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RESEARCH

Practice preference of thromboprophylaxis following spine surgery - an international expert survey of AO spine members

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Abstract

Study design International survey.

Objectives Thromboprophylaxis after thoraco-lumbar spine surgery has been a source of controversy for decades. Clear evidence-based guidelines for the best prophylaxis modality are still missing. In this international survey, we asked spine surgeons about their clinical practices.

Methods A survey was distributed electronically to global members of the AO Spine community. The survey consisted of 27 questions of which 14 were analyzed in this study. Twelve questions addressed general information and two the way in which thromboprophylaxis was performed in patients with or without heightened risk of venous thromboembolism by using LMWH, UFH or other methods. We defined consensus for binary (yes/no) questions at >80% or <20%; intermediate consensus between 60 and 80% or 20–40%; an agreement between 40 and 60% was designated controversial.

Results A total of 240 respondents between June 26, 2024 and July 10, 2024 were included. The distribution of regional practice was Asia Pacific (21%), Europe and Southern Africa (33%), Latin America (20%), Middle East and Northern Africa (15%), and North America (11%). The preferred method of thromboprophylaxis was controversial in patients without heightened risk of venous thromboembolism. In contrast, in patients with an increased risk of venous thromboembolism, an intermediate consensus of 75% was found for low molecular weight heparin only. However, pneumatic compression devices were the preferred method in high risk patients in North America.

Conclusions The way in which thromboprophylaxis is carried out continues to be controversial. There is a need for more studies to build strong guidelines and standardize thromboprophylactic practice.

Keywords Thromboprophylaxis · Spine surgery · Morbidity · Mortality · Thrombosis · Bleeding

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Introduction

Venous thromboembolism (VTEs) in the form of deep venous thrombosis, pulmonary embolism, myocardial infarction and ischemic stroke remain significant sources of morbidity and mortality in patients undergoing thoracolumbar spine surgery [1–13]. Rates of venous thromboembolism after spine surgery vary from 0.2–13.6% [14]. Furthermore, when a venous thromboembolism is diagnosed and the patient is subsequently anticoagulated, this can increase the risk of feared complications such as epidural hematomas, intracranial bleeding or operation site wound complications following pharmacological thromboprophylaxis [14–24]. It has also been noted that patients who develop venous thromboembolisms are at higher risk for wound site complications [8].

Despite these risks, there is a notable lack of evidence to determine the optimal method of thromboprophylaxis [2, 3, 12, 14, 20, 25–28]. This uncertainty is even reflected in widely recognized guidelines, such as the North American Spine Society 2009 edition [29], offering limited direction.

The limited evidence results in heterogeneous practices amongst spine surgeons globally in the use of perioperative thromboprophylaxis [14, 16, 25, 30] representing either individual or institutional preferences rather than a robust evidence-based approach.

Surgeons usually choose from the following venous thromboembolism-prophylaxis regimes: unfractionated heparin, low molecular weight heparin (LMWH), mechanical compression devices, Aspirin or no prophylaxis [1, 4, 6, 7, 14–20, 22, 23, 25, 31–50].

We aim to address this lack of consensus due to lack of high-quality evidence by identifying the most effective and safest thromboprophylaxis strategies in the context of elective lumbar spine surgery through a series of studies in cooperation with the AO Spine Foundation. As a first step in this process, we sought to gather insight into the daily clinical practice pertaining to postoperative thromboprophylaxis employed by spine surgeons.

Our secondary focus was to identify any relationship between the practice preferences in providing thromboprophylaxis with regard to global practice regions, clinical focus, specialty of practice, institution type, individual clinical experience and individual case volume.

Methods and materials

Ethical considerations

This survey was organized with the help of the AO Spine foundation. A waiver was acquired from Swissethics, which is the umbrella organization of the cantonal ethics committees in Switzerland. Participants were informed about the purpose of the survey, the voluntary nature of their participation, and the confidentiality of their responses. Consent was implied through the completion of the survey.

Survey distribution

The survey was distributed to members of the AO Spine Foundation worldwide and the responses were divided into the following AO spine practice regions: Asia Pacific; Europe and Southern Africa; Latin America; Middle East and Northern Africa and North America. AO Spine is a clinical division of the AO Foundation, which is an independent medically-guided nonprofit organization. The survey was disseminated electronically on June 26, 2024. Participants were given a period of two weeks to complete the survey, with the final submission deadline set for July 10, 2024.

Inclusion/exclusion criteria

Inclusion criteria were spine surgeons who are AO Spine members. Exclusion criteria were incomplete surveys or implausible answers.

Survey design

A survey consisting of 27 questions with branching logic was designed to assess the clinical practices related to postoperative thromboprophylaxis among spine surgeons and other health professionals involved in the care of patients after elective thoraco-lumbar spine surgery. The questions were constructed to gather detailed information on various aspects of thromboprophylaxis.

In order to improve readability, in this publication we focused on questions 1–14, which deal with the daily practice of thromboprophylaxis of the participating AO spine members. The answers to questions 15–27, which deal with the implications of potential complications with or without thromboprophylaxis are presented in a second publication.

Questions 1 and 2 focused on geographical distribution and questions 3 to 5 on specialty, practice focus and setting. These questions should help identify correlations in practice in different world regions, specialties and institutions. Questions 6 and 7 focused on clinical experience; questions 8 to 10 on the number of surgeries performed per year; and finally questions 11 to 14 focused on daily practice in regards to providing thromboprophylaxis. The relevant survey questions are shown in Appendix 1.

Data source

Responses were collected electronically through Survey Monkey©. The survey included a mix of multiple-choice questions, drop down boxes and scale questions. Open-ended answers were possible if the participant could not find a matching answer in the multiple-choice sections. These questions allowed for both quantitative and qualitative analysis.

Proof of plausibility/missing data

Data integrity was evaluated according to specific rules to delete erroneously entered data and cases with missing information (proof of plausibility, Appendix 2). Responses with missing data or implausible answers were excluded.

Definition of the outcomes

We specially compared the four types of thromboprophylaxis used after thoraco-lumbar spinal surgery listed below in patients *with or without* a heightened risk of venous thromboembolism:

1. compression stockings,
2. intermittent pneumatic compression devices,
3. low molecular weight heparin,
4. other prophylaxis (aspirin, unfractionated heparin, early mobilization or direct oral anticoagulants).

Sensitivity analyses

Two sensitivity analyses were performed to test the reliability of the results. First, the excluded survey responses were included in the main study population and compared in relation to the primary focus to avoid exclusion bias. Second, the data of the main study population were randomly split into two groups based on the day they underwent the survey in an alternating manner. Both groups were analyzed for the primary focus.

Data analysis

The main data presentation includes descriptive statistics. Descriptive statistics were used to describe participants' responses. We defined consensus at >80% (positive consensus) or <20% (negative consensus). Consequently, we specified intermediate consensus at 60–80% or 20–40%. As a result, an approval between 40 and 60% was determined to be controversial. Relevant differences between groups were defined >20% (absolute) in binary (yes/no) questions.

Continuous variables are expressed as means (+/- standard deviation). Categorical variables are presented as absolute and relative frequencies. Continuous variables were compared using Mann-Whitney U-test. Categorical variables with a consensus at 60–100% or 0–40% were compared with Fisher's exact test. Two-sided p values <0.05 were considered statistically significant. Data analysis was performed using SPSS Statistics 29™ (SPSS Inc, Chicago, Illinois, USA).

Results

During the study period (June 26, 2024 to July 10, 2024), 370 spine surgeons and members of the AO Spine community received and opened the survey. Of these, 265 (72%) completed the survey. Among these, 25 respondents did not meet inclusion criteria because of missing or implausible data. The final study population included 240 completed surveys.

Population characteristics

The regional distribution of the 240 respondents were as follows: Asia Pacific (21%), Europe and Southern Africa (33%), Latin America (20%), Middle East and Northern Africa (15%), and North America (11%). The clinical specialties were neurosurgery (30%) and orthopaedics/trauma (70%). The respondents' clinical focus included multiple answers, these were as follows: degenerative (91%), deformities (51%), spinal cord injury (72%), and tumor (49%). The practice settings were mentioned as academic/university (37%), private (30%), public (31%), and other (2%, which included a combination of university, private or public hospitals). 65% of the respondents completed a spine fellowship. The clinical experience of the respondents was distributed as follows: 27% had five years or less of experience, 37% had between 5 and 15 years, and 36% had more than 15 years. The mean case volume was reported 244 (±244) cases for any spine surgery across all regions, 154 (±141) cases for spine surgeries specifically involving the lumbar region, and 94 (±96) cases for fusion surgeries in the lumbar spine region. Furthermore, Tables 1 and 2 present the variations in responses regarding when and how thromboembolic prophylaxis is utilized, based on clinical experience. Any type of deep venous thromboprophylaxis (compression stockings, intermittent pneumatic compression devices, Aspirin, low molecular weight heparin, unfractionated heparin, early mobilisation and direct oral anticoagulants) is used by 89% of the participants. Amongst

Table 1 Thromboprophylaxis after thoraco-lumbar spinal surgery in patients WITHOUT heightened risk of venous thromboembolism (n = 240)

	Compression stockings		Intermittent pneumatic Compression devices		Low molecular Weight heparin		Other prophylaxis	
	Yes (n=134)	No (n=106)	Yes (n=94)	No (n=146)	Yes (n=114)	No (n=126)	Yes (n=34)	No (n=206)
Clinical specialty (%)								
Neurosurgery (n=73)	47 (64)	26 (36)	26 (36)	47 (64)	41 (56)	32 (44)	11 (15)	62 (85)
Ortho/Trauma (n=167)	87 (52)	80 (48)	68 (41)	99 (59)	73 (44)	94 (56)	23 (14)	144 (86)
Practice setting (%)								
University (n=88)	44 (50)	44 (50)	37 (42)	51 (58)	43 (49)	45 (51)	15 (17)	73 (83)
Private (n=72)	46 (64)	26 (36)	30 (42)	42 (58)	**24 (33)***	**48 (67)***	7 (10)	65 (90)
Public (n=74)	42 (57)	32 (43)	22 (30)	52 (70)	**45 (61)***	**29 (39)***	12 (16)	62 (84)
Other (n=6)	2 (33)	4 (67)	**5 (83)***	**1 (17)***	2 (33)	4 (67)	0 (0)	6 (100)
Spine Fellowship (%) (n=155)	94 (61)	61 (39)	73 (47)	82 (53)	65 (42)	90 (58)	22 (14)	133 (86)
Years of practice (%)								
5 yrs or less (n=64)	41 (64)	23 (36)	26 (41)	38 (59)	37 (58)	27 (42)	10 (16)	54 (84)
5-15 yrs (n=90)	46 (51)	44 (49)	35 (39)	55 (61)	43 (48)	47 (52)	13 (14)	77 (86)
>15 yrs (n=86)	47 (55)	39 (45)	33 (38)	53 (62)	34 (40)	52 (60)	11 (13)	75 (87)
Case volume (n=240)								
Any spine surgery on any spine region	246±248	241±240	250±215	240±262	216±173	270±292	215±150	249±256
Any spine surgery on LUMBAR spine region	159±163	148±107	162±140	149±142	141±117	166±160	140±96	156±147
FUSION spine surgery on LUMBAR spine region	96±109	90±77	100±100	89±93	88±86	98±104	96±69	93±100

Continuous variables are expressed as means +/- standard deviations (SD). Categorical variables are presented as absolute and relative frequencies. *p<0.05 Yes versus No. Other prophylaxis include: aspirin, unfractionated heparin, early mobilization or direct oral anticoagulants. Other practice setting includes a combination of university, private or public. The numbers in parentheses refer to the line

Table 2 Thromboprophylaxis after thoraco-lumbar spinal surgery in patients WITH heightened risk of venous thromboembolism (n=240)

	Compression stockings		Intermittent pneumatic Compression devices		Low molecular Weight heparin		Other prophylaxis	
	Yes (n=129)	No (n=111)	Yes (n=113)	No (n=127)	Yes (n=180)	**No (n=60)**	Yes (n=50)	No (n=190)
Clinical specialty (%)								
Neurosurgery (n=73)	45 (62)	28 (38)	38 (52)	35 (48)	**63 (86)***	**10 (14)***	14 (19)	59 (81)
Ortho/Trauma (n=167)	84 (50)	83 (50)	75 (45)	92 (55)	**117 (70)***	**50 (30)***	36 (22)	131 (78)
Practice setting (%)								
University (n=88)	42 (48)	46 (52)	39 (44)	49 (56)	69 (78)	19 (22)	20 (23)	68 (77)
Private (n=72)	**46 (64)***	**26 (36)***	39 (54)	33 (46)	50 (69)	22 (31)	13 (18)	59 (82)
Public (n=74)	39 (53)	35 (47)	29 (39)	45 (61)	56 (76)	18 (24)	17 (23)	57 (77)
Other (n=6)	2 (33)	4 (67)	**6 (100)***	**0 (0)***	5 (83)	1 (17)	0 (0)	6 (100)
Spine Fellowship (%) (n=155)	90 (58)	65 (42)	82 (53)	73 (47)	**109 (70)***	**46 (30)***	33 (21)	122 (79)
Years of practice (%)								
5 yrs or less (n=64)	36 (56)	28 (44)	32 (50)	32 (50)	49 (77)	15 (23)	**19 (30)***	**45 (70)***
5-15 yrs (n=90)	51 (57)	39 (43)	41 (46)	49 (54)	68 (76)	22 (24)	16 (18)	74 (82)
>15 yrs (n=86)	42 (49)	44 (51)	40 (47)	46 (53)	63 (73)	23 (27)	15 (17)	71 (83)
Case volume (n=240)								
Any spine surgery on any spine region	223 ± 225	262 ± 265	250 ± 215	240 ± 262	236 ± 227	268 ± 291	244 ± 246	244 ± 245
Any spine surgery on LUMBAR spine region	154 ± 141	160 ± 125	162 ± 140	149 ± 142	156 ± 152	148 ± 103	153 ± 155	154 ± 138
FUSION spine surgery on LUMBAR spine region	92 ± 103	96 ± 86	100 ± 100	89 ± 93	96 ± 101	87 ± 81	99 ± 101	92 ± 95

Continuous variables are expressed as means +/- standard deviations (SD). Categorical variables are presented as absolute and relative frequencies. *p<0.05 Yes versus No. Other prophylaxis include: aspirin, unfractionated heparin, early mobilization or direct oral anticoagulants. Other practice setting includes a combination of university, private or public. The numbers in parentheses refer to the line

these, 40% of the respondents use risk stratification criteria to implement prophylaxis.

Primary focus

The practice preference of thromboprophylaxis remained controversial in patients undergoing thoraco-lumbar spine surgery without heightened risk of venous thromboembolism (Fig. 1). In contrast, in patients with an increased risk of venous thromboembolism, an intermediate consensus was only found for low molecular weight heparin (75%; Fig. 1).

Secondary focus

The thromboprophylaxis modality used in patients without heightened risk of venous thromboembolism depends on global practice regions (Fig. 2A). In Europe and Southern Africa compression stockings and low molecular weight heparin are used significantly more often resulting in an intermediate consensus. In contrast, in the regions of Asia Pacific, Latin America, and North America low molecular weight heparin is used significantly less. Intermittent pneumatic compression devices are the preferred method in North America (Fig. 2A). However, in patients with heightened risk of venous thromboembolism, low molecular weight heparin is the most used method in all regions. This result was significant and correlated with an intermediate consensus in all regions except North America (Fig. 2B).

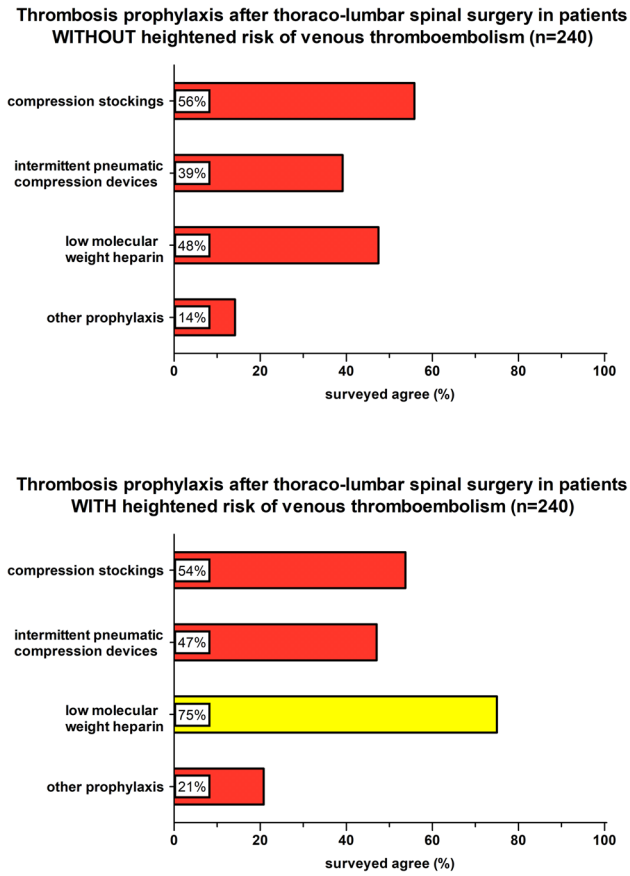


Fig. 1 Thromboprophylaxis after thoraco-lumbar spinal surgery in patients WITHOUT (figure above) or WITH (figure below) heightened risk of venous thromboembolism (n=240). Yellow: 60-80% agreed. Red: <60% agreed. Other prophylaxis include: aspirin, unfractionated heparin, early mobilization or direct oral anticoagulants

In patients with heightened risk of venous thromboembolism, neurosurgeons (yes: 86% versus no: 14%, $p=0.009$) and orthopedics/trauma surgeons (yes: 70% versus no: 30%, $p=0.009$) predominately used low molecular weight heparin. Surgeons who completed spine fellowship used low molecular weight heparin equally often in patients with heightened risk of venous thromboembolism as orthopedics/trauma surgeons (yes: 70% versus no: 30%, $p=0.03$; Table 2). The same was found for all subgroups related to clinical experience in years of practice, with an agreement of more than 70% for low molecular weight heparin. However, these results were not significant. A similar result was found for practice focus, see Fig. 3B.

Clinical specialty had no significant influence on other methods of thromboprophylaxis (Tables 1 and 2) in patients with and without heightened risk of venous thromboembolism.

In patients without heightened risk of venous thromboembolism, more low molecular weight heparin was used in public (yes: 61% versus no: 39%, $p=0.008$) compared to private hospitals (yes: 33% versus no: 67%, $p=0.005$; Table 1).

The case volume had no significant influence in the way in which thromboprophylaxis was carried out.

Sensitivity analyses

If we include all 265 surveys (25 excluded surveys plus the main study population of 240 surveys) in the analysis for the primary focus, the results are comparable in patients without heightened risk of venous thromboembolism (compression stockings: 55%, intermittent pneumatic compression devices: 38%, low molecular weight heparin: 47%, other prophylaxis: 16%) and in patients with heightened risk (compression stockings: 53%, intermittent pneumatic compression devices: 46%, low molecular weight heparin: 73%, other prophylaxis: 22%). Similar results were found in the secondary sensitivity analysis.

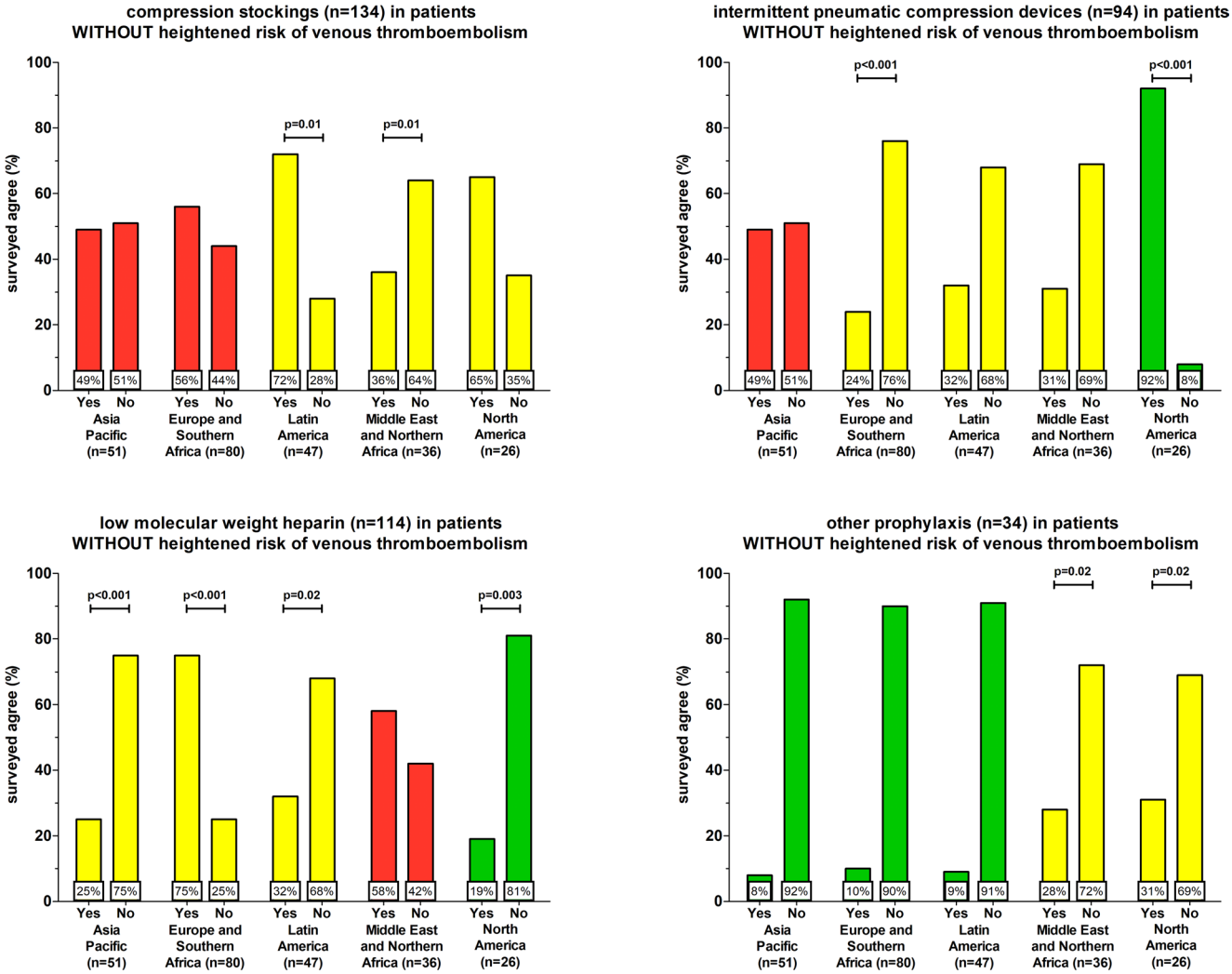


Fig. 2 **A** Thromboprophylaxis after thoraco-lumbar spinal surgery in patients WITHOUT heightened risk of venous thromboembolism (n=240) related to the region. Green: >80% agreed. Yellow: 60-80% agreed. Red: <60% agreed. The numbers in parentheses in the graph titles are the total number of agreed prophylaxis (i.e. surveyed agreed with other prophylaxis in n=34). The numbers are given to make it clear that the significance does not only refer to the difference between yes and no. Other prophylaxis include: aspirin, unfractionated heparin, early mobilization or direct oral anticoagulants. **B** Thromboprophylaxis after thoraco-lumbar spinal surgery in patients WITH heightened risk of venous thromboembolism (n=240) related to the region. Green:>80% agreed. Yellow: 60-80% agreed. Red: <60% agreed. The numbers in parentheses in the graph titles are the total number of agreed prophylaxis (i.e. surveyed agreed with other prophylaxis in n=34). The numbers are given to make it clear that the significance does not only refer to the difference between yes and no. Other prophylaxis include: aspirin, unfractionated heparin, early mobilization or direct oral anticoagulants

Discussion

A global intermediate consensus of 75% supports the perioperative use of low molecular weight heparin in patients with heightened risk of venous thromboembolism when all available data are analyzed together. Interestingly, in Europe, low molecular weight heparin is the preferred method for high-risk patients, while in North America, pneumatic compression devices are favored, both with a high consensus level.

Both approaches are supported by a high level of consensus within their respective regions.

As the varying guidelines across continents and countries indicate, European protocols tend to prioritize pharmacological methods such as low molecular weight heparin, while North American practices show a clear preference for mechanical prophylaxis [29, 51].

Both neurosurgeons and orthopedic/trauma surgeons significantly opted to use low molecular weight heparin in patients with a heightened risk of venous thromboembolism. This observation extends to physicians who have completed a spine fellowship as well. This reflects a broad agreement in the necessity for more effective pharmacological thromboprophylaxis, particularly in patient with one or more risk

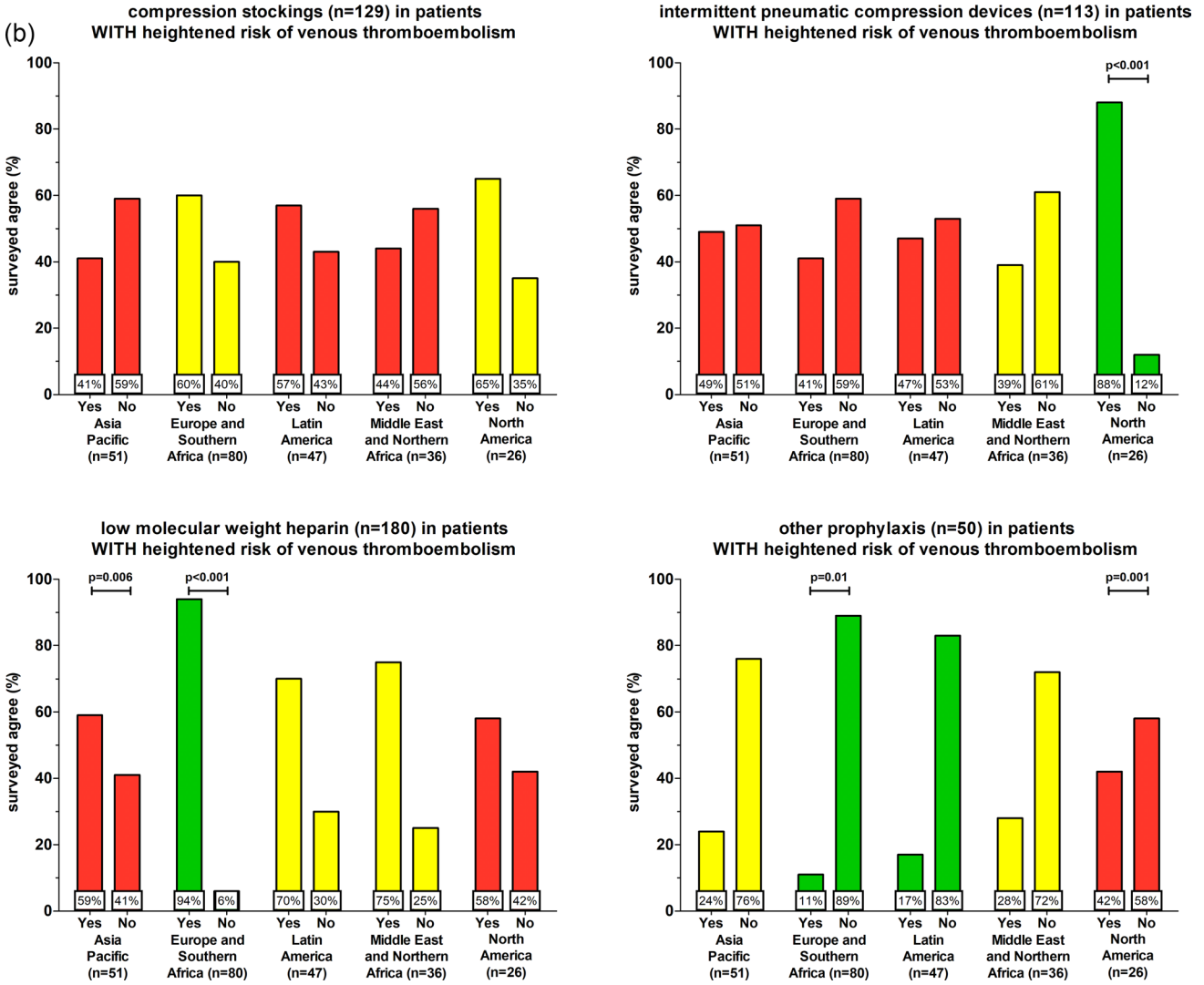


Fig. 2 (continued)

factors with increased likelihood of venous thrombosis [8, 12, 16, 27, 37].

The practice setting per se seems to have a significant effect on the chosen prophylaxis modality. While public hospitals significantly administer more low weight heparin to their patients even without heightened risk for developing venous thromboembolisms, private hospitals prefer mechanical alternatives especially compression stockings even in patients at high risk. The reason for the discrepancy between public and private institution is unclear. It is possible that private institutions might be concerned that potential postoperative bleeding complications could potentially lead to litigation [21, 43], thus choosing to be more restrictive with pharmacological prophylaxis.

Nevertheless, the way in which thromboprophylaxis should be carried out is controversial and variable depending on the AO Spine practice region. The willingness to use low molecular weight heparin does increase globally in the high-risk patient group however, there is a strong discrepancy between North America and Europe and Southern Africa. While Europe and Southern Africa seem to apply low molecular weight heparin fairly liberally in high-risk patients, North America opts to continue with more conservative mechanical prophylaxis. Possible explanation for this difference is the limited direction offered by current guidelines [3, 29, 34, 52]. Because of this and the generally more litigious nature of the North American health care system, physicians might possibly be more hesitant to apply pharmacological prophylaxis which might result in potentially catastrophic bleeding complications [19] when an efficacious mechanical alternative is available [9, 27, 31, 37].

The only significant correlation to practice focus and prophylaxis modality was found in high risk patients undergoing tumor surgery with a consensus for the use of low

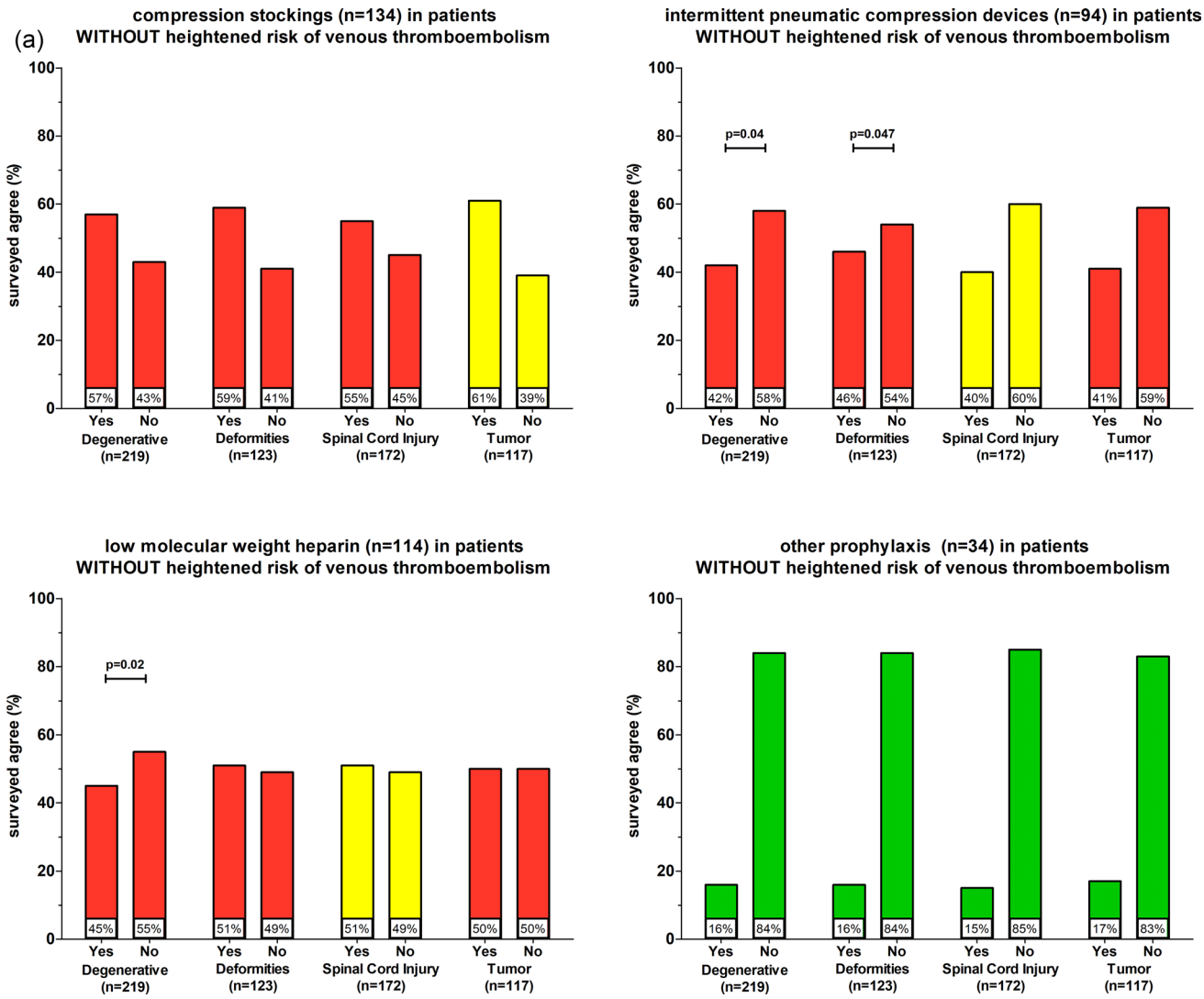


Fig. 3 **A** Thromboprophylaxis after thoraco-lumbar spinal surgery in patients WITHOUT heightened risk of venous thromboembolism (n=240) related to the clinical focus. Green: >80% agreed. Yellow: 60-80% agreed. Red: <60% agreed. The numbers in parentheses in the graph titles are the total number of agreed prophylaxis (i.e. surveyed agreed with other prophylaxis in n=34). The numbers are given to make it clear that the significance does not only refer to the difference between yes and no. Other prophylaxis include: aspirin, unfractionated heparin, early mobilization or direct oral anticoagulants. **B** Thromboprophylaxis after thoraco-lumbar spinal surgery in patients WITH heightened risk of venous thromboembolism (n=240) related to the clinical focus. Green: >80% agreed. Yellow: 60-80% agreed. Red: <60% agreed. The numbers in parentheses in the graph titles are the total number of agreed prophylaxis (i.e. surveyed agreed with other prophylaxis in n=34). The numbers are given to make it clear that the significance does not only refer to the difference between yes and no. Other prophylaxis include: aspirin, unfractionated heparin, early mobilization or direct oral anticoagulants

molecular weight heparin in this group. This seems prudent since malignancy is in itself a risk factor for developing venous thromboembolisms [37, 40] and should therefore be treated more aggressively.

It is worth noting that the survey intentionally left the term “high risk” broadly defined, allowing respondents to apply their own clinical judgment. However, the clear consensus in tumor cases — where high risk was explicitly defined — suggests that a more precise definition across all scenarios might have yielded stronger, more consistent results.

Of note, spinal cord injuries did not have a significant rate of pharmacological prophylaxis and only an intermediate consensus for the use of low molecular weight heparin in the high-risk group. This practice is in contrast to the known higher incidence of venous thromboembolisms after trauma and the known efficacy of low molecular weight heparin in avoiding venous thromboembolisms [22, 37, 43, 53–55]. It should be noted that our questionnaire did not distinguish between trauma-related and acquired spinal cord injuries, which may explain the observed intermediate consensus.

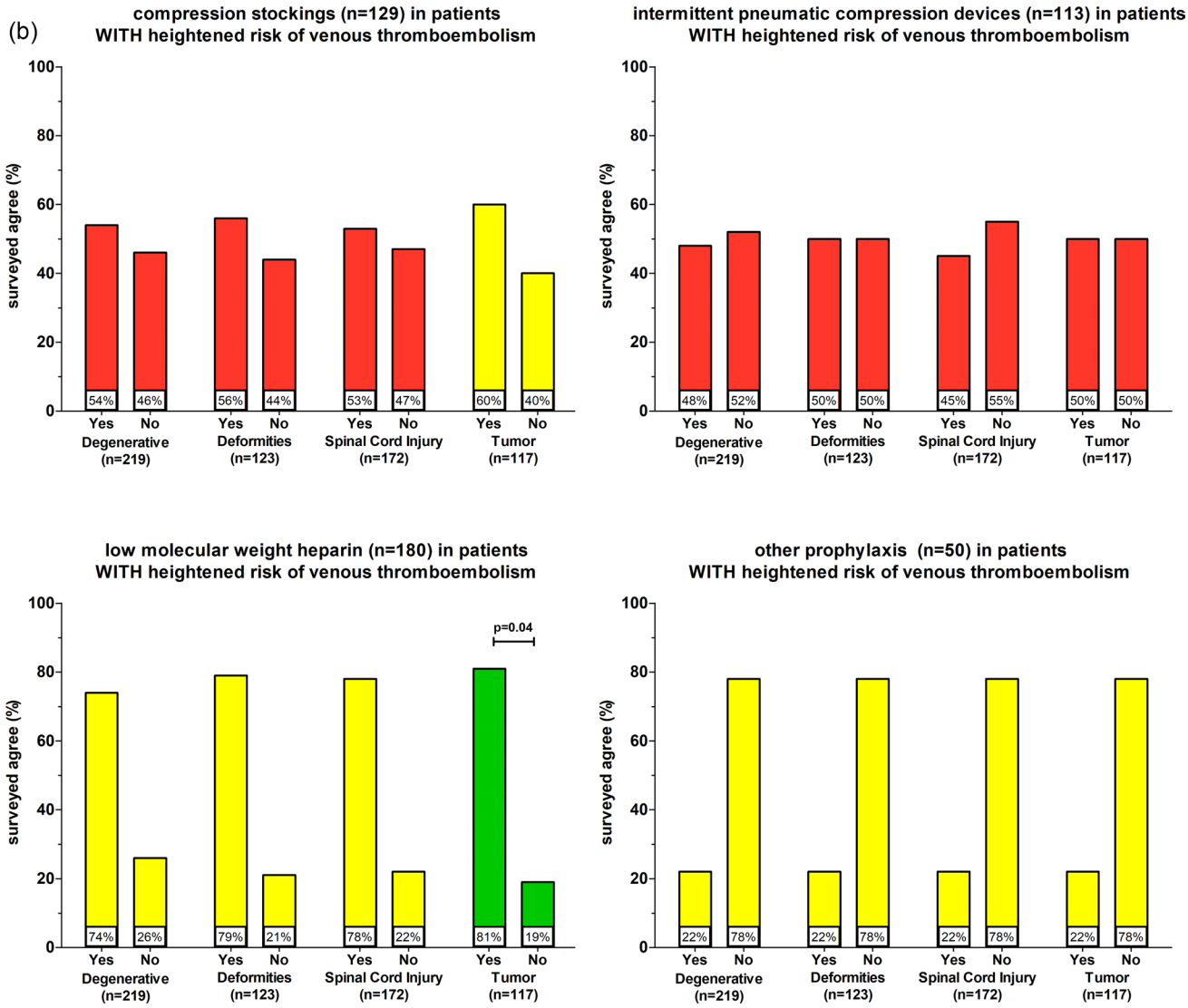


Fig. 3 (continued)

Interestingly the use of other prophylaxis including aspirin, unfractionated heparin, early mobilization or direct oral anticoagulants was uncommon in all groups despite studies indicating a potential benefit in their use [32].

Limitations

Due to lack of high-quality studies and consistent guidelines on thromboembolic prophylaxis in spine surgery, our aim was to explore current clinical practices and expert opinions, and to assess whether they are consistent with one another. Thus, acknowledging the potential for bias given the survey-based design which may affect the validity of the collected information.

The most important limitation of this survey is that it is not a controlled study. Nevertheless, after several proof of plausibility and sensitivity analyses, our results could be validated to be reliable. Furthermore, the study did not asses the test-retest reliability of the questionnaire. As a result, we cannot rule out the possibility that participants may have provided different responses if the questionnaire had been administered at another time point.

Our analyses included 265 responses, which corresponds to a 72% completion rate. Although the reasons for non-response among 28% of invited participants remain unknown, the achieved 72% completion rate is higher than typical online survey response rates, which are reported to average around 44% in the literature [56]. Nonetheless, non-response bias cannot be entirely ruled out.

Therefore, the limited number of participants may not necessarily reflect global practice patterns and our findings need to be confirmed through large multicenter studies. However, a strength of our survey is the global inclusion of

AO Spine members, giving us a good idea of regional differences in daily practice.

Conclusion

In summary, the way in which thromboprophylaxis is, could or should be carried out continues to be controversial. However, in patients with heightened risk of venous thromboembolism, an intermediate consensus was found for the use of low molecular weight heparin. This underscores the urgent need for high-quality studies comparing the efficacy and safety of different prophylactic strategies. Clear, evidence-based guidelines are essential to standardize care and guide spine surgeons in making informed, consistent decisions across diverse clinical settings.

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Author contributions A.D. First Author, Corresponding Author, Wrote the original draft. Was integral in conceptualization and survey creation. A.K. Co-First Author, Helped in writing the original draft. Was integral in conceptualization. Main reviewer and editor. H.B. Helped in writing the original draft. Was mainly responsible for data analysis and visualizationM.F. Help in reviewing and editing the manuscript. Integrated expert opinionA.K.D. Help in reviewing and editing the manuscript. Integrated expert opinion. AO representative.S.M. Help in reviewing and editing the manuscript. Integrated expert opinion. AO representative.U.E. Last Author, One of the main reviewers. Involved in conceptualization and mentoring. Provided departemental resources.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Conflict of interests The authors declare no competing interests.

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References

1. Voth D et al (1992) Prevention of deep vein thrombosis in neurosurgical patients: a prospective double-blind comparison of two prophylactic regimen. Neurosurg Rev 15(4):289–294
2. Schoenfeld AJ et al (2013) Patient-based and surgical characteristics associated with the acute development of deep venous thrombosis and pulmonary embolism after spine surgery. Spine (Phila Pa 1976) 38(21):1892–1898
3. Samama CM et al (2006) Venous thromboembolism prevention in surgery and obstetrics: clinical practice guidelines. Eur J Anaesthesiol 23(2):95–116
4. Takahashi H et al (2012) Incidence of venous thromboembolism after spine surgery. J Orthop Sci 17(2):114–117
5. Tetzlaff JE et al (1998) Spinal anesthesia for elective lumbar spine surgery. J Clin Anesth 10(8):666–669
6. Dearborn JT et al (1999) Thromboembolic complications after major thoracolumbar spine surgery. Spine (Phila Pa 1976) 24(14):1471–1476
7. Smith MD et al (1994) Deep venous thrombosis and pulmonary embolism after major reconstructive operations on the spine. A prospective analysis of three hundred and seventeen patients. J Bone Joint Surg Am 76(7):980–985
8. Gephart MG et al (2012) Venous thromboembolism after thoracic/thoracolumbar spinal fusion. World Neurosurg 78(5):545–552
9. Epstein NE (2006) Efficacy of pneumatic compression stocking prophylaxis in the prevention of deep venous thrombosis and pulmonary embolism following 139 lumbar laminectomies with instrumented fusions. J Spinal Disord Tech 19(1):28–31
10. Boachie-Adjei O et al (1991) Management of adult spinal deformity with combined anterior-posterior arthrodesis and Luque-Galveston instrumentation. J Spinal Disord 4(2):131–141
11. Oskouian RJ Jr., Johnson JP (2002) Vascular complications in anterior thoracolumbar spinal reconstruction. J Neurosurg 96(1 Suppl):1–5
12. Fineberg SJ et al (2013) The incidence and mortality of thromboembolic events in lumbar spine surgery. Spine (Phila Pa 1976) 38(13):1154–1159
13. Udén A (1979) Thromboembolic complications following scoliosis surgery in Scandinavia. Acta Orthop Scand 50(2):175–178
14. Rockson HB et al (2019) Venous thromboembolism prophylaxis for patients having elective spine surgery: when, why, and how much. J Bone Joint Surg Am 101(13):1220–1229
15. Ginzburg E et al (2003) Randomized clinical trial of intermittent pneumatic compression and low molecular weight heparin in trauma. Br J Surg 90(11):1338–1344
16. Epstein NE (2005) A review of the risks and benefits of differing prophylaxis regimens for the treatment of deep venous thrombosis and pulmonary embolism in neurosurgery. Surg Neurol 64(4):295–301 discussion 302
17. Rokito SE, Schwartz MC, Neuwirth MG (1996) Deep vein thrombosis after major reconstructive spinal surgery. Spine (Phila Pa 1976) 21(7):853–858 discussion 859
18. Gruber UF et al (1984) Prevention of thromboembolic complications with miniheparin-dihydroergotamine in patients undergoing lumbar disc operations. Eur Arch Psychiatry Neurol Sci 234(3):157–161
19. Gerlach R et al (2004) Postoperative nadroparin administration for prophylaxis of thromboembolic events is not associated with an increased risk of hemorrhage after spinal surgery. Eur Spine J 13(1):9–13
20. Mosenthal WP et al (2018) Thromboprophylaxis in spinal surgery. Spine (Phila Pa 1976) 43(8):E474-e481
21. Devlin JW, Tyburski JG, Moed B (2001) Implementation and evaluation of guidelines for use of Enoxaparin as deep vein

thrombosis prophylaxis after major trauma. Pharmacotherapy 21(6):740–747
22. Harris S, Chen D, Green D (1996) Enoxaparin for thromboembolism prophylaxis in spinal injury: preliminary report on experience with 105 patients. Am J Phys Med Rehabil 75(5):326–327
23. Al-Dujaili TM et al (2012) Deep venous thrombosis in spine surgery patients: incidence and hematoma formation. Int Surg 97(2):150–154
24. Cain JE Jr. et al (1995) The morbidity of heparin therapy after development of pulmonary embolus in patients undergoing thoracolumbar or lumbar spinal fusion. Spine (Phila Pa 1976) 20(14):1600–1603
25. Glotzbecker MP et al (2009) Thromboembolic disease in spinal surgery: a systematic review. Spine (Phila Pa 1976) 34(3):291–303
26. Catre MG (1997) Anticoagulation in spinal surgery. A critical review of the literature. Can J Surg 40(6):413–419
27. Geerts WH et al (2004) Prevention of venous thromboembolism: the seventh ACCP conference on antithrombotic and thrombolytic therapy. Chest 126(3 Suppl):338s–400s
28. Zuckerman SL et al (2023) Management of anticoagulation/antiplatelet medication and venous thromboembolism prophylaxis in elective spine surgery: concise clinical recommendations based on a modified Delphi process. Spine (Phila Pa 1976) 48(5):301–309
29. Bono CM et al (2009) An evidence-based clinical guideline for the use of antithrombotic therapies in spine surgery. Spine J 9(12):1046–1051
30. Bryson DJ, Uzoigwe CE, Braybrooke J (2012) Thromboprophylaxis in spinal surgery: a survey. J Orthop Surg Res 7:14
31. Wood KB et al (1997) Prevention of deep-vein thrombosis after major spinal surgery: a comparison study of external devices. J Spinal Disord 10(3):209–214
32. Nelson LD Jr. et al (1996) Deep vein thrombosis in lumbar spinal fusion: a prospective study of antiembolic and pneumatic compression stockings. J South Orthop Assoc 5(3):181–184
33. Kurtoglu M et al (2004) Venous thromboembolism prophylaxis after head and spinal trauma: intermittent pneumatic compression devices versus low molecular weight heparin. World J Surg 28(8):807–811
34. Brambilla S et al (2004) Prevention of venous thromboembolism in spinal surgery. Eur Spine J 13(1):1–8
35. Janni W et al (2001) Prospective randomized study comparing the effectiveness and tolerance of various low-molecular-weight heparins in high risk patients. Zentralbl Chir 126(1):32–38
36. Du W et al (2015) Comparison of rivaroxaban and parnaparin for preventing venous thromboembolism after lumbar spine surgery. J Orthop Surg Res 10:78
37. Akeda K et al (2014) Prevalence and countermeasures for venous thromboembolic diseases associated with spinal surgery: a follow-up study of an institutional protocol in 209 patients. Spine (Phila Pa 1976) 39(10):791–797
38. Kulkarni AG et al (2020) The practice of continuation of anti-platelet therapy during the perioperative period in lumbar minimally invasive spine surgery (MISS): how different is the morbidity in this scenario?? Spine (Phila Pa 1976) 45(10):673–678
39. Cornwell EE (2002) Compliance with sequential compression device prophylaxis in at-risk trauma patients: a prospective analysis. Am Surg 68(5):470–473
40. Agnelli G (2004) Prevention of venous thromboembolism in surgical patients. Circulation 110(24 Suppl 1):IV-4-IV-12
41. Lee HM et al (2000) Deep vein thrombosis after major spinal surgery: incidence in an East Asian population. Spine (Phila Pa 1976) 25(14):1827–1830
42. Soleman J et al (2016) Non-instrumented extradural lumbar spine surgery under low-dose acetylsalicylic acid: a comparative risk analysis study. Eur Spine J 25(3):732–739
43. Deep K et al (2001) Prophylaxis of thromboembolism in spinal injuries–results of enoxaparin used in 276 patients. Spinal Cord 39(2):88–91
44. Britt LD et al (1996) Incidence and prophylaxis of deep vein thrombosis in a high risk trauma population. Am J Surg 172(1):13–14
45. Nicol M et al (2009) Incidence of thromboembolic complications in lumbar spinal surgery in 1,111 patients. Eur Spine J 18(10):1548–1552
46. Strom RG, Frempong-Boadu AK (2013) Low-molecular-weight heparin prophylaxis 24 to 36 hours after degenerative spine surgery: risk of hemorrhage and venous thromboembolism. Spine (Phila Pa 1976) 38(23):E1498–E1502
47. Namboothiri S (2012) Incidence of deep vein thrombosis after major spine surgeries with no mechanical or chemical prophylaxis. Evid Based Spine Care J 3(3):29–33
48. Kang SB et al (2011) Does low-dose aspirin increase blood loss after spinal fusion surgery? Spine J 11(4):303–307
49. Rocha E, Imberti D, Paschina E (2007) Low-molecular-weight heparins: before or after surgery? New concepts and evidence: congress report from the Sigma tau/rovi satellite symposium (Rome, italy, 13 November 2006). Clin Drug Investig 27(5):357–366
50. Korinth MC, Gilsbach JM, Weinzierl MR (2007) Low-dose aspirin before spinal surgery: results of a survey among neurosurgeons in Germany. Eur Spine J 16(3):365–372
51. Samama CM et al (2024) European guidelines on peri-operative venous thromboembolism prophylaxis: first update.: executive summary. Eur J Anaesthesiol 41(8):561–569
52. Deep K et al (2002) Prophylaxis of thromboembolism in spinal injuries–survey of practice in spinal units in the British isles. Injury 33(4):353–355
53. Louie P et al (2020) Perioperative anticoagulation management in spine surgery: initial findings from the AO spine anticoagulation global survey. Glob Spine J 10(5):512–527
54. Green D et al (2005) Evolving risk for thromboembolism in spinal cord injury (SPIRATE study). Am J Phys Med Rehabil 84(6):420–422
55. O'Donnell M, Weitz JI (2003) Thromboprophylaxis in surgical patients. Can J Surg 46(2):129–135
56. Shiyab W et al (2023) Solutions to address low response rates in online surveys. Eur J Cardiovasc Nurs 22(4):441–444

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