4, pp. 564-568. doi: 10.1016/j.wneu.2011.05.058.
31. American Academy of Orthopaedic Surgeons Patient Safety Committee, R.P. Evans. Surgical site infection preven- tion and control: an emerging paradigm. J. Bone Joint Surg. Am., 2009, vol. 91, no. Suppl. 6, pp. 2-9. doi: 10.2106/JBJS.I.00549.
32. Waly F., Alzahrani M.M., Abduljabbar F.H., Landry T., Ouellet J., Moran K., Dettori J.R. The Outcome of Using Closed Suction Wound Drains in Patients Undergoing Lumbar Spine Surgery: A Systematic Review. Global Spine J., 2015, vol. 5, no. 6, pp. 479-485. doi: 10.1055/s-0035-1566288.
33. Amiri AR, Fouyas IP, Cro S, Casey AT. Postoperative spinal epidural hematoma (SEH): incidence, risk factors, onset, and management. Spine J. 2013;13(2):134–40.
34. Choi H.S., Lee S.G., Kim W.K., Son S., Jeong T.S. Is Surgical Drain Useful for Lumbar Disc Surgery? Korean J. Spine, 2016, vol. 13, no. 1, pp. 20-23. doi: 10.14245/kjs.2016.13.1.20.
35. Blank J, Flynn JM, Bronson W, Ellman P, Pill SG, Lou JE, et al. The use of postoperative subcutaneous closed suction drainage after posterior spinal fusion in adolescents with idiopathic scoliosis. J Spinal Disord Tech. 2003; 16(6):508–12.
36. Walid MS, Abbara M, Tolaymat A, Davis JR, Waits KD, Robinson 3rd JS, et al. The role of drains in lumbar spine fusion. World Neurosurg. 2012;77(3- 4):564–8.
37. Mirzai H., Eminoglu M., Orguc S. Are drains useful for lumbar disc surgery? A prospective, randomized clinical study. J.

Spinal Disord. Tech., 2006, vol. 19, no. 3, pp. 171-177.
38. Liu Y., Li Y., Miao J. Wound drains in posterior spinal surgery: a meta-analysis. J. Orthop. Surg. Res., 2016, vol. 11, p. 16. doi: 10.1186/s13018- 016-0351-8.
39. biomechanical analysis. Spine (Phila Pa 1976). 2003 Sep 15;28(18):2066-71. doi: 10.1097/01.BRS.0000084665.31967.02. PMID: 14501915.
40. Polly DW Jr, Orchowski JR, Ellenbogen RG. Revision pedicle screws. Bigger, longer shims--what is best? Spine (Phila Pa 1976). 1998 Jun 15;23(12):1374-9. doi: 10.1097/00007632-199806150-00015. PMID: 9654629.
41. Shea TM, Laun J, Gonzalez-Blohm SA, Doulgeris JJ, Lee WE 3rd, Aghayev K, Vrionis FD. Designs and techniques that improve the pullout strength of pedicle screws in osteoporotic vertebrae: current status. Biomed Res Int. 2014;2014:748393. doi: 10.1155/2014/748393. Epub 2014 Mar 3. PMID: 24724097; PMCID: PMC3958762.
42. Pingel A, Kandziora F, Hoffmann CH. Osteoporotic L1 burst fracture treated by short-segment percutaneous stabilization with cement-augmented screws and kyphoplasty (hybrid technique). Eur Spine J. 2014;23:2022-3.
43. Curry, S. J., Krist, A. H., Owens, D. K., Barry, M. J., Caughey, A. B., Davidson, K. W., Doubeni, C. A., Epling, J. W., Kemper, A. R., Kubik, M., Landefeld, C. S., Mangione, C. M., Phipps, M. G., Pignone, M., Silverstein, M., Simon, M. A., Tseng, C.-W., & Wong, J. B. (2018). Screening for Osteoporosis to Prevent Fractures. JAMA, 319(24), 2521. https://doi.org/10.1001/jama.2018.7498
44. Krenzlin H, Schmidt L, Jankovic D, Schulze C, Brockmann MA, Ringel F, Keric N. Impact of Sarcopenia and Bone Mineral Density on Implant Failure after Dorsal Instrumentation in Patients with Osteoporotic Vertebral Fractures. Medicina (Kaunas). 2022 May 31;58(6):748. doi: 10.3390/medicina58060748. PMID: 35744011; PMCID: PMC9228941.
45. Yabu A, Hoshino M, Tabuchi H, Takahashi S, Masumoto H, Akada M, Morita S, Maeno T, Iwamae M, Inose H, Kato T, Yoshii T, Tsujio T, Terai H, Toyoda H, Suzuki A, Tamai K, Ohyama S, Hori Y, Okawa A, Nakamura H. Using artificial intelligence to diagnose fresh osteoporotic vertebral fractures on magnetic resonance images. Spine J. 2021 Oct;21(10):1652-1658. doi: 10.1016/j.spinee.2021.03.006. Epub 2021 Mar 13. PMID: 33722728.