Original Article

Role of Calf Muscle Electrostimulation in Preventing Early Post-operative Deep Vein Thrombosis after Hip Region Surgeries

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Abstract

Background: Hip fracture and hip arthroplasty patients have a high risk of deep vein thrombosis (DVT), but routine anticoagulant prophylaxis is not always possible in elderly, fragile patients. Neuromuscular electrical stimulation of calf muscles may improve venous flow and act as a simple mechanical prophylaxis. **Material and Methods:** This prospective randomised comparative study included 60 patients (41 men, 19 women; 26–75 years) undergoing surgery around the hip joint under spinal anaesthesia. All had pre-operative duplex Doppler ultrasound of both lower limbs to exclude existing DVT. Patients were randomised into Group A (n=30), who received perioperative calf-muscle electrostimulation with the Venio Plus™ device, and Group B (n=30), who received no intraoperative prophylaxis. All patients received similar postoperative mobilisation and physiotherapy. Bilateral Doppler ultrasound was repeated on the 7th postoperative day to detect new DVT. **Results:** No pre-operative DVT was detected. On day seven, DVT occurred in 2 of 60 patients (3.3%), both in Group B. Incidence of DVT was 0% in Group A and 6.7% in Group B. Peroperative stimulation produced an absolute risk reduction of 6.7 percentage points, relative risk 0.20, and number needed to treat 15. However, because only two events were seen, the difference between groups did not reach statistical significance. **Conclusion:** Peroperative calf muscle electrostimulation appears safe and shows a clear protective trend against early DVT after hip-related surgery, when combined with early mobilisation. Still, the study is small and underpowered, so larger multi-centre trials are required before this method can be recommended as a stand-alone alternative to pharmacological prophylaxis.

Keywords: deep vein thrombosis, hip fracture surgery, hip arthroplasty, neuromuscular electrical stimulation, calf muscle stimulator, mechanical thromboprophylaxis.

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Introduction

Venous thromboembolism (VTE), which includes deep vein thrombosis (DVT) and pulmonary embolism, is now recognised as a major cause of preventable hospital death and long-term disability worldwide.[1] Risk is especially high in patients undergoing lower-limb orthopaedic procedures because of trauma, venous stasis during surgery, postoperative immobility, and a hypercoagulable state.[2]

Hip fracture and hip arthroplasty patients form one of the highest-risk groups. Recent screening studies in elderly hip fracture surgery report postoperative DVT in about one quarter of patients, even when low-molecular-weight heparin is given as per guidelines.[3] After primary total hip arthroplasty, modern chemoprophylaxis has reduced symptomatic VTE to below 1%, whereas historical series without prophylaxis reported DVT rates approaching 50%, highlighting the natural risk in this population.[4] Despite these advances, VTE still occurs early after surgery and may present as silent distal DVT or sudden fatal pulmonary embolism.

International guidelines from the American Society of Hematology classify major hip and knee surgery as very high VTE risk and recommend pharmacological prophylaxis with low-molecular-weight heparin or equivalent for most patients, combined with mechanical methods in selected cases.[5] However, many patients with hip fractures are elderly, frail, anaemic, or have contraindications to anticoagulants, for example, recent head injury, spinal anaesthesia, renal dysfunction, or high bleeding risk. In such situations, clinicians often rely mainly on early mobilisation, ankle–calf exercises, and simple mechanical prophylaxis. Yet, nursing audits show that adherence to stockings or pneumatic compression devices is variable in busy wards.[6]

Neuromuscular electrical stimulation (NMES) of the calf muscle pump has re-emerged as a promising mechanical option. By delivering low-voltage impulses to the calf, NMES increases venous flow velocity, reduces stasis, and may partially reproduce the physiological effects of walking during periods

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when the patient must remain on the operating table or in bed. A recent systematic review and meta-analysis in surgical and immobilised patients reported that NMES significantly reduced DVT compared with no prophylaxis, with an effect size comparable to that of traditional mechanical devices. However, most included trials were small and heterogeneous.[7] Another meta-analysis focusing on high-risk inpatients suggested that adding NMES on top of routine care further decreased DVT incidence without increasing bleeding, but called for more procedure-specific trials, especially in orthopaedic surgery.[6]

Evidence specifically for perioperative calf muscle electrostimulation during hip surgery under spinal anaesthesia is still very limited, and data from Indian settings are almost absent. Most centres use either pharmacological prophylaxis alone or simple ankle exercises, and routine Doppler surveillance is rarely performed, so early distal DVT may be missed.[3] Therefore, there is a clear need to test whether focused perioperative calf-muscle electrostimulation can provide effective DVT prophylaxis when systemic anticoagulation is not used, and whether this strategy is practical on routine orthopaedic operating lists. In this context, the present study was planned to compare the incidence of lower-limb DVT in patients undergoing hip joint surgery with and without peroperative calf muscle electrostimulation, using duplex Doppler ultrasound performed before surgery and on the seventh postoperative day.

Materials and Methods

The study design and setting were a simple prospective randomised comparative study. A study was conducted in the Department of Orthopaedic Surgery on patients undergoing hip joint surgery under spinal anaesthesia. A total of 60 patients were taken. Ethical clearance was taken from the Institutional Ethics Committee, and written consent was obtained from every patient.

Participants and criteria of 60 patients, 41 were men, and 19 were women. The age range was 26 to 75 years. We excluded patients who already had DVT, patients taking antithrombotic drugs, open fracture cases and patients with pacemaker.

Grouping and intervention, eligible patients were randomised into two groups of 30 each.

- Group A received perioperative calf muscle electrostimulation as DVT prophylaxis.
- Group B did not receive any prophylaxis, taken as a control.

All patients were encouraged to engage in active exercise and were given passive physiotherapy as tolerated. In Group A, we used the Venio Plus™ stimulator device on the calf muscle during surgery. The device delivered low-voltage current, with a peak around 8–10 V, and 4-second contraction and 7-second relaxation cycles. For each patient, we recorded the side involved, the type of surgery, the duration of surgery, and the intraoperative patient and limb positions. After surgery, patients were mobilised in bed as tolerated. Static and dynamic exercises were started on the first post-operative day.

Doppler ultrasound protocol: Preoperative Doppler ultrasound of both lower limbs was done in all patients to rule out pre-existing DVT. The same was repeated on the 7th post-operative day to see fresh thrombus. Both scans were done on the same Logiq P6 Pro machine with a linear probe 5.38–12 MHz. We examined bilateral common femoral, superficial femoral, popliteal, anterior tibial, and posterior tibial veins. We checked for thrombus, flow pattern, compressibility, and augmentation. DVT was diagnosed when a thrombus was seen with absent flow and loss of compressibility or augmentation. Thrombosis was labelled proximal when involving the popliteal or more proximal veins. It was called distal when only tibial or calf muscle veins were involved. If both segments were involved we kept it as proximal DVT.

Statistical analysis. Data was analysed using SPSS version 21.0 for Windows. Age was expressed as mean ± standard deviation. Categorical data like sex, side, diagnosis, surgery type, and DVT presence were shown as counts and percentages. Comparison between Group A and Group B was performed using the Pearson Chi-square test with continuity correction, or the Fisher exact test when appropriate. A two-tailed P value < 0.05 was considered statistically significant. Relative risk and absolute risk reduction, with 95% confidence intervals, were calculated for DVT between the two groups.

Results

A total of 60 patients were studied, 30 in Group A and 30 in Group B. Overall, 41 were men, and 19 were women. In Group A, 25 patients were male, and five were female. In Group B, 23 were male, and seven were female. Both groups showed male predominance, and the sex distribution was almost identical between the groups. Left-sided surgery was more common in both groups. In Group A, 21 patients (70%) had left-sided involvement, and 9 (30%) had right-sided involvement. In Group B, 18 patients (60%) had left-sided symptoms and 12 (40%) had right-sided symptoms. The limb side pattern was broadly similar in the two groups.

Table 1: Basic patient profile and limb side in both groups

Variable	Group A – With calf muscle electrostimulation (n = 30)	Group B – Without electrostimulation (n = 30)
Age (years)	47.0 ± 15.3 (26–75)	49.7 ± 13.2 (26–80)
Sex		
Male, n (%)	25 (83.3%)	23 (76.7%)
Female, n (%)	5 (16.7%)	7 (23.3%)
Limb operated		
Left, n (%)	21 (70.0%)	18 (60.0%)
Right, n (%)	9 (30.0%)	12 (40.0%)

Table 2: Age group distribution of patients in Group A and Group B

Age group (years)	Group A (n = 30) n (%)	Group B (n = 30) n (%)	Total (n = 60) n (%)
25–35	7 (23.3%)	3 (10.0%)	10 (16.7%)
35–45	7 (23.3%)	8 (26.7%)	15 (25.0%)
45–55	6 (20.0%)	9 (30.0%)	15 (25.0%)
55–65	3 (10.0%)	6 (20.0%)	9 (15.0%)
65–75	5 (16.7%)	1 (3.3%)	6 (10.0%)
75–85	2 (6.7%)	3 (10.0%)	5 (8.3%)
Total	30 (100%)	30 (100%)	60 (100%)

The age of patients ranged from mid-twenties to mid-eighties. The maximum number of patients in both groups was in the middle age bands. In Group A, seven patients (23.3%) were in 25–35 years and another 7 (23.3%) in 35–45 years. Six patients (20%) were aged 45-55 years. Only 3 (10%) were 55–65 years, 5 (16.7%) were in 65–75 years, and 2 (6.7%) were in 75–85 years.

In Group B, three patients (10%) were 25–35 years, 8 (26.7%) were 35–45 years, and 9 (30%) were 45–55 years. Six patients (20%) were 55–65 years old, 1 (3.3%) was 15–75 years old, and 3 (10%) were 15–85 years old. In both groups, the majority of patients were aged 35-55 years. Only a small proportion were at the extremes of age. The age pattern between the two groups looked generally comparable.

Table 3: Diagnosis pattern in both groups

Diagnosis	Group A (n = 30) n (%)	Group B (n = 30) n (%)	Total (n = 60) n (%)
Fracture acetabulum	2 (6.7%)	0 (0.0%)	2 (3.3%)
Fracture neck of femur	10 (33.3%)	12 (40.0%)	22 (36.7%)
Intertrochanteric fracture femur	6 (20.0%)	7 (23.3%)	13 (21.7%)
Fracture shaft femur	8 (26.7%)	0 (0.0%)	8 (13.3%)
Septic arthritis	1 (3.3%)	0 (0.0%)	1 (1.7%)
Avascular necrosis (AVN)	3 (10.0%)	11 (36.7%)	14 (23.3%)
Total	30 (100%)	30 (100%)	60 (100%)

Overall, the most common diagnosis was fracture of the neck of the femur, seen in 22 of 60 patients (36.7%). Intertrochanteric fracture of the femur was present in 13 patients (21.7%), and avascular necrosis in 14 patients (23.3%). Shaft femur fractures formed 8 cases (13.3%). Less common lesions were acetabular fractures (2 cases, 3.3%) and septic arthritis (1 case, 1.7%). In Group A, a fracture of the femoral neck was present in 10 patients (33.3%). Intertrochanteric fractures were 6 (20%) and shaft femur fractures 8 (26.7%). AVN was seen in 3 patients (10%). Two patients (6.7%) had an acetabulum fracture, and one (3.3%) had septic arthritis. In Group B, the fracture neck of the femur was slightly higher, 12 patients (40%). Intertrochanteric fractures were 7 (23.3%). AVN was common in this group, 11 cases (36.7%). There were no shaft fractures, no acetabular fractures, and no septic arthritis in Group B. So both groups had similar broad fracture spectra around the hip, but AVN was more common in Group B, and shaft fractures were seen only in Group A

Table 4: Type of surgery done in Group A and Group B

Surgical procedure	Group A (n = 30) n (%)	Group B (n = 30) n (%)	Total (n = 60) n (%)
Open reduction and internal fixation	2 (6.7%)	0 (0.0%)	2 (3.3%)
Closed reduction with cannulated lag screw fixation	4 (13.3%)	4 (13.3%)	8 (13.3%)
Hemiarthroplasty / total hip arthroplasty	9 (30.0%)	19 (63.3%)	28 (46.7%)
Dynamic hip screw fixation	3 (10.0%)	1 (3.3%)	4 (6.7%)
Proximal femoral nailing	4 (13.3%)	6 (20.0%)	10 (16.7%)
IMILN fixation	7 (23.3%)	0 (0.0%)	7 (11.7%)
Girdlestone procedure	1 (3.3%)	0 (0.0%)	1 (1.7%)
Total	30 (100%)	30 (100%)	60 (100%)

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Table 5: Incidence of DVT with and without calf muscle electrostimulation

Group / prophylaxis status	No. of patients (n)	DVT positive, n (%)	DVT negative, n (%)
Group A – With calf muscle electrostimulation	30	0 (0.0%)	30 (100.0%)
Group B – Without calf muscle electrostimulation	30	2 (6.7%)	28 (93.3%)
Total	60	2 (3.3%)	58 (96.7%)

Preoperative Doppler did not show DVT in any patient. On the 7th postoperative day, fresh DVT was seen in 2 out of 60 patients, both from Group B without electrostimulation. No DVT occurred in Group A. So DVT incidence was 0 percent in the prophylaxis group and 6.7 percent in the control group, with an overall DVT rate of 3.3 percent in this series

Table 6: Effect of calf muscle electrostimulation on risk of DVT

Measure	Value
Risk of DVT without prophylaxis	6.7%
Risk of DVT with prophylaxis	0.0%
Absolute risk reduction (ARR)	6.7 percentage points
Relative risk (RR) for DVT (prophylaxis vs no prophylaxis)	0.20
Odds ratio (OR)	0.19
Number needed to treat (NNT)	15

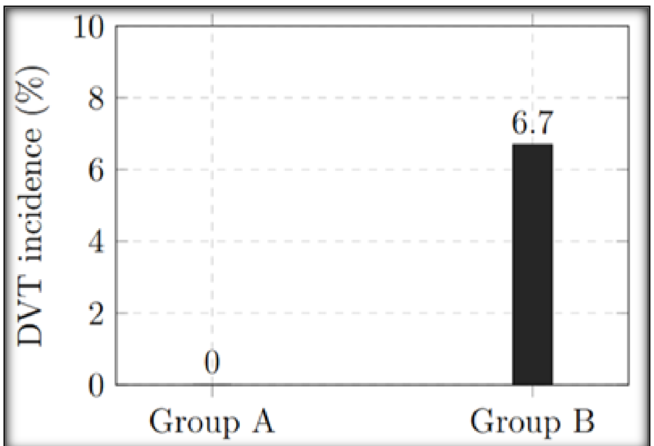

Figure 1: DVT incidence in two groups

The control group without prophylaxis had a DVT risk of 6.7 percent, while the prophylaxis group had zero risk. This gave an absolute risk reduction of 6.7 percentage points with calf muscle electrostimulation. The relative risk of 0.20 shows that the DVT risk in the prophylaxis group was about one-fifth of that in the control group. The odds ratio of 0.19 also suggests a protective effect. The number needed to treat was 15, meaning that treating about 15 patients may prevent 1 DVT case. But these estimates are based on only two DVT events, so statistical power is low, and the true effect size may vary; interpretation should be cautious.

Discussion

In this study, we found an overall DVT incidence of 3.3% after hip-related surgery, with both Doppler-positive events seen only in the group without calf muscle electrostimulation. Our rate is very close to the 4% incidence reported in a recent Pakistani hip-fracture cohort in which no routine thromboprophylaxis was used and Doppler surveillance was performed up to 6 weeks.[8] This supports the concept that DVT burden in South-Asian hip fracture patients is lower than many Western series but still clinically relevant in selected high-risk individuals.[8,9]

Global guidelines classify major hip and femur surgery as high-risk for venous thromboembolism and recommend pharmacologic prophylaxis combined with mechanical methods whenever bleeding risk allows.[9,10] However, recent reviews also stress the need to tailor prophylaxis based on individual VTE and bleeding risk, local resources, and patient preference, rather than applying one fixed regimen.[10,11] In our setup, many patients had fracture surgery under spinal anaesthesia with variable bleeding risk and limited access to pharmacologic agents, so exploring a simple mechanical option like perioperative calf NMES was practical.

Large epidemiologic and perioperative datasets consistently show that advanced age, hip and pelvic fractures, obesity, prior VTE, and prolonged immobility are strong independent predictors of DVT.[12,13] Many of our patients had multiple of these risk factors, so even the modest absolute event rate seen here may represent a real thrombotic tendency. At the same time, the relatively low overall incidence is in line with Asian data, where genetic and lifestyle factors probably modulate VTE risk compared with Western populations.[8]

Network meta-analysis in elective hip and knee arthroplasty suggests that several chemoprophylaxis strategies, including LMWH, DOACs, and aspirin, provide similar protection against symptomatic VTE when adherence is high, but at the cost of higher drug prices and potential bleeding.[10,14] This has renewed interest in strengthening mechanical methods and early mobilisation, especially in low-resource or high-bleeding-risk settings.[9] Our protocol of spinal anaesthesia, early bed exercises, and next-day mobilisation in both groups follows this trend. It is likely to have contributed to the low DVT rate in the whole cohort.

Recent high-quality evidence now supports neuromuscular electrical stimulation as an additional mechanical strategy for surgical patients. A 2025 meta-analysis of 16 trials showed NMES significantly reduced postoperative DVT compared with basic prophylaxis or compression stockings and also improved femoral venous peak velocity and D-dimer levels. However, the certainty of evidence was low. [Yang, 10.1016/j.ctcp.2024.101932] Another systematic review of 11 randomized trials reported a pooled risk ratio of about 0.55 for DVT with NMES, again highlighting the benefit but also major heterogeneity and risk of bias.[15] A more recent meta-analysis of randomized trials confirmed that NMES reduces VTE events and improves venous flow, yet called for better-designed studies in specific surgical populations.[7,15]

Orthopaedic-focused work also points towards a physiological advantage of NMES. In a randomized study of patients undergoing total hip arthroplasty, Calbiyik et al. showed that adding NMES to standard LMWH significantly increased femoral venous peak velocity and reduced calf diameter compared with compression bandage alone, suggesting more effective venous emptying.[16] A trial in elderly total-hip replacement patients found that postoperative NMES improved early functional recovery and was associated with lower D-dimer levels and better limb swelling scores, without additional device-related complications.[17] These findings support the mechanistic basis for the zero-event trend we observed in the intraoperative NMES group, despite our stimulation period being shorter than in most published protocols.

Taken together, our results fit within this evolving evidence base. We observed a numerical reduction in DVT from 6.7% in controls to 0% with perioperative calf electrostimulation, yielding an absolute risk reduction of 6.7 percentage points and an estimated NNT of about 15. Still, the difference did not reach statistical significance because the study was underpowered with only two events. The direction of effect remains clinically meaningful and consistent with the risk reduction observed in larger meta-analyses of NMES.[7,15] In a busy government hospital where pharmacologic prophylaxis cannot be offered to every patient, this kind of simple, low-cost mechanical adjunct could still be valuable, especially for moderate-risk cases where bleeding concern limits anticoagulant use.

Our study has a few strengths. We used bilateral Doppler ultrasound before surgery to exclude pre-existing DVT and repeated the scan on the seventh postoperative day using the same machine and protocol, which reduces misclassification. All patients received standardized postoperative mobilisation and physiotherapy, and both groups were comparable in age, sex, and surgical profile, limiting confounding. At the same time, there are important limitations. The sample size was small with very low event count, so the true effect size of calf NMES remains uncertain. Follow-up Doppler was performed only up to day seven; therefore, late DVT or PE after discharge could have been missed. We assessed only intraoperative calf electrostimulation and did not continue stimulation into the early postoperative period, as many other trials have, potentially underestimating the full potential of this method. Finally, this is a single-centre study in an Indian tertiary hospital, so generalisability to different ethnic groups and practice patterns is limited.

Our data suggest that perioperative calf muscle electrostimulation is safe and may reduce early DVT after hip-related surgery when combined with routine mobilisation. Still, larger multi-centre randomized trials with extended postoperative NMES and longer follow-up are needed before it can be recommended as a stand-alone alternative to pharmacologic prophylaxis.

Conclusion

In our study, perioperative calf muscle electrostimulation demonstrated a clear protective effect; DVT occurred only in the control group, not in any of the stimulated patients. Overall, DVT incidence was low, but the absolute risk reduction of about 7 percent and NNT around 15 still look clinically meaningful in this high-risk surgery group. The technique was simple and inexpensive, and no device-related complications were observed, making it practical even in resource-limited theatres. However, the sample size was small, and the follow-up was short, so larger multi-centre trials are needed before calf electrostimulation can be recommended as a stand-alone alternative to pharmacological prophylaxis.

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Conflicts of interest

There are no conflicts of interest.

References

1. Lutsey PL, Zakai NA. Epidemiology and prevention of venous thromboembolism. Nature Reviews Cardiology 2022;20:248–62. https://doi.org/10.1038/s41569-022-00787-6.
2. Zambelli R, Nemeth B, Touw CE, Rosendaal FR, Rezende SM, Cannegieter SC. High risk of venous thromboembolism after orthopedic surgery in patients with thrombophilia. Journal of Thrombosis and Haemostasis 2020;19:444–51. https://doi.org/10.1111/jth.15163.
3. Rostagno C, Gatti M, Cartei A, Civinini R. Early deep venous thrombosis after hip fracture surgery in patients in pharmacological prophylaxis. Journal of Clinical Medicine 2025;14:726. https://doi.org/10.3390/jcm14030726.
4. Wong DW-Y, Lee Q-J, Lo C-K, Law KW-K, Wong DH. Incidence of Venous Thromboembolism after Primary Total Hip Arthroplasty with Mechanical Prophylaxis in Hong Kong Chinese. Hip & Pelvis 2024;36:108–19. https://doi.org/10.5371/hp.2024.36.2.108.
5. Anderson DR, Morgano GP, Bennett C, Dentali F, Francis CW, Garcia DA, et al. American Society of Hematology 2019 guidelines for management of venous thromboembolism: prevention of venous thromboembolism in hospitalized surgical patients. Blood Advances 2019;3:3898–944. https://doi.org/10.1182/bloodadvances.2019000975.
6. Liu F, Tan J, Pan Y. Prevention of deep vein thrombosis in postoperative orthopedic patients: a hybrid meta-analysis and clinical case study. Frontiers in Medicine 2025;12:1603191. https://doi.org/10.3389/fmed.2025.1603191.
7. Yang J, Qi H, Huang J, Xu M, Xue Z, Wang Y. Effectiveness of neuromuscular electrical stimulation on venous thromboprophylaxis in surgical patients: A systematic review and meta-analysis. Complementary Therapies in Clinical Practice 2024;58:101932. https://doi.org/10.1016/j.ctcp.2024.101932.
8. Khan Z, Imran A, Zia A, Akhtar S, Yousaf H, Khan A. INCIDENCE OF DEEP VENOUS THROMBOSIS AFTER HIP FRACTURE SURGERY DETERMINED BY DOPPLER ULTRASONOGRAPHY. Journal of Population Therapeutics and Clinical Pharmacology 2023:582–7.

https://doi.org/10.53555/jptcp.v30i8.5037.

9. Uzel K, Azboy İ, Parvizi J. Venous thromboembolism in orthopedic surgery: Global guidelines. Acta Orthopaedica Et Traumatologica Turcica 2023;57:192–203. https://doi.org/10.5152/j.aott.2023.23074.
10. Nicholson M, Chan N, Bhagirath V, Ginsberg J. Prevention of venous thromboembolism in 2020 and beyond. Journal of Clinical Medicine 2020;9:2467. https://doi.org/10.3390/jcm9082467.
11. Delegates I-VG. Recommendations from the ICM-VTE: General. Journal of Bone and Joint Surgery 2022;104:4–162. https://doi.org/10.2106/jbjs.21.01531.
12. Xia Z, Chen W, Wang Q. Risk factors for venous thromboembolism following surgical treatment of fractures: A systematic review and meta-analysis. International Wound Journal 2022;20:995–1007. https://doi.org/10.1111/iwj.13949.
13. Pastori D, Cormaci VM, Marucci S, Franchino G, Del Sole F, Capozza A, et al. A Comprehensive review of risk factors for venous thromboembolism: From Epidemiology to Pathophysiology. International Journal of Molecular Sciences 2023;24:3169. https://doi.org/10.3390/ijms24043169.
14. Lewis S, Glen J, Dawoud D, Dias S, Cobb J, Griffin X, et al. Venous Thromboembolism Prophylaxis Strategies for People Undergoing Elective Total Hip Replacement: A Systematic Review and Network Meta-Analysis. Value in Health 2019;22:953 69. https://doi.org/10.1016/j.jval.2019.02.013.
15. Xu Y, Li Y, Chai Z, Tao Y, Lin H, Zheng C. Effectiveness of Neuromuscular Electrical Stimulation in Preventing Venous Thromboembolism: A Meta-Analysis Based on Randomized Controlled Trials. Clinical and Applied Thrombosis/Hemostasis 2025;31:10760296251366423. https://doi.org/10.1177/10760296251366423.
16. Calbiyik M, Yılmaz S. Role of neuromuscular electrical stimulation in increasing femoral venous blood flow after total hip prosthesis. Cureus 2022;14:e29255. https://doi.org/10.7759/cureus.29255.
17. Zhao Y, Zhang B, Wang Y, Liu J. Effectiveness of neuromuscular electrical stimulation for enhanced recovery after total hip replacement surgery: a randomized controlled trial. Geriatric Orthopaedic Surgery & Rehabilitation 2022;13:21514593221129528. https://doi.org/10.1177/21514593221129528.