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Thromboelastography for the Prevention of Perioperative Venous Thromboembolism in Orthopedics

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Abstract

We have reviewed a large number of relevant literature to determine the deficiencies of orthopedics in the diagnosis and prevention of venous thromboembolism (VTE) events during the perioperative period, and found that the TEG technology has been widely used after liver transplantation, which may make up for the deficiencies. This review expounds the detection principle and latest thromboelastography (TEG) development, and highlights the advantages of TEG over previous screening methods in diagnosing hypercoagulability. By analyzing the correlation and consistency between TEG and conventional coagulation test, reliable indexes for diagnosing hypercoagulability and important parameters for guiding perioperative anticoagulation treatment were summarized. Furthermore, our work contributes to further studies of TEG in orthopedics. Based on the research results, we believe that TEG may help orthopedists to identify and predict VTE events, use anticoagulants, eventually reduce the occurrence of VTE events.

Keywords

thromboelastography, perioperative period, venous thromboembolism, orthopedics

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Introduction

Venous thromboembolism (VTE) refers to a series of diseases in which pathological factors disrupt the coagulation–fibrinolysis system balance, causing blood to coagulate abnormally in venous vessels, leading to venous blood circulation disorders. VTE mainly includes pulmonary embolism (PE) and deep vein thrombosis (DVT). Pulmonary thromboembolism (PTE) is the most common PE, with an incidence rate of > 90% of PE. PE and DVT are manifestations of VTE in different parts of the body and stages of development.[1–4] According to Vichorw (1840), the three factors that influence thrombus formation in patients are venous stasis, vascular endothelial injury, and a disrupted balance between coagulation and fibrinolysis. Such as older age, long sickness duration, immobilization, vascular traction during operation, use of general anesthesia, transfusion, and use of bone cement and other factors to varying degrees affected the vascular endothelium and blood flow, broke the balance of coagulation and fibrinolysis system, promote the formation of VTE in orthopedic patients during the perioperative period. Thus, affected patients constitute the population that is most predisposed to VTE.[5–7] The incidence of VTE after a major orthopedic surgery is approximately 0.87%–3.29% in Europe and America,[3,8,9] and that of Asia is approximately 1.1%–1.4%.[3]

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VTE incidence after orthopedic spine surgery is 0.3%–31%.[7,10] Approximately 20–55% of patients diagnosed with DVT develop post-thrombotic syndrome (PTS) within the first 2 years after diagnosis, and 5–10% of patients develop severe PTS after a poor prognosis, greatly affecting their long-term quality of life.[2] Approximately 79% of VTE cases are derived from the distal vein, and 61% of DVT cases are associated with the asymptomatic presence of a thrombus.[11] In this case, the embolus flows into the pulmonary artery and hinders pulmonary artery blood circulation, which is life-threatening, and in many scenarios, perioperative complications and unexpected death occur.[1,3,4] Early detection of VTE and the adoption of preventive measures are very important in the orthopedic perioperative period to reduce the disease burden of VTE.

Many relevant guidelines recommend the use of D-dimer, color Doppler ultrasound, venography, and other techniques for VTE screening. However, these techniques have limitations. D-dimer level is affected by other clinical factors, such as the presence of malignant tumors, inflammation, pregnancy, and surgery. Therefore, although it has a high sensitivity, its specificity is low.[12–14] Color Doppler ultrasound is the preferred method for DVT diagnosis because of its high diagnostic accuracy, but its accuracy in distal venous thrombosis and central iliac vein thrombosis is low and is affected by the skill of the operator. Venography is the gold standard for DVT diagnosis in the lower extremities. However, it is an invasive procedure, and its applicability is limited by the disadvantages of contrast agent allergy, nephrotoxicity, and further damage to the blood vessels by the contrast agent.[1–4] In recent years, several multicenter high-quality experiments have sought to improve diagnostic accuracy for VTE using other screening techniques.

Thromboelastography (TEG) is a type of viscoelastic test (VET) that can dynamically monitor the coagulation reaction from fibrin formation to clot dissolution, providing information, such as the start time of clotting, rate of clot formation, maximum strength of the clot, and degree of fibrinolysis. TEG can reflect the overall clotting process comprehensively, and it is more accurate, faster, and less traumatic than other common techniques in the assessment of abnormal blood clotting. TEG has been widely used in clinical fields, such as liver transplantation surgery, cardiothoracic surgery, trauma, and intensive care to detect blood coagulability and guide blood transfusion management. In recent years, TEG has also been developed in obstetrics, gynecology, and orthopedics.[15–19] This review focuses on the detection principle of TEG and its application in the diagnosis and prevention of VTE in the perioperative period in orthopedic patients.

Origin, Classifications, and Detection Principle of TEG

TEG was first reported by Dr Hellmut Harter in 1948.[20] Until the 1960s, Starzl et al. attempted to use TEG to guide blood component therapy and antifibrinolytics in liver transplant patients to reduce the high incidence of bleeding and thromboembolic events;[21–23] this marked the introduction of its use in clinical medicine. TEG technology was increasingly used in the mid-1980s, with its continuous improvement, as well as its reagents, to guide the management of blood transfusion in patients undergoing liver transplantation. TEG increasingly received attention and was introduced in cardiothoracic surgery and trauma management early in the 21st century.[15–17,24]

The most commonly used VET systems are rotational TEG (ROTEM) and TEG. TEG mainly includes standard kaolin TEG and rapid TEG (r-TEG), with different activators and pathways. ROTEM can be specifically divided into extrinsic activator thromboelastometry（EXTEM）, intrinsic activator thromboelastometry (INTEM), fibrin-based thromboelastometry(FIBTEM), and aprotinin thromboelastometry (APTEM). Heparinase-modified thrombelastometry (HEPTEM) may also be considered when high levels of heparin (4-8U/mL) are believed to be detected in the blood. Other types of tests on thromboelastometry are ROTEM Platelet, FF TEC, platelet mapping. The detection parameters and reference value ranges for TEG and ROTEM are different, but the detection principle is similar; a close correlation was found between detected parameters.[15,17,25–28] In this paper, we mainly discuss the standard kaolin TEG for the prevention of VTE in orthopedic patients.

The TEG analyzer is composed of a pin and heated reagent cup. Fresh whole blood (0.36 mL) or blood mixed with 3.2% trisodium citrate anticoagulant is added to the reagent cup, which contains the activator. The cup is maintained at 37 °C and rotated by 4°45′ every 5 s. Clot formation, contraction, and fibrinolysis under the action of platelets, fibrin, and coagulation factors are detected; the movement of the pin is affected by the shear force of the clot. Clot formation time, clot strength, and fibrinolysis time are depicted on a thermosensitive paper by the pin at the rate of 2 mm/min.[15,26,29,30] Standard kaolin TEG uses a kaolin activator, and r-TEG is activated by a mixture of kaolin and tissue factors. Study have shown that the mean time required for an r-TEG result is 30.8 ± 5.72 min and that for a standard kaolin TEG result is 41.5 ± 5.66 min, which are shorter than the mean time for coagulation tests (CCT) (64.9 ± 18.8 min).[31]

The United States Food and Drug Administration has approved two blood viscoelasticity analyzers, TEG5000 and TEG6 s, for clinical monitoring. Different from TEG6s, TEG5000 uses an electromechanical transducer to connect with a pin, which is suspended by a torsion wire, to measure whole blood viscoelasticity; each test is performed separately. The TEG6 s uses a vibrating-membrane LED optical interface and a vibration technology. Whole blood is introduced into a four-channel microfluidic chamber, forming a meniscus, which is vertically vibrated at a frequency of 20 Hz to 500 Hz, and the resonant frequency is indirectly proportional to clot strength. An infrared detector evaluates the vertical oscillation frequency of the meniscus under LED illumination, with the detector converting the signal to a TEG curve. TEG6 s assesses the clot at once using four tests, including standard kaolin TEG, kaolin TEG with heparinase, r-TEG, and TEG-functional fibrinogen. By referring to the results of different assays, TEG6 s can provide TEG graphical images within 10 min. In addition, TEG6 s enables automatic pipetting and titration of reagents, thereby improving inspection standard

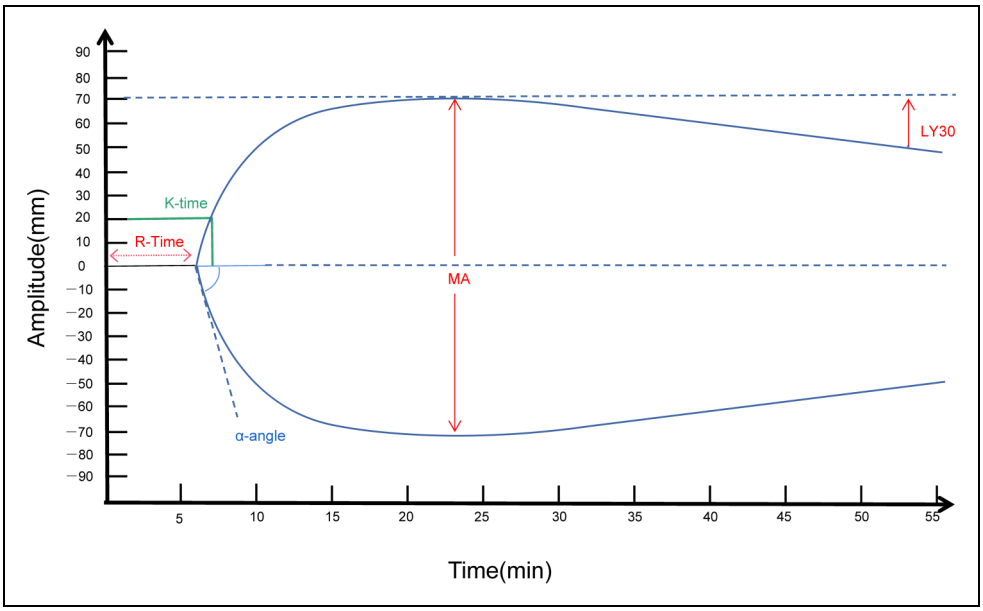

Figure 1. Schematic diagram of TEG detection.

flow.[32–35] A review of the existing literature suggests that the performance of these two analytical instruments is highly consistent and strongly related.[32–35] A test result with good accuracy can be obtained using either of the two TEG analyzers, and more high-quality experimental evidence is expected to support and improve this conclusion in the future.

Main Parameters of TEG

In the process of detecting coagulation function, TEG can produce nearly 20 parameters, among which the most important and commonly used parameters are clotting initiation time (R), clot formation time (K), alpha angle (α-angle), and maximum amplitude (MA). As demonstrated in Figure 1, other parameters, such as coagulation index, lysis index, elasticity constant, and clot firmness, have also been reported[15,17,26,36–43]

R(min): R represents the time when the transducer moves 2 mm from the starting point, indicating that fibrin has begun to act, reflecting the effect of coagulation factors and the coagulation quality of the intrinsic coagulation system. R reduction suggests that the blood may be in a hypercoagulable state.

K(min): K is the time required for the transducer to move from 2 mm to 20 mm on the TEG curve. K is affected by fibrinogen and platelets, reflecting the time at which a clot reaches a stable intensity. A decrease in K indicates that the blood may be in a hypercoagulable state.

α-angle(°): The α-angle is shown on the curve as the angle formed between the single-sided amplitude curve and the horizontal amplitude, within the range of 2–20 mm. This reflects the rate of clot formation; a larger angle indicates faster clot coagulation.

MA (mm): MA refers to the maximum amplitude obtained on the curves; it represents the maximum distance between two curves, reflecting the maximum strength of the clot formed by the interaction of fibrin and platelets through GPIIb/IIIa receptors.

Currently, CCT is the most widely used coagulation test in clinical practice. CCT is performed using centrifuged plasma, based on the coagulation cascade. However, this test reflects only a part of the clotting cascade, and its timeliness is less than that of TEG. The main parameters of CCT are fibrinogen (FIB), activated partial thromboplastin time (APTT), international normalized ratio (INR), platelet count (PLT), and prothrombin time (PT).[36–44] Its results are often compared with those of TEG, to demonstrate the efficacy of TEG in monitoring blood coagulation.

Detectability of VTE in a Hypercoagulable State Using TEG

The correlation analysis of these two results is presented in Table 1. WEN et al. performed a correlation analysis of the test results of TEG and CCT in different states, and the authors found that R had a modertate positive correlation with APTT and PT, and a very weak negative correlation with FIB in the hypercoagulable state. Further, K had a medium negative correlation with FIB. A substantial positive correlation was found between α angle and FIB, but a medium negative correlation was found with PLT. In addition, MA had a substantial positive correlation with PLT and a moderate positive correlation with FIB.[39] Wu et al. proposed that R had a moderate positive correlation with APTT, K was significantly substantially correlated with PLT, and both α-angle and MA had a stable positive correlation with FIB and PLT.[45] LIU et al. confirmed the views of the above scholars in their orthopedic clinical experiment. They reported a moderate positive correlation between R

Table 1. Correlation of thromboelastography (TEG) with conventional coagulation tests（CCT) in different experiments.

Reference	Item	r	Intensity
Wen et al.[39]	R and PT	0.316*	moderate
	R and APTT	0.258*	moderate
	R and FIB	−0.125*	fair
	K and FIB	−0.411*	moderate
	α-angle and FIB	0.538*	substantial
	α-angle and PLT	−0.261*	moderate
	MA and FIB	0.381*	moderate
	MA and PLT	0.515*	substantial
Wu et al.[45]	R and APTT	0.364*	moderate
	K and FIB	−0.061*	fair
	K and PLT	0.512*	substantial
	α-angle and FIB	0.544*	substantial
	α-angle and PLT	0.472*	moderate
	MA and FIB	0.677*	substantial
	MA and PLT	0.7219*	substantial
Liu et al.[43]	R and APTT	0.3327*	moderate
	K and FIB	−0.560*	substantial
	α-angle and FIB	0.4246*	moderate
	MA and FIB	0.391*	moderate
	MA and PLT	0.4078*	moderate

*$P < 0.05$.

and APTT, a substantial negative correlation between K and FIB, and a moderate positive correlation between α angle and FIB. A moderate positive correlation was observed between MA and FIB, or between MA and PLT.[43]

Therefore, we inferred that R maintains a moderate correlation with APTT. A stable and significant correlation between K, α-angle, and FIB is not difficult to obtain under an abnormal coagulation state, and the correlation between these parameters and FIB is better than that with PLT. This suggests that K and α angle are easily affected by fibrinogen and could reflect the fibrinogen level. Compared with FIB, a stable and substantial correlation was found between MA and PLT, indicating that MA was mainly affected by platelets. This conclusion is consistent with the findings of Wang et al. wherein MA is affected by 80% platelets and 20% fibrin.[46]

There were some inconsistencies in the diagnosis results. In the research by Geng et al. the R of patients undergoing knee joint surgery had a substantial consistency with APTT, but a fair consistency with PT was noted. However, only α-angle had a slight consistency with PLT, and K and α-angle had moderate consistency with FIB. The consistency between MA and PLT was poor. Furthermore, the conclusion in the hip joint group was completely different from that in the knee joint group. R only had a fair consistency with APTT but not with PT; K had a non-significant consistency with PLT and FIB; and α-angle and MA both showed slight consistency with PLT and FIB.[37] WEN et al. proposed that the consistency between R and APTT and between R and PT was fair. They also recognized that K and FIB had moderate consistency, but the consistency with PLT was fair. Moreover, α-angle and FIB had a fair consistency, and PLT, FIB, and PLT had moderate consistency with MA.[39] These findings are presented in Table 2.

By reviewing the opinions of different scholars, the authors believe that the following are the main reasons for the difference in results between TEG and CCT. First, TEG has technical advantages over CCT. The detection parameters of TEG are more sensitive; Geng et al. reported that TEG was more sensitive than CCT in detecting changes in postoperative hypercoagulability in both knee and hip surgery groups.[37] The results of Zhu et al. are consistent with those of Geng, with the AUC of α angle, MA, and CI being 0.665, 0.669, and 0.808, respectively. The diagnostic abilities of α angle, MA, and CI are superior to those of INR and PT.[47] Moreover, due to cascade reaction-related limitations of CCT, 3P tests must be added to improve the judgment of coagulation function.[39] Second, the blood samples used by the two detection technologies are different. CCT uses whole blood centrifuged plasma which doesn't contain components such as platelets, leukocytes and erythrocytes, leading to CCT ignoring physical factors such as blood viscosity in the detection process. Furthermore, R only affected by endogenous coagulation activation pathway, under the influence of factors such as intraoperative bleeding volume, rehydration, anticoagulation drugs, surgery duration, surgery difficulty, and individual differences, there is a more or less consistent difference in the detection results of the two technologies.[37,47,48]

Assisting the Diagnosis of Perioperative Hypercoagulability in Orthopedic Patients

Controversies have not prevented scholars from affirming that TEG can diagnose a hypercoagulable state after surgery and prevent VTE events, and most existing studies also verify and

Table 2. Consistency of thromboelastography (TEG) with conventional coagulation tests (CCT) in different experiments.

Reference	Item	k	Intensity
Knee surgery group of Geng[37]	R and PT	0.362*	fair
	R and APTT	0.674*	substantial
	K and FIB	0.488*	moderate
	α-angle and FIB	0.428*	moderate
	α-angle and PLT	0.055*	slight
	MA and PLT	0.083*	slight
Hip surgery group of Geng[37]	R and APTT	0.224*	fair
	K and PLT	−0.79	substantial
	α-angle and FIB	0.098*	slight
	α-angle and PLT	−0.102*	slight
	MA and FIB	0.149*	slight
	MA and PLT	0.175*	slight
Wen et al.[39]	R and PT	0.227*	fair
	R and APTT	0.291*	fair
	K and FIB	0.481*	moderate
	K and PLT	0.312*	fair
	α-angle and FIB	0.357*	fair
	α-angle and PLT	0.271*	fair
	MA and FIB	0.551*	moderate
	MA and PLT	0.467*	moderate

*$P < 0.05$.

support this view.[48] Weng et al. used TEG to test the coagulation function of patients after knee-hip replacement on the first, fourth, and seventh days after operation.[49] Huang et al. also used TEG to test the changes in coagulation function within 24 h after total knee replacement.[50] Although the data obtained by the two groups were slightly different at approximately 24 h, the conclusions of these studies were similar. They believed that most coagulation functions of patients after joint replacement were in a low coagulation state within 24 h after the operation. R and K were higher than those prior to operation, and the values of α-angle and MA were lower than those prior to operation. After 24 h, the coagulation function gradually recovered or became hyperfunctional. In Weng et al.'s experiment, R gradually decreased, reaching the lowest point on the fourth day, and α-angle and MA continuously increased and reached the highest value at the detection endpoint. K continuously decreased until the lowest value was observed on the last day of the test. This test result is somehow consistent with the initial anticoagulation time recommended in the guidelines.[3,4] Most patients were in a hypercoagulable state after surgery, and anticoagulation measures should be adjusted according to the situation to prevent postoperative VTE.

TEG can also effectively identify high-risk patients with VTE prior to surgery. Liu et al. collected whole blood samples from 40 elderly patients 4 h after fracture and compared the coagulation monitoring results of TEG and CCT. They found that the K and R of elderly patients with fractures were significantly lower than those in the control group. The α-angle, MA, and CI of the aged with fractures were significantly higher than those of the control group.[43] Wang et al. found that prior to knee-hip replacement, the percentage of TEG in diagnosing coagulation disorder was 11.4% higher than that of CCT, and a significant difference was found between them.[40] After summarizing various articles, a meta-analysis showed that TEG was basically reliable in the diagnosis of hypercoagulable state, although the sensitivity for the diagnosis of hypercoagulable state was only 56%, the specificity was 76%, and the diagnostic advantage ratio was 3.6.[18]

TEG is an advantageous tool for orthopedic patients to monitor changes in blood coagulation function in the future; however, current TEG technology cannot completely replace CCT. Detection of extrinsic activated coagulation pathways is less sensitive than INR because R is limited by the kaolin activator.[36,39] PLT-induced coagulopathy may not be detectable by MA when PLT is $<50 \times 10^9$/L.[36] The main reason is that TEG currently has no unified reference value range, which is mostly determined by regional medical knowledge or TEG analyzer manufacturers, limiting the development of TEG technology in the field of orthopedics. For example, there is some controversy surrounding the reference value of the MA. Gary et al. reported that an MA of > 65 mm was a sensitive predictor of perioperative venous thrombosis in trauma. They further proposed that when MA is > 65 mm, the risk probability of VTE increases 3.6 times, and the risk of VTE increases 6.7 times when the MA value exceeded 72 mm. The odds ratios for the VTE diagnosis were 3.66 and 6.70, respectively.[51] However, the recommended MA range for the diagnosis of hypercoagulable states differs according to the research by McCrath et al. They proposed that an MA of > 68 mm is considered an independent risk factor for VTE events after surgery. When MA is > 68 mm, the sensitivity and specificity for the diagnosis of a hypercoagulable state are 80% and 62%, respectively.[52]

In summary, TEG is an effective tool for detecting the hypercoagulable state of blood in orthopedic patients and

predicting VTE occurrence during the perioperative period. K, α-angle, MA have relatively more stable correlation and consistency than those of other TEG parameters; they are reliable and sensitive indicators for the diagnosis of hypercoagulability. MA mainly reflects the quality and effect of PLT coagulation, and K and α-angle mainly depict the role of fibrinogen in blood coagulation. Therefore, these three parameters are recommended to clinical workers as important reference indicators for diagnosing the hypercoagulable state. However, completely replacing CCT with TEG test results is not recommended. R and MA are limited by the existing technology, and the main reason is the absence of a unified reference range for TEG analyzers worldwide. Thus, diagnosis should be based on the existing reference standards in combination with other examination data, such as CCT, color Doppler ultrasound, and lower extremity Doppler sonography, to identify early blood hypercoagulable state, intermuscular vein, and small distal limb embolism.

Guiding the use of Anticoagulant Drugs During the Perioperative Period

According to R, MA, and CI, the hypercoagulable state can be divided into three types: enzymatic hypercoagulability (CI>3, R $\leq$ 5 min, MA$\leq$70 mm), platelet PLT hypercoagulability (CI>3, R > 5 min, MA > 70 mm), and mixed hypercoagulability (CI>3, R $\leq$ 5 min, MA > 70 mm). TEG detection can clarify the classification of the perioperative hypercoagulable state, which is conducive to the accurate use of anticoagulant drugs.[49,53]

Warfarin, low molecular weight heparin (LMWH), rivaroxaban and aspirin (ASA) are the anticoagulant drugs recommended by relevant guidelines for the prevention of VTE. Thus, it is necessary to determine the changes in the above anticoagulant drugs in vivo for personalized anticoagulation treatment in orthopedics.

Warfarin is commonly used as an anticoagulant that inhibits the activation of exogenous coagulation pathway. Since the standard kaolin TEG only uses a kaolin activator without tissue factors, R is only sensitive to coagulation activated by intrinsic activation pathways and less sensitive to extrinsic activation pathways. r-TEG or ROTEM is recommended to test the anticoagulant effect of warfarin in vivo.[33,36,54]

LMWH is an anticoagulant obtained by chemical or enzymatic degradation of ordinary heparin. The experiment conducted by Tekkesin et al. showed that the R of TEG could effectively detect the anti-Xa activity within 12 h after injection of LMWH; CI was also significantly related to anti-Xa activity within 24 h. The results of R were closely related to the peak drug concentration. This finding suggests that R and CI might be sensitive indicators for monitoring LMWH; it could provide a reasonable reference for doctors to regulate the concentration of drugs in vivo.[55] Coppell et al. proposed that R could sensitively detect very low concentrations of LMWH (0.005 U/mL).[56] The conclusions of Song et al. are the same as those of scholars. Their experimental results showed that during the medication period, a significant difference in the R value between LMWH twice daily and LMWH once daily was observed.[57]

Rivaroxaban, a new factor Xa inhibitor, has been widely used in anticoagulant therapy in recent years because of its advantages, such as no routine monitoring, rapid onset, evident anticoagulant effect, fixed dosage, and convenient administration.[4,58,59] Bai et al. found that TEG could detect changes in the anticoagulant effects of enoxaparin sodium and rivaroxaban at different time points after total hip arthroplasty. Compared to that of the enoxaparin group, the R value of the rivaroxaban group was significantly increased on the seventh day after surgery, and the MA and CI values were significantly decreased. However, in other tests such as CCT, D-dimer, fibrinogen degradation products, and deep vein thrombosis events, only D-dimer changed significantly between the two groups, indicating that the anticoagulant effect of rivaroxaban was superior to that of enoxaparin sodium. The TEG parameter sensitivity was proven to be higher than that of CCT.[60] Bethany et al. reported that the PT value in CCT is insensitive to the monitoring of rivaroxaban at therapeutic doses. No significant linear relationship exists between the dose of rivaroxaban and the prolongation of the APTT value. Therefore, TEG is an effective method for detecting the anticoagulant effect of rivaroxaban compared to CCT.[61] Jian et al.'s findings are consistent with those of these scholars.[62]

Aspirin (ASA), an inhibitor of cyclooxygenase-1 (COX-1), reduces thrombosis by irreversibly inhibiting platelet aggregation and inhibits intimal hyperplasia.[50,63] In an experiment to explore the perioperative medication safety of ASA, Li et al. found that during the perioperative period of posterior lumbar fusion, compared with the aspirin-free group (Group 2), the R and K of patients in the aspirin-extended group (Group 1) were relatively increased and MA and α-angles were relatively decreased, and they were not statistically significant. This conclusion is consistent with the outcomes of CCT of patients in the two groups and confirmed with the incidence of objective events. While exploring the safe range of aspirin, TEG also proved to be a sensitive tool for monitoring changes in aspirin in vivo, and it can accurately and fairly reflect real results.[64] In addition to detecting changes in ASA in the body, TEG also assists doctors in screening for highly sensitive antiplatelet drugs by combining tests of platelet inhibition pathways such as the arachidonic acid (AA) pathway (which inhibits cyclooxygenase-reducing TXA2 production) and the adenosine diphosphate (ADP) pathway (which inhibits ADP receptors).[65,66] Li et al. tested platelet inhibition rates induced by AA and ADP pathways. They found that the AA inhibition rate of ASA was higher than that of clopidogrel.[66]

In summary, TEG accurately reflects the hypercoagulable state of orthopedic patients. It is also an important tool for detecting the efficacy of anticoagulant drugs, and can guide the rational use of these drugs in orthopedic patients during the perioperative period. Combined with the three hypercoagulable states divided by TEG, regulating the postoperative anticoagulants use and exploring the individual safe treatment

range of different drugs is beneficial. The R and CI of TEG can sensitively detect the anticoagulant LMWH effect in blood, and R has a dependent relationship with the peak value of the serum concentration of LMWH. Therefore, we suspect that R may establish a specific correlation with the LMWH specific dose and frequency. However, this idea requires further verification through more scientific research in the future. Compared with PT and APTT in CCT, TEG can accurately reflect the anticoagulant effect of rivaroxaban. TEG can help clinicians select the optimal antiplatelet drugs by combining two inhibition pathways of platelet inhibition, AA and ADP. Some scholars have emphasized that ASA can be reasonably used for anticoagulation in low-risk patients with VTE without increasing complications, such as postoperative hemorrhage.

Conclusion

Compared with other diagnostic methods recommended by guidelines, TEG has some advantages in the accurate diagnosis and prediction of perioperative VTE events in orthopedics. TEG can reflect the coagulation process from coagulation factor initiation, stable development of fibrin formation, and platelets and fibrin interaction until final fibrinolysis in an all-round approach. It can evaluate the various blood component roles in coagulation, serving as a tool that can fully demonstrate coagulation. TEG can not only accurately diagnose the hypercoagulable blood state but also distinguish the types of the hypercoagulable state according to R, MA, and CI and further guide the correct use of anticoagulant drugs and drug management according to the specific types of a hypercoagulable state. Improving the quality of perioperative anticoagulation in the orthopedic department. However, owing to the objective factors, such as the current technical level of TEG testing, surgical site and method, and range of standard reference values, further application of TEG in related specialties, such as orthopedics, is difficult. We expect that more high-quality clinical trials of TEG will be conducted in the future to provide a more sensitive and reliable parameter threshold for the application of TEG in related specialties, such as orthopedics, and to promote the rapid development of TEG technology.

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