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The effectiveness of pneumatic compression devices in preventing venous thromboembolism in patients undergoing elective spine surgeries

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ABSTRACT

Objectives: Venous thromboembolic events are devastating complications that may arise following spine surgery with rates ranging from 0% to 14% in the literature. Orthopedic procedures increase the risk of thromboembolic events, and diagnosis is often challenging due to the varying presentations. Most research on venous thromboembolism (VTE) and international standards emphasizes that prevention such as mechanical prophylaxis is more crucial than therapy. This study aimed to assess the effectiveness of pneumatic compressive devices in preventing VTE in spinal surgery patients.

Methods: This retrospective cohort study assessed the outcomes of mechanical prophylaxis in the form of pneumatic devices in 547 patients at our institution over five years from 2016 to 2021. Above-knee pneumatic compression stockings were applied before, during, and after surgery with patient outcomes being recorded.

Results: Data was collected from 547 patients, who underwent elective spinal surgery at our center between January 2016 and January 2021. The mean age was 47.27 years (±20.84), and most patients were male (63.1%). Most patients were classified as having a low risk (35.6%) or mild risk (43.5%) of VTE determined by the Caprini score. Following spinal surgery, only one patient in our cohort experienced post-operative VTE (0.18%).

Conclusion: Pneumatic compression effectively prevents VTE in patients undergoing elective spine surgery. Although pharmacologic prophylaxis has traditionally been used to prevent VTE, pneumatic compressive devices represent an alternative or supplementary approach to reduce the risk of VTE further.

Keywords: Deep vein thrombosis, Pneumatic compression, Pulmonary embolism, Spine surgery, Venous thromboembolism

INTRODUCTION

Venous thromboembolism (VTE) represents one of the most prevalent complications following spinal surgery. It is a source of morbidity and mortality in patients with complication rates ranging from 0% to 14% in the literature.[1-3] This condition comprises deep venous thrombosis (DVT) and pulmonary embolism (PE) and is of substantial concern following many surgical

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procedures.[4] Thus, early detection and the adoption of preventative measures are critical to ensure optimal outcomes.

In accordance with Virchow's triad, venous stasis, vascular damage, and hypercoagulable state are the three elements that increase the risk of developing thromboembolic events. Therefore, it is preconceived that orthopedic procedures put a patient at risk for thromboembolic consequences because they involve surgery adjacent to neurovascular systems and a period of post-operative recuperation during which the patient is relatively immobilized posing a high risk for DVT and/or PE. Moreover, circumferential fusion using anterior approaches involves manipulation around the inferior vena cava, which can cause transient vascular injury and lead to venous stasis raising the risk of thromboembolic complications.[5]

In addition, the current literature indicates that combined anterior and posterior approaches in spine surgery result in an increased risk for VTE compared to only posterior approaches. Irrespective of the surgical approach, the primary risk factors for VTE are prolonged surgical time, high volume blood loss, number of fused levels, and the number of blood transfusion units given. Therefore, patients who experience prolonged surgical times and augmented excessive bleeding during spine surgery should be identified as high-risk patients and managed/monitored accordingly.[6] Other risk factors have also been shown to predispose thromboembolic complications including tobacco use, malignancy, and hormonal therapy or oral contraceptives. Because pulmonary emboli do not have a constant, distinct presentation, diagnosing them can be difficult.[5] Major surgery includes abdominal, pelvic, knee, and hip replacement. Lower limb problems such as fractures, varicose veins, malignancy, immobility, cardiovascular disease, oral contraceptives, hormonal replacement, obesity, long travel, and lastly neurological disorders are also risk factors according to British Thoracic Society guidelines.[7]

The research suggests that asymptomatic PE has an alarmingly high frequency of up to 12%.[8] Depending on a patient's underlying pulmonary reserve, PE symptoms can range from non-existent to mild to severe.[8] Shortness of breath, increased heart rate, and fever are frequent but not sensitive signs of PE when present.[8,9] Clinical presentation may also be affected by patient's symptoms, which may vary depending on their cardio/pulmonary function, pain tolerance, size of the thrombus, and absence or presence of pulmonary ischemia.[5]

Many practitioners have traditionally used venography, colorful Doppler ultrasound, computerized tomography (CT), and ventilation-perfusion scans to detect DVT or PE. Multi-detector computerized tomography (MDCT) has recently been employed as a sensitive and precise method of detecting DVT and PE despite radiation issues and using dye material in conjunction with MDCT procedures.[10,11]

Most of the research on VTE and international standards strongly emphasizes the idea that revention is more crucial and economical than therapy, as if VTE develops, it can have catastrophic consequences. Only one-third of all hospitalized patients at risk receive adequate preventative treatment even though hospitalization accounts for almost two-thirds of all VTE occurrences.[12] Many preventative measures have been employed including aspirin, low-dose heparin, elastic stockings, and intermittent pneumatic calf compression. Due to the possibility of a post-operative spinal hematoma, the use of thromboprophylaxis is debatable.

Since there are many modalities for preventing pre- and post-operative VTE, there is a need to evaluate the most effective methods for preventing PE and DVT in patients undergoing spinal surgery. Therefore, this study aimed to assess the effectiveness of pneumatic compressive devices in preventing VTE in spinal surgery patients.

MATERIALS AND METHODS

This retrospective cohort study was conducted at the orthopedic surgery department at King Khalid University Hospital, Riyadh, Saudi Arabia. Data was retrospectively collected from patients, who underwent elective spinal surgery at this single center.

Patient selection

Patients were included in the final analysis if they underwent elective spinal surgery for lumbar spinal stenosis, lumbar spondylolisthesis, idiopathic scoliosis or cervical spine stenosis over the five-year study period from January 2016 to January 2021. Trauma patients, oncology patients, cardiac patients, and patients with a history of DVT/PE were excluded from the final analysis.

Data collection

Mechanical prophylaxis in the form of pneumatic compressive devices was assessed in 547 patients undergoing spine surgery for lumbar spinal stenosis, lumbar spondylolisthesis, idiopathic scoliosis, and cervical spine stenosis over five years from 2016. An above-knee pneumatic compression stocking was applied upon admission to the hospital before surgery and continued during the hospital stay postoperatively. The patients were discharged home after mobilization and followed up in a plaster room weekly for two weeks. Patients, who developed clinical signs of leg swelling or pain and respiratory symptoms suspicious of PE, were further investigated with Doppler ultrasound and/or spiral chest CT to assist in a diagnosis.

A data sheet was utilized to record information from patient charts on E-Sihi. The study variables investigated included the patient's medical record number, the case start date, diagnosis, primary procedure and schedule priority, and demographics including date of birth, sex, body mass index (BMI), and other comorbidities. In addition, operative characteristics were recorded including operation time, the incidence of bleeding, patient Caprini score, and length of hospital stay. Finally, patient outcomes were noted to determine the effectiveness of pneumatic compression including post-operative Doppler, spiral CT, the incidence of complications, and reoperation rates.

Data analysis

Data collected were analyzed using the Statistical Package for the Social Sciences 28.0 (Chicago, IL, USA) and Microsoft Excel 16.46 (Microsoft, Redmond, WA, USA). A Pearson Correlation coefficient was computed to determine the relationship between age and Caprini, between Caprini and hospital stay, between Caprini and surgical time, and between Caprini and bleeding during surgery.

Ethical considerations

All obtained information was kept confidential and used only for the study. The principal investigator and coinvestigators were the only personnel with access to this information.

RESULTS

Patient characteristics

Data was collected from 547 patients, who underwent elective spinal surgery at our center between January 2016 and January 2021. The mean age was 47.27 years (±20.84), and most patients were male (63.1%). In addition, patients had a mean height of 158.3 cm (±16.19) and an average BMI score of 29.01kg/m^2 (±7.25). A summary of the patient demographics is depicted in Table 1.

Table 1: Demographics of included patients who underwent elective spinal surgery during the study period.

	Sex	*n*	Mean	SD
Age	M	345	40.03	20.403
	F	202	45.97	21.541
Height (cm)	M	345	156.45	14.761
	F	202	161.53	17.952
Weight (kg)	M	345	73.82	20.932
	F	202	77.34	22.945
BMI (kg/m^2)*	M	345	29.37	7.457
	F	202	28.39	8.684

SD: Standard deviation, *BMI: Body mass index

Risk of VTE

Most patients were classified as having a low risk (35.6%) or mild risk (43.5%) of VTE as determined by the Caprini score. Low risk of VTE was more prevalent in females than males (42.6% vs. 31.6%). Similarly, a larger percentage of male patients had a moderate or high risk of VTE compared to female patients (20.9% vs. 20.3%) [Table 2]. The differences in VTE risk between male and female patients in this study were not statistically significant ($P = 0.186$).

Risk of VTE and patient characteristics

A significant positive relationship was observed between patient age and the risk of VTE as determined by the Caprini score ($P = 0.001$). In addition, patient BMI significantly impacted the Caprini score ($P = 0.016$). Surgery time, bleeding, and hospital stay had no significant impact on the risk of VTE ($P > 0.001$) [Table 3]. These findings demonstrate that patient demographics, specifically age and BMI, significantly impacted the risk of VTE while operative variables including surgery time and hospital stay had no significant impact on this risk.

Postsurgical outcomes

Following spinal surgery, only one patient in our cohort experienced post-operative VTE (0.18%). Twenty patients underwent reoperation; however, the rationale for these additional procedures was unrelated to VTE.

DISCUSSION

Pneumatic compression may represent an effective intervention for lowering the risk of VTE and PE following spine surgery with the findings demonstrating that only patient demographics, specifically age and BMI, had a significant impact on the risk of VTE in 547 patients undergoing elective spinal surgery.

Pneumatic compression represents a method of mechanical prophylaxis, an alternative or supplementation to pharmacologic prophylaxis in post-surgical patients. Mechanical prophylaxis devices include graduated compression stockings such as those proposed in this study and intermittent pneumatic compression devices that facilitate a reduction in venous stasis in a patient's lower extremities. The benefit of pneumatic compression over pharmacologic prophylaxis is that it does not carry a risk of bleeding. Hence, mechanical prophylaxis interventions are recommended in patients with a high risk of bleeding or contraindication to anticoagulants.[13] Nonetheless, the American Society of Hematology guidelines still recommend using medication-based prevention in all patients with no high risk of bleeding warranting further

Table 2: Risk of venous thromboembolism in patients, determined by the Caprini score.

	Caprini Score				Total
	Low risk VTE*	Mild risk of VTE	Moderate risk of VTE	High risk of VTE	
Sex					
F					
Count	86	75	24	17	202
% within sex	42.6	37.1	11.9	8.4	100.0
% of Total	15.7	13.7	4.4	3.1	36.9
M					
Count	109	163	48	25	345
% within sex	31.6	47.2	13.9	7.2	100.0
% of Total	19.9	29.8	8.8	4.6	63.1
Total					
Count	195	238	72	42	547
% within sex	35.6	43.5	13.2	7.7	100.0
% of Total	35.6	43.5	13.2	7.7	100.0

*VTE: Venous thromboembolism

Table 3: Correlation between patient variables and the risk of venous thromboembolism.

	CAPRINI	Age	Surgery Time	Bleeding	BMI Patients	Hospital Stay
Age						
Pearson Correlation	0.141	1	−0.275	−0.158	0.472	−0.019
Sig. (2-tailed)	0.001		0.000	0.000	0.000	0.657
Surgery time						
Pearson Correlation	0.012	−0.275	1	0.304	−0.237	0.160
Sig. (2-tailed)	0.786	0.000		0.000	0.000	0.000
Bleeding						
Pearson Correlation	0.053	−0.158	0.304	1	−0.097	0.246
Sig. (2-tailed)	0.220	0.000	0.000		0.024	0.000
BMI*						
Pearson Correlation	0.103	0.472	−0.0237	−0.097	1	−0.026
Sig. (2-tailed)	0.016	0.000	0.000	0.024		0.541
Hospital stay						
Pearson Correlation	0.067	−0.019	0.160	0.246	−0.026	1
Sig. (2-tailed)	0.119	0.657	0.000	0.000	0.541	

*BMI: Body mass index, Sig.: Significance

research into the effectiveness of pneumatic compression as an alternative.[14] The available literature substantiates the use of pneumatic compression to prevent VTE in patients undergoing surgery. Pranata *et al.* conducted a systematic review and meta-analysis to investigate the effectiveness of this intervention in neurosurgical patients with the findings demonstrating a significant reduction in the incidence of VTE ($P < 0.001$) following intermittent pneumatic compression.[4]

Conventionally, pharmacological prophylaxis has been utilized to prevent VTE in patients; however, this approach has been associated with various complications and adverse events in the available literature. Pharmacologic approaches include low-dose unfractionated heparin and low-molecular-weight heparins. The most common adverse events of their use include immune-mediated skin lesions and bleeding complications.[15,16]

Epstein *et al.* discussed the optimal prophylaxis against DVT and PE in patients undergoing anterior cervical spine surgery. They found that intermittent pneumatic compression stockings were as effective as heparin therapy without the likelihood of bleeding in anterior cervical spinal surgery patients, as only one patient developed DVT and PE. After investigating the etiology, the patient was found to have a positive Factor V Leiden mutation.[17] Another study published by the same author evaluated the efficacy of pneumatic compression stockings in preventing DVT and PE in patients undergoing lumbar laminectomies with instrumented fusions. They compared the effectiveness of pneumatic compression stockings with low-dose heparin

therapy in spinal surgery and found the results to be similar. In this research, four (2.8%) patients with pneumatic compression stockings developed DVT postoperatively and required an inferior vena cava filter. One of these patients developed PE and was found to have Factor V Leiden mutation.[18] Koo *et al*. compared the effectiveness of two intermittent pneumatic compression interventions for preventing DVT and PE in knee and spine surgery. They found no significant difference in the results. The rate of post-operative asymptomatic DVT in moderate- to high-risk patients was 20.6% with the application of intermittent pneumatic compression.[19]

In our study, a significant risk factor for VTE following spinal surgery was found to be an increase in age, which is widely established in the current evidence. As described by Choi *et al*., the incidence of VTE in children is substantially low. It continues to be low till late adolescence and early 20s with an incidence of 0.9% among 3611 cancer children over 15 years.[20] Similarly, it has been described that an estimated 60% of all events of VTE occur in patients aged 70 years and over.[21] Pneumatic compression in the elderly population is feasible according to other research with Lim *et al*. describing the hemodynamic stabilizing effects of continued pneumatic compression of the lower extremities in patients aged 65 years or younger.[22] Elevated BMI also represents a significant risk factor for VTE as identified in our research and the available literature. Nicholson *et al*. detailed that an elevated BMI of >30 increases the risk of the first event of VTE by 2.3 fold.[23] Abuoglu *et al*. described the adoption of pneumatic compression as a new protocol for VTE prevention in overweight and obese subjects undergoing bariatric surgery substantiating the use of this intervention in individuals of any weight.[24]

Limitations

Although this research sought to determine the effectiveness of pneumatic compression for preventing VTE in spinal surgery patients, there was limited data available following the adoption of this intervention. Therefore, this study followed a feasibility design and evaluated the potential effectiveness of pneumatic compression in this patient population by determining VTE risk factors and assessing patient post-operative outcomes. Future research should address these limitations and comprise a control group that receives standard care to enable appropriate comparisons. Furthermore, this study was conducted at a single center, and additional data from other sites must be incorporated to facilitate externally valid results.

CONCLUSION

Pneumatic compression effectively prevents VTE in patients undergoing elective spine surgery. Although pharmacologic prophylaxis has traditionally been used to prevent VTE, pneumatic compressive devices represent an alternative or supplementary approach to reduce the risk of thromboembolic events further.

RECOMMENDATIONS

Further research is required to substantiate the evidence provided in our research and compare the incidence of VTE between patients receiving pharmacologic or mechanical prophylaxis. It is also important to determine the effectiveness of these interventions used in combination.

AUTHORS' CONTRIBUTIONS

AAA designed the study, provided the data material, and provided logistic support. NAA analyzed, interpreted the data, and wrote the initial and final manuscript. FTA and MHA collected and analyzed the data. NAA, SFA, and SHA wrote the initial draft, reviewed the literature, and participated in data collection and statistical analysis. All authors have critically reviewed and approved the final draft and are responsible for the manuscript's content and similarity index.

ETHICAL APPROVAL

IRB approval for the study was received by February 5, 2023, project number E-23-7562

DECLARATION OF PATIENT CONSENT

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patients have given their consent for their clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

USE OF ARTIFICIAL INTELLIGENCE (AI)-ASSISTED TECHNOLOGY FOR MANUSCRIPT PREPARATION

The authors confirm that there was no use of artificial intelligence (AI)-assisted technology for assisting in the writing or editing of the manuscript and no images were manipulated using AI.

CONFLICTS OF INTEREST

There are no conflicting relationships or activities.

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