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ORIGINAL RESEARCH

Effect of Intermittent Pneumatic Compression Device on Coagulation and Fibrinolysis and Distal Deep Venous Thromboembolism in Patients Undergoing Gynaecology Laparoscopic Surgery During Perioperative Care: A Retrospective Cohort Study

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Background and Aim: Most studies focus on preventing deep-vein thromboembolism (DVT) in gynecologic malignancy patients, while peri/postoperative hemostatic disorders in benign gynecologic conditions are understudied. This study evaluated if sequential pneumatic compression (IPC) modulates coagulation, fibrinolysis, and DVT incidence in benign-condition patients undergoing minimally invasive laparoscopic surgery.

Methods: A retrospective cohort study (Jan 2021–Aug 2022) at the Second Affiliated Hospital of Guangzhou University of Chinese Medicine enrolled adult Chinese women with benign gynecologic disorders who had laparoscopic surgery. Patients were divided into IPC (used compression sleeves intraoperatively/early postoperatively) and no-IPC groups. Hemostatic indices (PT, INR, APTT, FIB, DDi, FDP) and DVT (monitored clinically, confirmed via duplex ultrasonography) were recorded. GraphPad Prism 8.0 was used for statistics (paired t-tests, Mann–Whitney tests; $p<0.05$=significant).

Results: 119 patients were included (IPC: 62; no-IPC: 57). Both groups had significant postoperative changes in PT, INR, DDi, FDP, PT% and TT ($p<0.001$). The IPC group showed better pre-/postoperative ratios of PT, INR and FDP vs the no-IPC group ($p<0.05$), but DVT incidence was similar (3.2% vs 3.3%), with all cases being distal calf DVT.

Conclusion: Distal DVT incidence is low in benign gynecologic surgery patients. IPC regulates surgery-induced coagulation/ fibrinolysis activation, aiding peri/postoperative prevention.

Keywords: coagulation, fibrinolysis, IPC, gynecology, laparoscopy, DVT

Introduction

Venous thromboembolism—which comprises deep-vein thrombosis (DVT) and its potential sequel, pulmonary embolism (PE)—is a leading postoperative hazard after extensive gynaecologic procedures. Without prophylaxis, DVT develops in roughly 10–15% of patients, and close to half of those cases progress to PE.[1,2] A clot lodged in the deep venous system blocks venous return, triggering acute symptoms such as dyspnoea, limb swelling, erythema, and calf tenderness, and may later culminate in chronic post-thrombotic syndrome. PE secondary to postoperative DVT is implicated in about 40% of unexpected deaths among women recovering from gynaecologic surgery,[3–5] generating substantial economic strain on healthcare systems.[6–8] Fortunately, these events represent one of the most preventable sources of postoperative morbidity and mortality when effective prophylactic strategies are implemented.

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Evidence shows that targeted prophylaxis markedly lowers VTE frequency and severity at a favourable cost.[5] Available strategies include systemic anticoagulants—standard or fractionated heparin regimens[9]—and non-pharmacological measures. The latter encompass graduated compression hosiery and sequential pneumatic compression devices, prized for user-friendliness, minimal complications, and virtually no bleeding hazard.[10–12] Sequential compression is especially valuable when anticoagulation is contraindicated.[13] By rhythmically inflating from ankle to calf, the sleeves imitate the muscle-pump, speed venous return, and curb stasis-driven clot formation.[13,14] Switching from open to endoscopic surgical techniques further diminishes thromboembolic risk thanks to faster ambulation and shorter hospitalisation.[15,16] Accordingly, active VTE prevention remains indispensable throughout the peri-operative course of less-invasive gynaecologic procedures.

Although guidelines on prophylaxis, diagnosis, treatment, and management of VTE have been proposed,[5,17] up to now most studies focus on patients with malignant gynecological diseases[18,19] or on safety evaluation of gynecological surgery,[20–22] and limited studies assess hemostatic imbalance in terms of coagulation and fibrinolysis, which is important in guiding perioperative and postoperative management of DVT.[23–25] Some studies attempt to measure the changes in haematosis parameters.[26,27] The meta-analyses by Zhang et al and Lima et al on perioperative venous thromboembolism (VTE) prophylaxis in gynecological laparoscopic surgery quantified the baseline deep vein thrombosis (DVT) risk in this population. However, the perioperative application of mechanical thromboprophylaxis on coagulopathies lacks sufficient evidence of hematosis, especially in gynecological benign patients undergoing minimal invasion surgery.

This study aims to examine the effect of mechanical compression on coagulation and fibrinolysis and the occurrence of DVT in Chinese patients with benign gynecological conditions undergoing minimal invasive gynecological surgery. An intermittent pneumatic compression (IPC) device was applied to bilateral lower extremities to produce mechanical compression. The primary outcomes assessed for coagulation blood test include prothrombin time (PT), international normalised ratio (INR), percentage of prothrombin time (PT%); activated partial thromboplastin time (APTT), plasma fibrinogen (FIB), plasma D-dimer (D-D), and fibrinogen degradation products (FDP) and the rate of DVT incidence.

Materials and Methods

This retrospective clinical study was conducted at the Department of Anesthesiology, The Second Affiliated Hospital of Guangzhou University of Chinese Medicine (Guangzhou, P. R. China) between January 2021 and August 2022. This study was approved by Ethics Committee of Guangdong Provincial Hospital of Chinese Medicine (approval number: ZE2025-131-01). Cases were identified by searching the hospital's Electronic Discharge Database. A comprehensive review of medical documentation was then conducted to collect relevant data. Inclusion criteria included as follows: The subjects were Chinese adult female patients from Guangdong province, each of whom had a diagnosis of benign gynecological disease (uterine fibroid, or ovarian cysts) was made and had indications of gynecological laparoscopic surgery. The exclusion criteria were as follows: those with a previous history of thrombotic disease, leg ulcer, and peripheral vascular disease before admission; those with blood coagulation disorders; those with malignant gynecological tumors or cancer treatment; those taking anticoagulants; those with a history of smoking, recent long trip travel, and acute medical illness; those with recent surgery; those without civil capacity. The patients who received standard minimally invasive gynecological surgery were recorded, and the patients were divided into a Device group and a Non-device group based on the patients applied with or without IPC during intraoperative and perioperative nursing care.

The Application of the DVT Device

In the Device groups, the Phlebo Press® DVT device (Shenzhen In-Situ Medical Equipment Co., Ltd, Guangdong, P. R. China) was applied on the lower limbs, delivering the standard of pneumatic compression therapy with circumferential, sequential, gradient compression by following the manufactory instructions. Bilateral calf-ankle mechanical pneumatic compression started intraoperatively and was continuously monitored for half an hour postoperatively in the recovery room. Anti-thromboembolism stockings were not applied for the patients in order to exclusively examine the effect of the mechanical compression method.

Gynecological Laparoscopic Surgery

Preoperative instrument preparation was made including a gynecological laparoscopic instrument kit, ultrasonic scalpel, electrosurgery, laparoscopic system, and lithotomy stand. Endotracheal intubation anesthesia was conducted, the perineum was disinfected with 0.1% Andoful the abdominal skin with 0.4% iodine, and the lines of various systems were connected. An arc-shaped incision below the umbilicus was made, followed by the establishment of an artificial pneumoperitoneum after the uterine manipulator was well placed. Then, the appropriate size of cuffs was placed and a laparoscope was inserted into the abdomen, the patient was placed in a lithotomy position. A lumbar puncture of pituitin was performed via contracting the uterus to reduce bleeding, and vital signs were closely monitored. The capsule of the fibroids was incised, culled, and removed, and then the abdominal cavity was fully flushed after the uterine defect was sutured. Any damage and bleeding to the organs in the abdominal cavity was carefully checked before suturing the skin incision.

Blood Collection

To examine the changes in hemostasis, two mL was drawn from the peripheral venous blood of the patients into the anticoagulant before the operation and on the morning of the second day after surgery, blood samples will be collected for coagulation function testing, respectively. PT, APTT, TT, INR, FIB, TT, DDi, and FDP were tested to assess abnormalities in coagulation and fibrinolysis. These parameters were detected by an automated coagulation analyzer (Sysmex, CS-5100, Japan). Samples displaying visible clots were not included in the data set. All coagulation tests were run within 1 hour of sampling. Coagulation methods were used for PT (ThromborelR S, test kit, SIEMES), TT (test thrombin time reagent test kit), and APTT (Dade Actin FSL APTT reagent kit), FIB (Dade thrombin reagent), DDi (INNovance D-Dimer), and FDP (FDP test kit Nanopia P-FDP) was detected by Turbidimetric inhibition immunoassay method, a control was used (Dade C-Trol 1; human plasma, Siemens Healthcare Diagnostics Product Ltd).

DVT Detection

Physical examination was performed for all patients, especially, being monitored for any signs of VTE, bleeding, breath difficulties, any signs and symptoms of DVT, such as edema, tenderness of the gastrocnemius muscles, warmth, erythema, and pain in the lower limbs, and bilateral dorsal pedis; artery pulsation was also recorded. The diameter of the legs was measured to monitor swelling.

Ultrasonographic Detection

Suspected thrombo-embolic events were investigated with bilateral colour-flow duplex ultrasonography (GE or Philips systems, USA). Each examination combined real-time B-mode imaging, sequential compressibility testing, and spectral Doppler analysis, scanning continuously from groin to ankle. Deep-venous segments interrogated included the external iliac, common and superficial femoral, profunda femoris (proximal portion), popliteal, peroneal, and the anterior and posterior tibial veins; superficial conduits—the great and small saphenous veins—were likewise reviewed. Spectral (pulsed-wave) Doppler was applied at selected sites to quantify flow direction and velocity profiles. All images were archived and later interpreted by a board-certified radiologist, who documented thrombus location, morphology, and haemodynamic impact. Daily bedside examination during inpatient stay (≈24–36 h), repeat ultrasound if any sign/symptom appeared, and a final duplex at discharge; asymptomatic patients were not rescanned beyond this window.

Treatments

Pharmacological thromboprophylaxis was used for patients with a diagnosis of acute DVT in the postoperative stage. Anticoagulation treatments included a subcutaneous injection of adroparin calcium (4100iu/0.4mL, qd) for one day and a subcutaneous injection of enoxaparin sodium (6000AXaIU/0.6mL, q12h) for 7 days, followed by orally administered rivaroxaban (15mg bid) for 3 days and discharged with oral taking rivaroxaban. All patients were closely observed in this study for symptomatic thromboembolism for at least three months.

Statistical Analyses

General conditions, complications, treatments, and laboratory coagulation parameters were collected as the clinical data. Statistical analysis was performed with GraphPad Prism (version 8.0, GraphPad Software Inc). The measurement data were expressed as mean ± standard deviation (x ± SD). Paired *t*-tests were used to determine the differences in prothrombin time (PT), PT%, APTT, INR, FIB, TT, DDi, and FDP between before operation and after operation within the Device and Non-device groups. Additionally, an unpaired *t*-test was used to compare the ratio of each of these parameters between the Non-device group and the Device group using the nonparametric Mann–Whitney test. A *p*-value < 0.05 was considered statistically significant.

Results

There were 119 Chinese adult female patients with benign gynecological disease receiving minimally invasive gynecological laparoscopy to meet selection criteria, including 62 patients in the Device group and 57 patients in the Non-device group. Basic demographic data showed that the age of the non-device group ranged from 34 to 59 years, with a mean age of 43.43 ± 8.96 years (n = 57). The mean age of the Device group was 45 ± 5.5 years (n = 62), ranging from 33 to 59 years (p = 0.46).

The value of PT was significantly increased in the patients after the operation when compared with those before the operation in both the Non-device group [before operation 11.97 ± 0.65 seconds (s) (n = 55) vs after operation 11.51 ± 0.82s (n = 55); $p < 0.001$; Figure 1A] and Device group [before operation 11.19 ± 0.60s (n = 61) vs after operation 11.99 ± 0.68s (n = 61); $p < 0.001$; Figure 1B]. However, the value of PT% was significantly decreased [the Non-device group: before operation 103.3 ± 9.99% (n = 55) vs after operation 94.64 ± 11.09% (n = 55), $p < 0.001$; Figure 2A] and [Device group before operation: 92.36 ± 8.99% (n = 61) vs after operation 81.25 ± 8.43% (n = 61); $p < 0.001$; Figure 2B].

A significant increase in INR was found in the patients after operation compared to those before operation in both Non-device group [before operation 0.93 ± 0.06 (n = 55) vs after operation 0.98 ± 0.08 (n = 55, $p < 0.01$ Figure 3A) and Device group [0.99 ± 0.07 (n = 61) vs 1.06 ± 0.08 (n = 61, $p < 0.001$; Figure 3B].

The value of TT was significantly decreased in the patients after the operation when compared with those before the operation in both the Non-device group [before operation 17.65 ± 0.89s (n = 51) vs after operation 17.03 ± 0.97s (n = 51), p = 0.001; Figure 4A] and Device group (before operation 17.25 ± 1.05s (n = 58) vs after operation 16.81 ± 0.66s (n = 58); $p < 0.001$; Figure 4B].

The values of DDi and FDP were significantly increased in the patients after the operation compared to those before the operation in both groups. The value of DDi was shown as follows: 0.59 ± 0.82 mg/L FEU (before operation, n = 56) vs 3.07 ± 4.65 mg/L FEU (after operation, n = 56) (p = 0.001) in Non-device group (Figure 5A); and 0.75 ± 0.99 mg/L FEU (before operation, n = 59) vs 3.32 ± 2.66 mg/L FEU (after operation, n = 59) ($p < 0.001$; Figure 5B) in the Device group, respectively. The value of FDP in the Non-device group was 3.05 ± 3.65 mg/L (before the operation, n = 55) vs

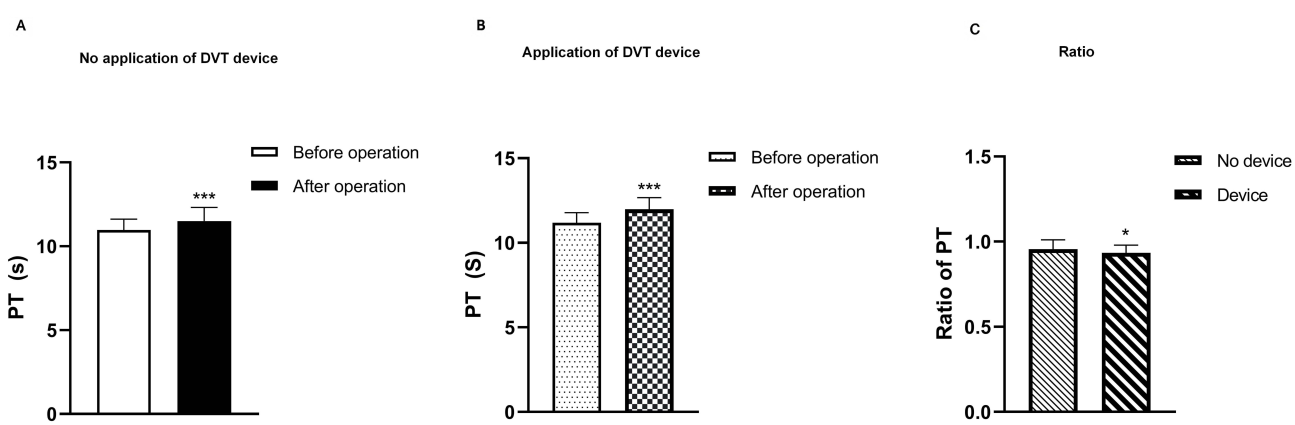

Figure 1 Comparisons of the values of PT and after the operation in the Non-device group (**A**) and device group (**B**). (**C**) Comparisons of the PT ratio of before the operation to after the operation between the Non-device group and Device group. Data were shown with mean ± SD. * $P < 0.05$. *** $P < 0.001$.

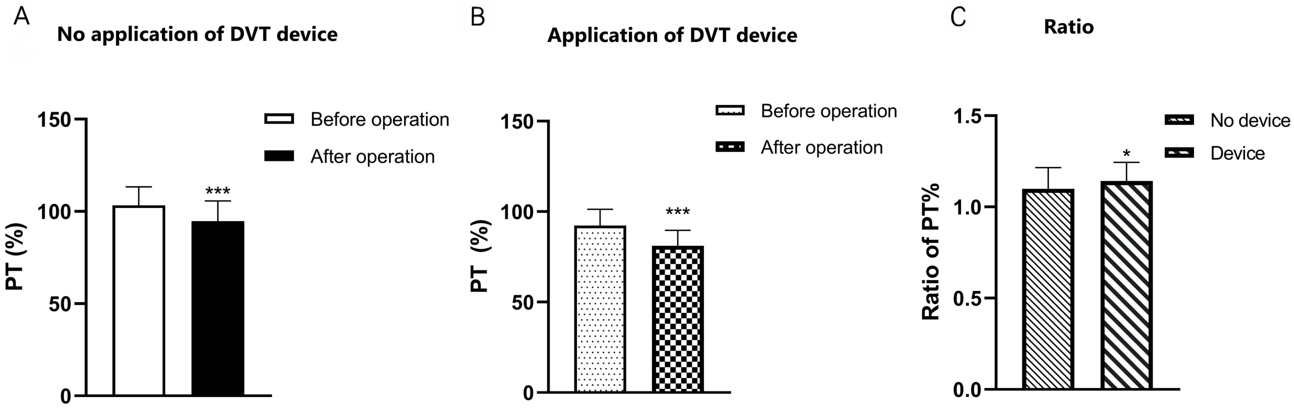

Figure 2 Comparisons of the values of PT% between before and after the operation in the Non-device group (**A**) and device group (**B**). (**C**) Comparisons of the PT% ratio of before the operation to after the operation between Non-device group and Device group. Data were shown with mean ± SD. * $P < 0.05$; *** $P < 0.001$.

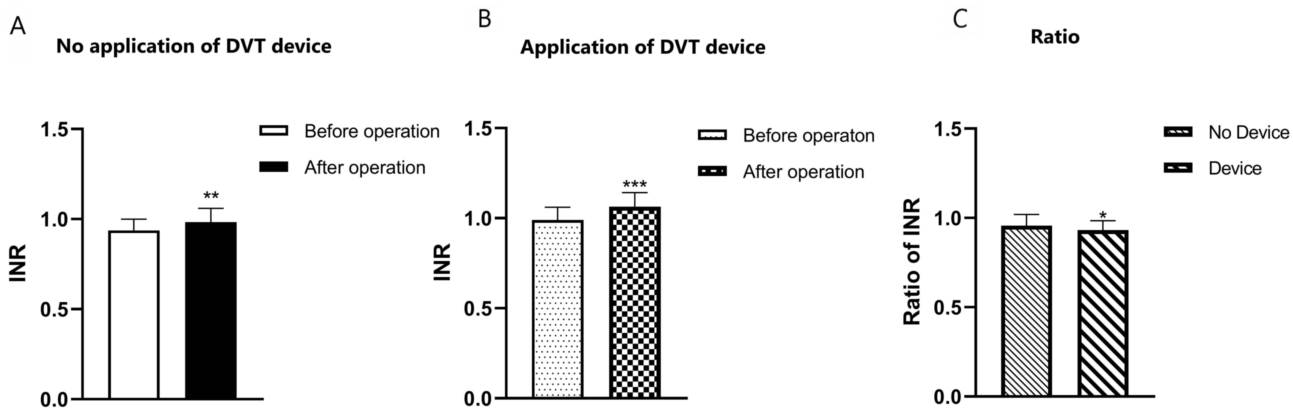

Figure 3 Comparisons of the values of INR between before and after the operation in the Non-device group (**A**) and device group (**B**). (**C**) Comparisons of the INR ratio of before the operation to after the operation between the Non-device group and Device group. Data were shown with mean ± SD. * $P < 0.05$; ** P < 0.01; *** $P < 0.001$.

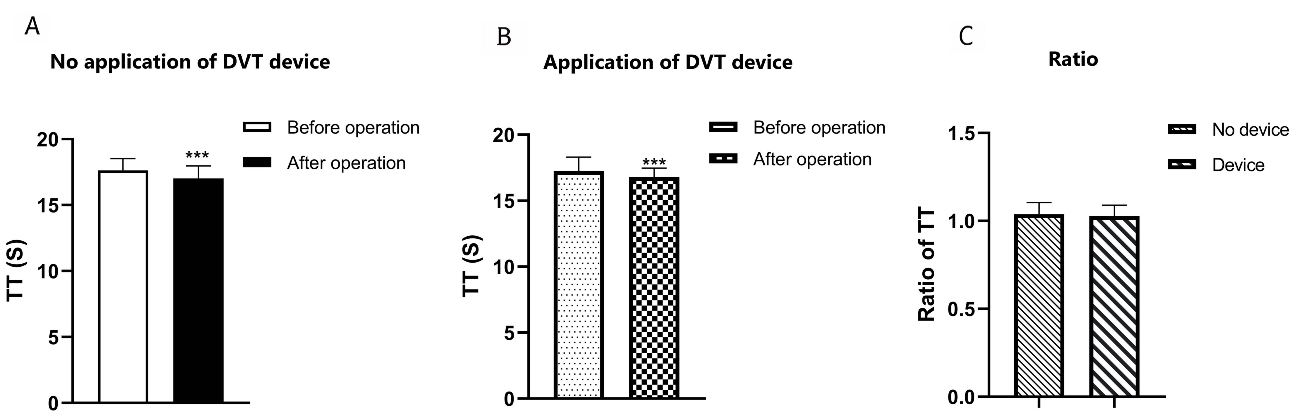

Figure 4 Comparisons of the values of TT between before and after the operation in the Non-device group (**A**) and device group (**B**). (**C**) Comparisons of the TT ratio of before the operation to after the operation between the Non-device group and Device group. Data were shown with mean ± SD. *** $P < 0.001$.

8.33 ± 7.2 mg/L (after the operation, n = 55) ($p < 0.001$; Figure 6A), and in the Device group, the value was 2.24 ± 1.98 mg/L (before operation; n = 61) vs after operation 9.08 ± 6.73 mg/L (n = 61) ($p < 0.001$; Figure 6B).

No statistically significant difference was found in both FIB and APTT when compared between before and after operation in both groups. The FIB values of before and after the operation were 2.77 ± 1.06 g/L vs 2.87 ± 0.91 g/L in the

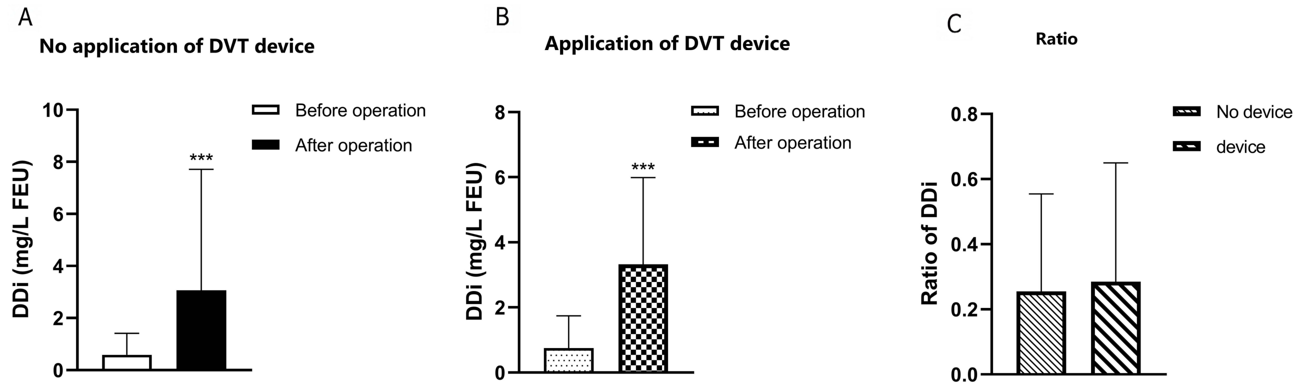

Figure 5 (**A**) Comparisons of the values of DDi between before and after the operation in the Non-device group and device group (**B**). (**C**) Comparisons of the DDi ratio of before the operation to after the operation between the Non-device group and Device group. Data were shown with mean ± SD. *** *P* < 0.001.

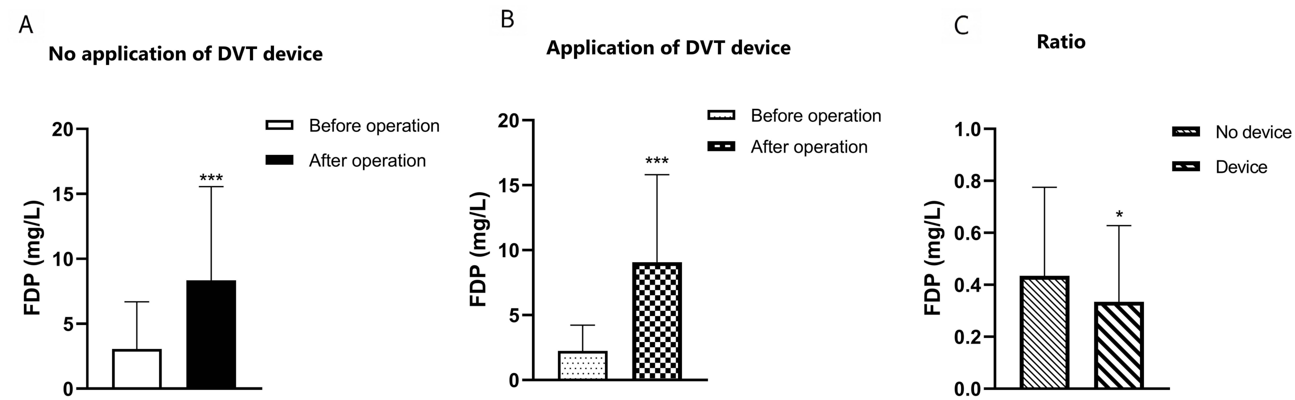

Figure 6 (A) Comparisons of the values of FDP between before and after the operation in the Non-device group (**A**) and device group (**B**). (**C**) Comparisons of the FDP ratio of before the operation to after the operation between the Non-device group and Device group. Data were shown with mean ± SD. * *P* < 0.05; *** *P* < 0.001.

Non-device group (p = 0.48; Figure 7A) and 2.77 ± 0.73 g/L vs 2.84 ± 0.66 g/L in the Device group (p = 0.44; Figure 7B), respectively. The APTT values of before operation and after operation were 26.99 ± 2.86 g/L vs 26.64 ± 2.70 g/L in the non-device group ((p = 0.36; Figure 8A) and 25.3 ± 2.74 g/L vs 25.24 ± 2.50 g/L in the device group (p = 0.89; Figure 8B).

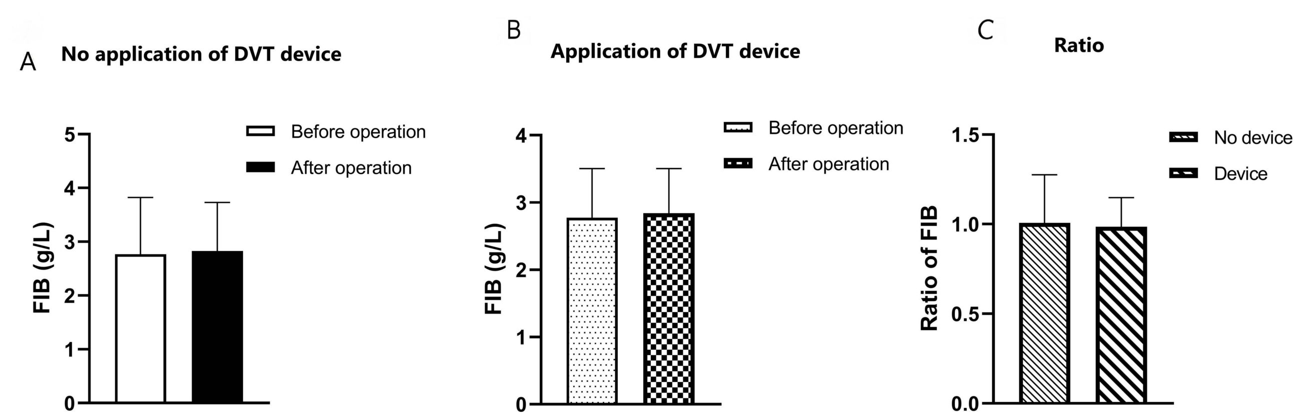

Figure 7 (A) Comparisons of the values of FIB between before and after the operation in the Non-device group (**A**) and device group (**B**). (**C**) Comparisons of the FIB ratio of before the operation to after the operation between the Non-device group and Device group. Data were shown with mean ± SD.

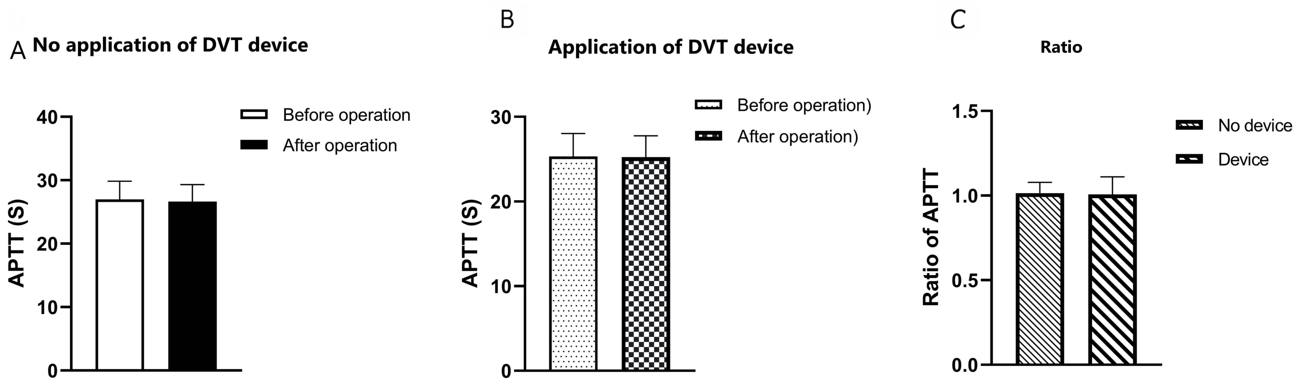

Figure 8 Comparisons of the values of APTT between before and after the operation in the Non-device group (**A**) and device group (**B**). (**C**) Comparisons of the APTT ratio of before the operation to after the operation between the Non-device group and Device group. Data were shown with mean ± SD.

It is worthwhile to note that a statistically significant difference was found in all parameters except the APTT and FIBT when compared before with after the operation in both groups, a ratio of each parameter obtained before and after the operation was thus compared between the Non-device and Device groups to distinguish the effect of the device on coagulative and fibrinolytic functions. The results showed that the PT ratio of before operation to after operation in the Device group was significantly decreased by 1.03 folds compared with that in the Non-device group [No 0.93 ± 0.04 (n = 55) vs 0.96 ± 0.05 (n = 61); $p = 0.03$; Figure 1C]. However, after the application of the device, the PT% ratio of before operation to after operation was significantly increased by 1.04 folds [No device 1.10 ± 0.11 (n = 55) vs Device 1.14 ± 0.10 (n = 61), $p = 0.03$; Figure 2C], conversely, the ratio of INR was reduced by 1.03 folds [No device 0.96 ± 0.85 (n = 55) vs Device 0.93 ± 0.05 (n = 61), $p = 0.04$; Figure 3C], similarly, the ratio of FDP was also significantly decreased by 1.3 folds [0.43 ± 0.34 (No device, n = 56) vs 0.33 ± 0.29 (Device, n = 59); $p = 0.03$; Figure 6C].

No significant difference was found in the TT, DDi, FIB, and APTT ratios of before operation to after operation in the Device group from those in the Non-device group. The values were described as follows: The TT ratio was 1.0 ± 0.07 (n = 51; Non-device group) verse 1.03 ± 0.06 (n = 58; Device group; $p = 0.24$; Figure 4C); the ratio of DDi was 0.26 ± 0.29 (n = 56, Non-device group) verse 0.28 ± 0.36 (n = 59, Device group; $p = 0.9$; Figure 5C); The ratio of FIB 1.00 ± 0.27 (n = 55, Non-device) verse 0.98 ± 0.16 (n = 61, Device group; $p = 0.88$; Figure 7C); The ratio of APTT (n = 55, No device 1.02 ± 0.06 verse 1.00 ± 0.10 (n = 61, the Device group, $p = 0.37$; Figure 8C), respectively.

The results of ultrasound images showed that 2 out of 57 patients without receiving IPC had bilateral thrombi in the lower limb, the incidence rate of DVT after operation was 3.3%. In the Device group, the incidence rate of DVT was 3.2% with two out of 62 patients receiving the compression, one patient had thrombi in the bilateral lower limbs and the other had unilateral thrombi in the calf. No clinical evidence of the occurrence of pulmonary embolism was found.

In the Non-device group, three days after the surgery, one patient presented with the intermuscular vein thrombosis in the left calf (Figure 9A), the peroneal vein and the partial muscle vein in the right leg (Figure 9B); And no thrombi were found in the deep and superficial veins in the thigh (Figure 9A and B). Physical examination showed no obvious tenderness in the bilateral gastrocnemius muscles and detectable bilateral dorsalis pedis artery pulsation. Anticoagulation treatment was given by subcutaneous injection of adroparin calcium and enoxaparin sodium. The patient was discharged with oral rivaroxaban until no thrombi were detected in both lower limbs by ultrasound 10 days after the treatment. Similarly, the other patient had no bilateral gastrocnemius tenderness and normal skin color with detectable bilateral dorsalis pedis artery pulsation 1 day after surgery; However, the results of USD imaging showed that thrombi were located in some intermuscular veins of the left calf (Figure 10A) and the mild varicose saphenous vein in the right calf (Figure 10B). Avoiding vigorous activity was advised and subcutaneous enoxaparin sodium was given. Although the blood flow in the left lower limb was smooth, thrombosis was formed in the right peroneal vein 7 days after the surgery, therefore, the frequency of orally taking rivaroxaban was increased from two times a day to four times a day, and coagulation tests were regularly done for 3 months, USD re-examination showed no thrombi in both lower limbs three months after the treatment.

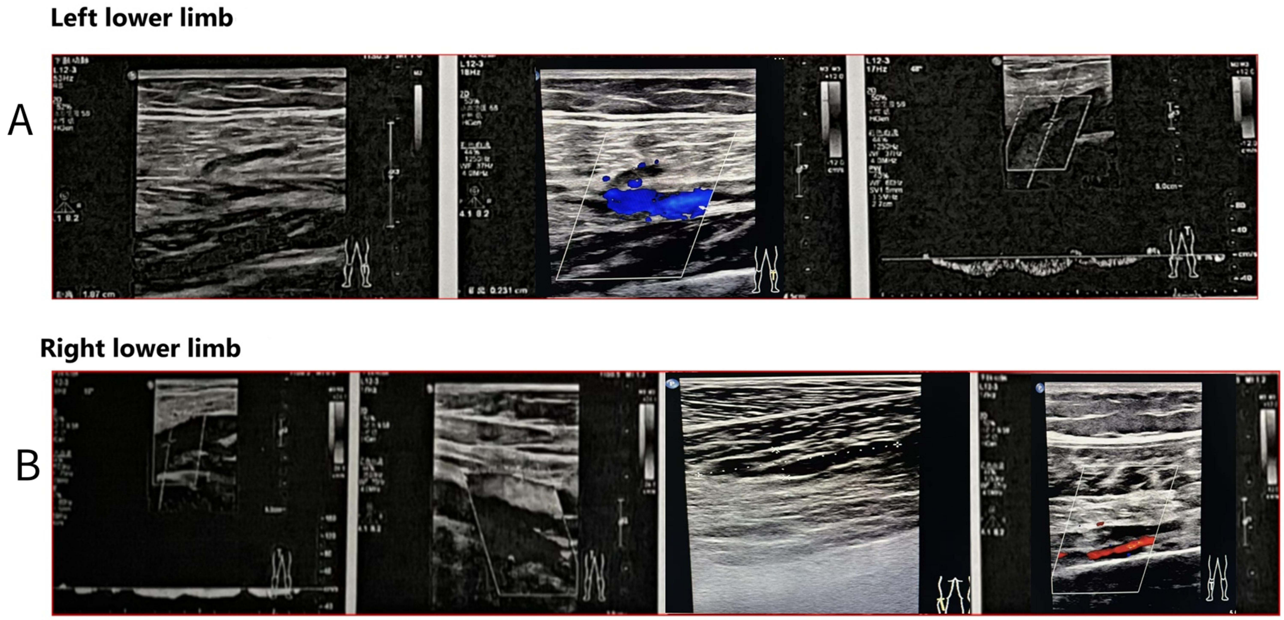

Figure 9 Venous ultrasound images showed thrombus formation in the intermuscular veins in the left calf (**A**) and the peroneal vein and the partial muscle vein in the right calf (**B**) of a representative patient in the Non-device group 3 days after surgery. The main vein of the left (**A**) and right (**B**) lower limb was displayed, and there was no obvious abnormality in its course. A slightly dilated vein can be seen between the left calf muscles, with a low echo pattern inside. The range was approximately 18.7 mm x 2.3 mm (**A**), and the peroneal vein and some of the intermuscular veins of the calf are slightly dilated, filled with low echoes with a width of 4.2 mm (**B**). (**A and B**) The lumen deformation of the probe compression was not obvious, and no obvious blood flow signal was seen inside. There was no clear solid echo in the lumen of the main vein of the remaining left and right lower limb, and the lumen can be closed when the probe is pressurized. CDFI + PW: The blood flow signal inside is well-filled; there is no obvious abnormality in the direction and speed of blood flow in a calm state. No thrombi were found in the deep and superficial veins in the left and right thigh.
Abbreviations: CDFI, Color Doppler flow imaging; PW, Pulsed-wave Doppler ultrasound.

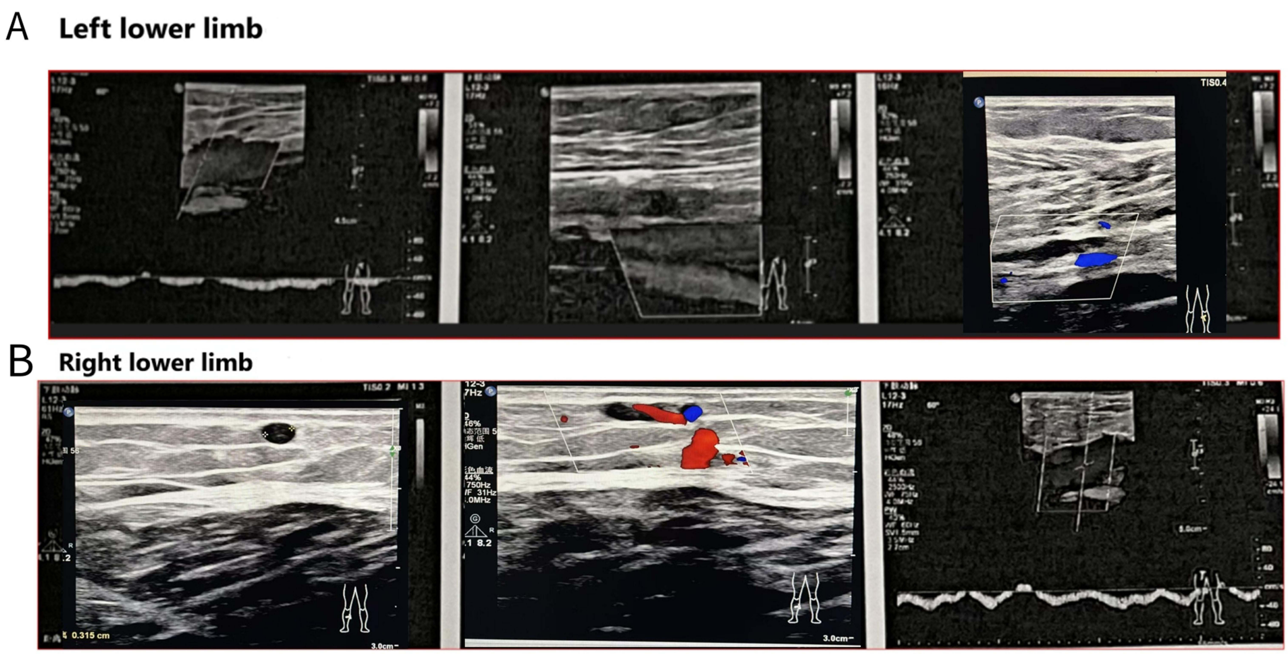

Figure 10 Venous ultrasound images showed a thrombus in the intermuscular veins in the left calf (**A**) and slightly varicosed right great saphenous vein (**B**) in the calf of another representative patient in the Non-device group 7 days after surgery. (**A**) The main vein of the left lower limb was displayed, and there was no obvious abnormality in its course. A slightly dilated vein can be seen between the left calf muscles, with a low echo pattern inside with a width of approximately 3.0 mm. The lumen deformation of the probe compression was not obvious, and no obvious blood flow signal was seen inside. (**B**) The main vein of the right lower limb was displayed. The right great saphenous vein in the lower leg is slightly tortuous, with low echo filling inside, which is 3.2 mm wider. The lumen is slightly deformed when the probe is compressed. CDFI: small blood flow signals are seen around the low echo in the lumen. (**A and B**) no obvious solid echo was observed in the lumen of the main vein of the remaining right lower limb, and the lumen can be closed when the probe is compressed. CDFI+ PW: The blood flow signal was well-filled; there was no obvious abnormality in the direction and speed of blood flow in a calm state.
Abbreviations: PW, Pulsed-wave Doppler ultrasound; CDFI, Color Doppler flow imaging.

In the Device group, one patient had bilateral thrombi including the right fibula vein and left calf vein but without detectable bilateral gastrocnemius tenderness 2 days after surgery. However, the levels of DDi and FDP were increased to 10.55 mg/L FEU and 25.16 mg/L, respectively. And Doppler ultrasound images showed perioperative acute left calf intermuscular vein thrombosis (Figure 11A) and right peroneal vein thrombosis (Figure 11B). Management was made by raising the patient's lower limbs, prohibiting compression on the affected legs, and measuring both calf circumferences. Implanting an inferior vena cava filter to prevent fatal pulmonary embolism was also recommended but the patient refused. The patient was discharged with regular monitoring of DDi levels, and regular nadroparin anticoagulation was suggested for at least 3 months.

The other patient had unilateral thrombi in the left calf muscular vein, which was detected 4 days after surgery (Figure 12), slight tenderness was detected only in the left gastrocnemius and no edema was seen in both lower limbs.

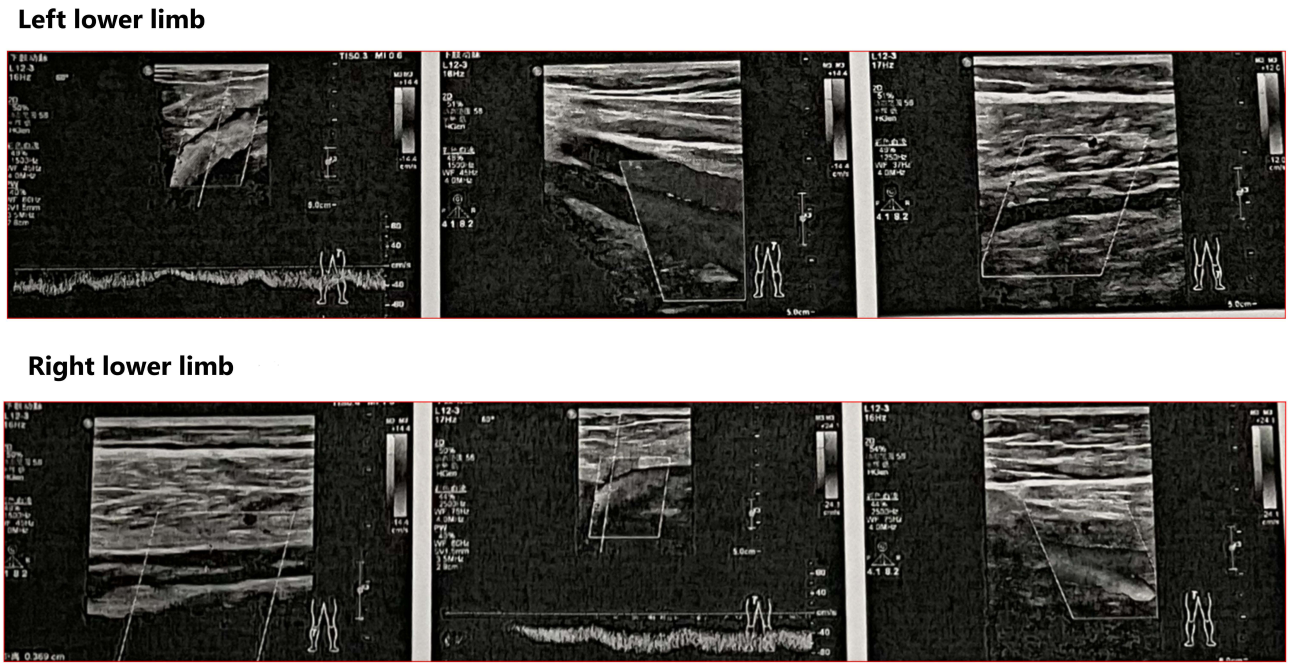

Figure 11 Venous ultrasound images showed the intermuscular vein thrombosis in the left calf (**A**) and peroneal vein thrombosis in the right calf of one representative patient in the Device group 2 days after surgery. The left (**A**) and right (**B**) lower limb vein trunk were displayed, and there is no obvious abnormality in the course. (A): Several slightly dilated veins can be seen in the left calf, which are filled with low echoes. The lumen was not deformed greatly when the probe was compressed, and no obvious blood flow signal was seen inside. (**B**): The lumen of some segments of the peroneal vein is slightly dilated, filled with low echoes, and was 3.7 mm wide. CDFI: No obvious blood flow signal was seen. No obvious solid echo is seen in the lumen of the remaining right lower limb vein trunks, and the lumen can be closed by probe pressure. No obvious solid echo was found in the lumen of the remaining left (**A**) and right (**B**) lower limb vein trunk, and the lumen can be closed when the probe is compressed. CDFI+ PW in both A and (**B**) The blood flow signal was well-filled; there was no obvious abnormality in the direction and speed of blood flow in a stable condition. No thrombi were found in the deep and superficial veins in the left and right thigh (**A** and **B**).
Abbreviations: CDFI, Color Doppler flow imaging; PW, Pulsed-wave Doppler ultrasound.

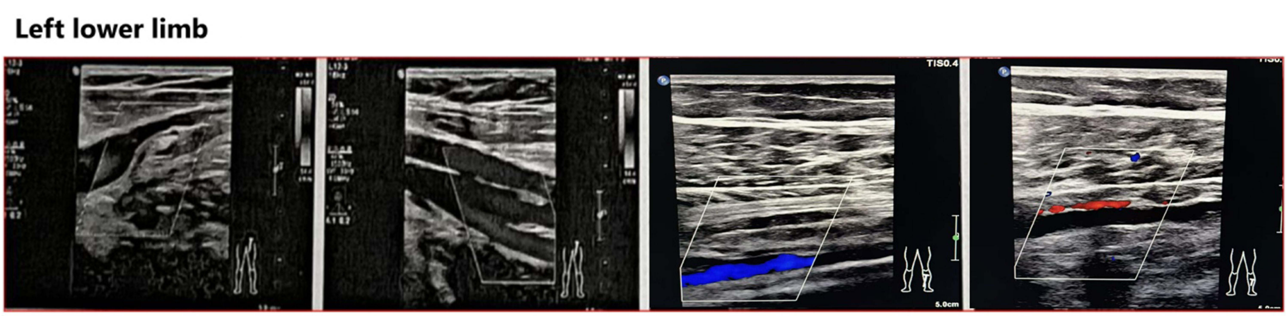

Figure 12 Venous ultrasound images showed the intermuscular vein thrombosis in the left calf of another representative patient in the Device group 4 days after surgery. Low echoes were found in the local intermuscular veins. The lumen was slightly deformed when the probe was compressed, and local blood flow filling defects were observed. No obvious abnormalities were found in the course of the remaining left lower limb veins. No obvious solid echoes were found in the lumen, and the lumen could be closed when the probe was pressurized. CDFI + PW: no abnormality of the blood flow signal filling was observed.

The management plan included avoiding standing or walking for long periods, raising the affected limb 10–15 degrees when resting, subcutaneous injection of adroparin calcium, and monitoring blood routine and coagulation; No pain and no signs of tenderness and edema were detected in both lower limbs 11 days after surgery, and the re-examination of the left lower limb by ultrasound showed no obvious thrombosis. The patient was discharged from the hospital with oral rivaroxaban.

Discussion

We examined whether sequential pneumatic compression applied around the time of minimally invasive gynaecologic surgery could influence haemostatic shifts and thrombus formation in women with benign disease. Demographic profiles were essentially alike in the compression and control cohorts. Surgical intervention alone increased PT, INR, D-dimer and FDP while reducing PT % and TT, with FIB and APTT unchanged, across both cohorts. Expressed as pre-/post-operative ratios, changes in PT, INR and FDP were smaller among women who received compression sleeves, implying partial attenuation of surgery-induced coagulation and fibrinolysis; the PT % ratio, in contrast, fell modestly further in this group. Ratios for TT, D-dimer, FIB and APTT did not differ between cohorts. Distal lower-limb DVT was detected by duplex ultrasound in 3.3 % of controls versus 3.2 % of patients given pneumatic compression, reflecting a similarly low post-operative incidence.

Prothrombin time (PT) gauges how long citrated plasma takes to form fibrin after tissue-factor activation, interrogating the extrinsic arm and shared portion of the coagulation cascade and flagging deficits in factors II, V, VII, X or low fibrinogen. Laboratory-to-laboratory variation in thromboplastin sensitivity is corrected by the international normalised ratio (INR)—the patient's PT expressed against a reference value generated with a World Health Organization calibration reagent—so results remain comparable. In our cohort both PT and INR rose after surgery, indicating procedure-related slowing of clot formation, likely from transient factor or fibrinogen consumption. Yet the pre-/post-operative increase was smaller among women who received intermittent pneumatic compression, suggesting that the device tempered this delay and may curb bleeding propensity. Because PT chiefly reflects the extrinsic pathway, these findings imply that sequential compression modulates this limb of coagulation and could, in turn, help lower downstream DVT risk.

Although PT and APTT both interrogate the final common arm of coagulation, APTT is primarily sensitive to the intrinsic system; abnormalities in fibrinogen or factors VIII, IX, XI, and XII prolong its duration. The assay records the clotting interval after citrated plasma is exposed to a surface activator together with calcium-phospholipid, thereby maximally engaging factor XII–initiated reactions.[28–30] In our series, absolute APTT values and their pre-/post-operative ratios remained unchanged in both cohorts, suggesting that neither the laparoscopic procedure nor sequential pneumatic compression perturbed intrinsic-pathway activity.

Fibrinogen is synthesised in the liver and circulates as the precursor of fibrin; thrombin time (TT) gauges how swiftly thrombin converts this precursor into a fibrin clot.[31] If TT is prolonged, a fibrinogen-antigen assay clarifies whether the issue stems from reduced protein quantity or a functional anomaly. As an acute-phase reactant, fibrinogen rises with tissue trauma, infection, inflammation, and malignancy and has been linked to thrombus formation and vascular damage.[32–35] In our series, TT fell significantly after surgery whereas fibrinogen concentration did not, indicating faster clot generation without quantitative change in the protein. TT- and fibrinogen-ratio comparisons showed no difference between compression and control cohorts, suggesting neither the laparoscopic procedure nor sequential compression influenced fibrinogen quantity or its conversion rate. Although fibrinogen— the most plentiful coagulation factor—contributes to plasma viscosity and thrombogenic potential,[36] its stable levels here imply viscosity was not materially altered.

During fibrinolysis, plasmin cleaves soluble fibrinogen as well as cross-linked fibrin, releasing fibrin(ogen)-degradation products (FDP). D-dimer is the terminal, cross-link-containing fragment of this breakdown and serves as a direct marker of active clot dissolution.[36] Because concentrations of both FDP and D-dimer rise quickly once secondary fibrinolysis and clot activation occur, they are routinely used to estimate thrombotic risk[37,38] and to gauge both the efficacy and bleeding hazard of thrombolytic therapy.[39] D-dimer's high negative-predictive value makes it particularly useful for excluding venous thromboembolism (VTE) in low-probability cases; if levels are elevated, definitive imaging is then pursued to confirm or rule out events of intermediate or high clinical likelihood.[40–43]

Our data showed a clear postoperative surge in both FDP and D-dimer across cohorts, pointing to a surgery-triggered boost in fibrinolysis. Yet, when expressed as pre-/post-operative ratios, only FDP rose less in the compression group, indicating that sequential pneumatic compression tempered this marker while leaving D-dimer largely unchanged. Earlier studies report pronounced FDP and D-dimer elevations in malignant gynaecologic tumours such as ovarian cancer, but negligible shifts in benign lesions;[44–46] the universal FDP increase we observed in fibroid patients therefore deviates from that pattern. Persistently high D-dimer in the compression cohort still reflects active fibrin turnover and a residual pro-thrombotic milieu, keeping deep-venous thrombosis on the radar. Heavy menstrual loss in fibroid patients, combined with peri-operative haemodynamic fluctuations, further heightens VTE vulnerability.[47] Given the sparse literature on fibrinolytic markers in benign gynaecology, additional studies are needed to clarify how peri-operative FDP and D-dimer kinetics relate to thrombotic risk.

Post-operative duplex scanning detected DVT in no more than 3.5% of women in either cohort, a figure comparable to that reported for benign gynaecologic surgery in Chinese patients.[48] Rates are markedly lower than those described for malignant cases, where laparoscopic procedures yield DVT frequencies of roughly 8–12%.[49,50] Incidence also differs by ethnicity: Asian populations consistently show fewer events than European cohorts, a gap thought to stem from genetic and dietary factors.[51–53]

In our series, every thrombus identified on duplex imaging lay below the knee. Such calf-vein events typically involve the peroneal, anterior or posterior tibial, or gastrocnemius–soleus channels. Two silent bilateral cases appeared in controls and two in the IPC cohort (one bilateral, one unilateral); no extension to popliteal-femoral/iliac segments and no pulmonary emboli were seen. The pneumoperitoneum required for laparoscopy raises intra-abdominal pressure above lower-limb venous return, dilating veins, slowing flow, and thickening blood.[54,55] Compared with above-inguinal thrombosis, risk factors and prevention strategies for calf DVT remain poorly defined.[2,31,56,57] Current ACCP guidance treats patients whose unprotected proximal-vein risk hovers around 5%—or whose distal-vein risk reaches roughly 20–40%—as high-risk, recommending peri-operative anticoagulation even for benign laparoscopic gynaecologic procedures.[5]

It is worthwhile to note that there are several limitations in this study. It is unclear whether no significant change in the incidence of DVT between the two groups is due to the small cohort size, larger-scale prospective cohort studies across multiple centers are needed. Moreover, we did not conduct a correlation analysis of the occurrence of DVT with these coagulation factors due to the relatively small cohort study, therefore, it would be beneficial to explore any potential association of hemostatic parameters with DVT occurrence in both benign and malignant gynecological patients in future research. And evaluation of the effect of additional prophylaxis when combined with compression stockings and chemical prophylaxis on hematosis would also provide better evidence for the intervention of DVT in these patients.Although this study has incorporated some factors related to venous thromboembolism (VTE) and deep vein thrombosis (DVT), it was unable to comprehensively include all potential factors due to the limitations of the study itself. Therefore, this study has certain limitations, and its generalization requires relatively specific conditions. And the Device vs Non-device group was determined by the attending anesthesiologist's clinical routine during the study period; it was neither randomized nor based on patient preference, and we now acknowledge this as a potential selection.

In summary, our results demonstrated dynamic changes of coagulation and fibrinolytic parameters in response to IPC application after surgery, although the occurrence of distal DVT in benign gynecological patients is low, the application of IPC can reduce the effects of surgery-induced activation of coagulation and fibrinolysis via its regulatory effects, which may guide clinicians and nurses to early identify the risk of DVT, consequently, making early prevention and management for patients undergoing gynecological laparoscopy during perioperative and postoperative care.

Conclusion

In this retrospective cohort of Chinese women undergoing benign gynecologic laparoscopy, peri-operative IPC mitigated the surgery-induced rise in PT, INR, D-dimer and FDP and produced a numerically equal (≈3%) distal DVT rate. These data suggest that mechanical calf-ankle compression can modestly attenuate early coagulation/fibrinolytic activation, although it did not significantly lower overall DVT incidence in this low-risk population. Prospective, adequately powered trials are required before IPC can be recommended as stand-alone prophylaxis in minimally invasive gynecologic surgery.

Data Sharing Statement

The data could not be shared openly, as required by our department. The raw data could be obtained upon reasonable request by the corresponding author.

Ethics Approval and Consent to Participate

This study was approved by Ethics Committee of Guangdong Provincial Hospital of Chinese Medicine (approval number: ZE2025-131-01). Informed consent was obtained from all the participants. All methods were carried out in accordance with Declaration of Helsinki.

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Disclosure

The authors have no conflicts of interest to declare.

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