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REVIEW

Study on Risk Factors and Treatment Strategies for Deep Vein Thrombosis in Patients with Multiple Myeloma

Yifei Guo[1], Lixiang Yan[1], Xi Yang[1], Chenyang Fan[1], Jianati Reaila[1], Yanan Jia[1], Xiaogang Hao[1], Feng Ju[2], Zhexin Shi[1]

[1]First Teaching Hospital of Tianjin University of Traditional Chinese Medicine, National Clinical Research Center for Chinese Medicine Acupuncture and Moxibustion, Tianjin, 300380, People's Republic of China; [2]Xinzhu Community Health Service Center, Xi'an, 710038, People's Republic of China

Correspondence: Zhexin Shi, First Teaching Hospital of Tianjin University of Traditional Chinese Medicine, National Clinical Research Center for Chinese Medicine Acupuncture and Moxibustion, Tianjin, 300380, People's Republic of China, Tel +8613752689966, Email shzhx0604@163.com

Abstract: Multiple myeloma (MM) is a malignant tumor originating from plasma cells, and in recent years, its incidence has shown a significant upward trend in our country. Venous thromboembolism (VTE) is a relatively common complication in multiple myeloma (MM) patients. Venous thromboembolism includes deep vein thrombosis (DVT) and pulmonary embolism (PE), with patients facing a high risk of DVT during treatment. Studies have shown that the procoagulant state of MM, inflammatory response, and the therapeutic drugs used significantly increase the incidence of DVT. However, the exact mechanisms behind the increased risk of venous thrombosis are not yet fully understood. The occurrence of DVT not only has a severely negative impact on patient survival rates but also leads to adjustments in treatment plans and a reduction in patients' quality of life. This article analyzes the relationship between risk factors for DVT and MM, exploring current diagnostic methods, risk assessment tools, and personalized preventive treatment strategies, ultimately proposing future research directions. Through a review and analysis of relevant literature, it aims to enhance the understanding of multiple myeloma and deep vein thrombosis, providing references for clinical diagnosis and treatment.

Keywords: multiple myeloma, deep vein thrombosis, risk factors, risk assessment, prevention and treatment strategies

Introduction

Epidemiological Characteristics of Multiple Myeloma

Multiple myeloma (MM) is a malignant proliferative disease of plasma cells characterized by the abnormal proliferation of monoclonal plasma cells in the bone marrow, leading to a series of clinical manifestations such as bone destruction, anemia, renal dysfunction, and immune deficiency. It has now been established that MM patients are at high risk of developing deep vein thrombosis (DVT), as demonstrated in a study conducted in 1999,[1] and this has also been confirmed in other studies.[2–4] The annual risk rate of DVT formation in the general population is 0.1–0.2%, while in cancer patients, the risk increases tenfold, reaching 10–20%. Cancer-associated thromboses account for 20% of all DVTs and are the second leading cause of death among outpatient cancer patients.[5] Notably, the incidence of deep vein thrombosis is even higher in patients with multiple myeloma, which is related to the disease itself and factors associated with treatment.[6,7]

Previous studies have shown that the incidence of multiple myeloma varies across different countries and regions. Typically, its incidence increases with age, with a median age of onset between 65 and 70 years.[8,9] The prevalence is slightly higher in men than in women. In recent years, due to advances in diagnostic technology and an aging population, the diagnostic rate of multiple myeloma has increased. Meanwhile, the continuous improvement of treatment methods, such as the application of targeted therapy and immunotherapy, has also significantly improved patient survival and impacted the epidemiological trends of the disease.

It is worth noting that patients with multiple myeloma often have a high risk of deep vein thrombosis (DVT). This is closely related to the hypercoagulable state caused by the disease itself and the medications used during treatment. Therefore, it is of great significance to conduct risk assessment and prevention of deep vein thrombosis in patients with multiple myeloma.

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Clinical Significance of Deep Vein Thrombosis

Deep vein thrombosis has multiple adverse effects on patient prognosis. First, deep vein thrombosis may lead to pulmonary embolism (PE), a serious complication that can cause shortness of breath, shock, and even death. Second, deep vein thrombosis can also cause post-thrombotic syndrome, which is characterized by limb swelling, pain, and skin ulcers, severely affecting the patient's quality of life. In addition, deep vein thrombosis can prolong the patient's hospital stay, increasing medical costs and resource consumption.[10] A study has shown that in patients with multiple myeloma, the occurrence of deep vein thrombosis is associated with an increased risk of death.[11]

The treatment methods for multiple myeloma are constantly evolving, including traditional chemotherapy, autologous stem cell transplantation, and new drugs such as immunomodulators (IMiDs), proteasome inhibitors, and monoclonal antibodies. However, certain treatment methods may increase the risk of deep vein thrombosis. Immunomodulators (IMiDs) and glucocorticoids can increase the risk of deep vein thrombosis. Currently, two main strategies are used clinically to reduce the risk of deep vein thrombosis in patients with multiple myeloma: pharmacological prevention and non-pharmacological prevention. Pharmacological prevention includes the use of anticoagulants such as low molecular weight heparin, warfarin, or novel oral anticoagulants (DOACs). Non-pharmacological prevention includes the use of intermittent pneumatic compression devices, encouraging patients to engage in appropriate exercise, and maintaining a healthy lifestyle.

Therefore, this review is primarily guided by the research question of whether immunomodulatory drugs (IMiDs) differ in their association with thrombotic risk, especially between commonly used agents such as lenalidomide and pomalidomide. Furthermore, this review seeks to explore whether the management of anticoagulation differs between these agents and whether they require specific prophylactic strategies. Addressing these questions can help clinicians make more informed decisions regarding individualized thromboprophylaxis in multiple myeloma (MM) patients receiving IMiDs.

The Pathological and Physiological Mechanisms of Multiple Myeloma and Deep Vein Thrombosis

Disease-Related Factors

Hypercoagulable State

The normal coagulation process involves complex intrinsic and extrinsic coagulation pathways, as well as the precise regulation of the anticoagulant system. The intrinsic coagulation pathway is activated by vascular damage, while the extrinsic coagulation pathway is initiated by the exposure of tissue factor. These pathways ultimately converge on the common pathway, activating coagulation factor X and prothrombin to form thrombin, which facilitates the conversion of fibrinogen to fibrin, leading to the formation of a thrombus. The anticoagulant system, such as protein C, protein S, and antithrombin III, maintains the balance of the coagulation system by inhibiting the activity of coagulation factors.[6]

Monoclonal (M) protein is associated with increased plasma viscosity and plays a major role in determining platelet function and coagulation factor disorders.[12,13] First, monoclonal M protein can lead to hyperviscosity syndrome, hypofibrinogenemia, decreased activity of coagulation inhibitors protein C and protein S, and impaired fibrinolysis. These may be the reasons for the increased risk of DVT in patients with myeloma.[14]

In addition, increased plasma viscosity in patients with multiple myeloma can lead to changes in blood rheology, increasing the risk of thrombosis.[15] Biomarkers of coagulation system activation in myeloma may be related to the disease, including endogenous thrombin generation in the determination of the rate and total amount of thrombin,[16] acquired activated protein C resistance (APCR), thrombin-activated fibrinolysis inhibitor (TAFi), soluble P-selectin, factor II, factor VIII, von Willebrand factor, antiphospholipid antibodies, and d-dimer levels, all of which can contribute to the occurrence of DVT.[17–20]

Inflammatory Cells

The release of inflammatory cytokines, especially interleukins, may change the coagulation mechanism to a hypercoagulable state,[21] with chronic inflammation playing an important role in thrombosis formation. The inflammatory response activates endothelial cells, platelets, and leukocytes, leading to an increase in procoagulant substance release and impairment of anticoagulant mechanisms, thus promoting thrombosis.[22] Inflammatory cytokines, such as IL-1β and IL-8, can activate platelets and endothelial cells, enhancing their procoagulant activity. IL-1β can stimulate endothelial cells to express tissue

factor, initiating the extrinsic coagulation pathway; IL-8, on the other hand, promotes the activation of neutrophils, causing the release of granules, damaging the vascular endothelium, and provoking thrombosis.[22]

A study indicates that inflammasome activation promotes venous thrombosis through pyroptosis. Using a mouse inferior vena cava (IVC) venous thrombosis model induced by flow restriction, a deficiency in caspase-1 (but not caspase-11) prevents flow restriction-induced thrombosis. After ligation, the expression of interleukin-1β in the IVC increased, suggesting that the inflammasome was activated during injury. A deficiency in Gasdermin D (GSDMD), a key mediator of pyroptosis, prevents flow-restriction-induced venous thrombosis. After inducing venous thrombosis, fibrin deposition occurs in the veins of wild-type mice, but not in the veins of caspase-1 deficient or GSDMD deficient mice.[23]

Other mechanisms include tumor burden,[24] increased tissue factor (TF) associated with microparticles; elevated von Willebrand factor (vWF), fibrinogen, or factor VIII; decreased protein C; and increased thrombin production.[25–29] A recent review summarized data on the association between elevated vWF/FVIII levels, increased thrombotic risk, and reduced overall survival in MM patients.[30]

Treatment-Related Factors

Immunomodulatory Agents (IMiDs)

Immune modulators (IMiDs) are an important class of drugs in the treatment of multiple myeloma, including thalidomide, lenalidomide, and pomalidomide. IMiDs have various modes of action in myeloma, but inhibiting the cereblon pathway and leading to NFκB downregulation seems to be a core function. However, IMiDs also have a pro-thrombotic side effect. They may increase the risk of thrombosis through the following mechanisms: IMiDs may lead to endothelial cell damage by inhibiting the VEGF pathway, thereby increasing the risk of thrombosis.[31]

Taking the representative IMiDs class drug thalidomide as an example, the use of thalidomide is associated with elevated levels of factor VIII (FVIII) and von Willebrand factor (VWF), which may be a trigger for DVT.[32] When thalidomide is used as a single agent, the risk of VTE is 2%,[33] which increases to as high as 26% and 35% when combined with dexamethasone at doses greater than 480 mg/month and with anthracycline drugs,[34,35] respectively. The use of high-dose dexamethasone in combination with thalidomide increases levels of P-selectin, as well as VWF and FVIII in circulation.[36]

Proteasome Inhibitor (PI)

Unlike IMiDs, PIs have a beneficial effect on thrombosis formation. For example, the representative drug bortezomib may have an anti-thrombotic effect. This may also explain the lower incidence of DVT in patients receiving bortezomib treatment.[37,38] Zangari et al observed a significant reduction in adrenaline and ristocetin-induced platelet aggregation after bortezomib treatment, as well as a decrease in the expression of P-selectin on the platelet surface.[39] This may also be related to DVT in patients with multiple myeloma.[40]

Hormonal Drugs

Hormonal drugs, such as dexamethasone and prednisone, are commonly used adjuvant medications in the treatment of multiple myeloma. Hormonal drugs may also increase the risk of thrombosis. Potential reasons include: the stimulating effect on liver synthesis of coagulation factors, causing dyslipidemia and insulin resistance. Hormonal drugs can stimulate the liver to synthesize more coagulation factors, leading to enhanced blood coagulation function and an increased risk of thrombosis.[41]

Therefore, further research on the association between treatment and thrombotic risk is necessary to better assess and manage the thrombotic risk in patients with multiple myeloma. In summary, the occurrence of DVT in patients with multiple myeloma is the result of a combination of factors, including the hypercoagulable state caused by the disease itself, inflammation, and the use of IMiDs, hormone therapies, and proteasome inhibitors during treatment. A deeper understanding of these pathophysiological mechanisms will aid in the development of more effective thromboprophylaxis and treatment strategies.

Diagnosis and Risk Assessment of Deep Vein Thrombosis

Diagnostic Methods

The diagnosis of deep vein thrombosis (DVT) relies on the comprehensive application of multiple tools, commonly used diagnostic tools include ultrasound (US) examination, D-dimer testing, and CT angiography. When choosing a diagnostic

method, it is important to consider factors such as the patient's clinical presentation, the probability of DVT, the feasibility of the examination, and associated risks. For hospitalized patients, due to their higher risk of DVT, more sensitive diagnostic methods, such as CTA, may be required. For outpatient patients, if the clinical likelihood is low and D-dimer is negative, DVT can be ruled out without the need for further imaging examinations.[42]

In recent years, with continuous advancements in technology, dynamic monitoring technology for DVT has also made significant progress. Dynamic monitoring refers to the continuous or regular assessment of a patient's risk of DVT, in order to timely detect and address potential thrombus formation. The potential benefits of dynamic monitoring lie in the early detection of DVT, timely treatment, thereby reducing complications and mortality associated with DVT. However, dynamic monitoring also has certain limitations, such as potentially increasing healthcare costs and leading to over-diagnosis and overtreatment. Therefore, when implementing dynamic monitoring strategies, it is essential to comprehensively consider factors such as the patient's risk factors, the feasibility of monitoring, and cost-effectiveness.

Risk Assessment Model

To prevent the increased risk of DVT in myeloma patients, a risk assessment model (RAM) has been proposed.[43] Generally, the first and most widely used RAM for cancer patients is the Khorana score; however, it is noteworthy that a recent retrospective study on myeloma patients indicates that the Khorana score has its limitations and cannot be used for scoring in MM.[44] In addition to clinical scoring models such as the Khorana, SAVED, and IMPEDE VTE scores, several biomarkers have shown value in thrombosis risk assessment. Among them, D-dimer is a widely used laboratory parameter reflecting ongoing fibrinolytic activity and is elevated in patients with thrombosis. Its use, along with platelet count, fibrinogen, and prothrombin time, may enhance the accuracy of risk stratification when combined with clinical prediction tools. However, their roles in MM-specific risk models require further validation.[42]

To address this situation, the HAS-RISC scoring system was developed, which classifies patients into low and high VTE risk categories.[45] Soon after, the SAVED score specifically for patients undergoing IMID treatment was released[46] (Table 1). The SAVED score is based on the SEER database of participants, identifying five significant risk factors for VTE through variable analysis: history of previous surgery, Asian ancestry (risk for DVT), history of previous DVT, age > 80 years, and dexamethasone dosage. 30% of patients were defined as high risk for DVT. Additionally, the IMPEDE VTE RAM (Table 2), developed based on a study of 4446 newly diagnosed myeloma patients, categorized patients into low risk (≤3 points), medium risk (4–7 points), or high risk (≥8 points) based on 6-month VTE.[47] This RAM was subsequently validated using 4,256 SEER patients and 575 treated patients, finding it to be effective for DVT risk assessment, indicating that the RAM could be used to decide on primary VTE prevention in prospective clinical trials.[48] Despite progress in the development of RAM, the demand in this area remains unmet.

Table 1 SAVED Risk Assessment Model (for Use in IMID-Treated Patients Only)

Predictor	Acronym	Score
Surgery (within 90 days)	S	2
Asian race	A	0
History of Venou:	V	3
Eighty (age ≥80ye	E	1
Dexamethasone	D	
High dose (160>mg/ cycle)		2
Standard dose (120–160mg\ cycle)		1

Notes: Risk stratification: ≤1 points: Low risk ≥2 points: High risk.

Table 2 IMPEDE VTE Risk Assessment Model

Predictor	Acronym	Score
	I	
Body Mass Index≥	M	
Pelvic,hip or femui	P	
Erythropoiesis-	E	
Doxorubicin	D	
Dexamethasone		4
High		2
Low dose (≤		
EvEthnicity/ race=	E	−3
History of Venousthromboembolis	V	5
Tunneled	T	2
Exisitingthrombop	E	−4
Therapeutic		
Exisitingthrombo		−3
Prophylactic		

Notes: Risk stratification: ≤3 points: Low risk 4–7 points: Intermediate-risk ≥8 points: High risk.

Prevention Strategies for Deep Vein Thrombosis

Pharmacological Prevention

In patients with multiple myeloma (MM), the risk of deep vein thrombosis (DVT) is significantly increased, especially during treatment with immunomodulatory drugs (IMiDs).[41] Thus, pharmacological prevention has become an important strategy. There is limited clinical trial data on pharmacological thromboprophylaxis in MM patients. We identified only a few randomized clinical trials in the literature from the past 5 years, confirming that novel oral anticoagulants (DOACs) have become the most popular class of drugs for the treatment and prevention of thromboembolic complications. NCT02958969 and Myelaxat are trials concerning the role of apixaban in this field (Table 3). They have investigated the prevention and safety of apixaban 2.5 mg/bd in myeloma patients treated with IMiDs. The number of trials in these two groups and the range of inclusion criteria for the enrolled patients: 50 patients in NCT02958969 and 104 patients in Myelaxat; both trials demonstrated encouraging results:[49,50] in NCT02958969, there were no thrombotic events, with only two minor bleeding events occurring from the beginning to 3 months; after 6 months, there were two thrombotic events and 12 bleeding events (11 minor events) and only one (major event).

Table 3 Prospective Trials Regarding the Use of DOACs for Prophylaxis of VTE in MM Patients on Treatment

Study title	Study Design	Inclusion Criteria	Exclusion Criteria	Interventions	Number Enrolled OF Patients	Results
NCTO2958969	Open-label, single arm	Symptomatic MMpatients;planned IMID therapy; ECOG<2	None	Prophylaxis of VTE with apixa-ban 2.5 mg/bd	50	At 3 months: 0 thrombotic

(*Continued*)

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Table 3 (Continued).

Study title	Study Design	Inclusion Criteria	Exclusion Criteria	Interventions	Number Enrolled OF Patients	Results
MYELAXAAT	Open-label, single arm	Symptomatic MMpatients;planned IMID therapy; ECOG<2	Anticoagulant orantiplatelet treatment	Prophylaxis ofVTE with apixa-ban 2.5 mg/bd	104	At 6 months: 2 thrombotic
TiMM	Randomized, dou-ble arm	Symptomatic MM patients;planned IMID therapy	None	Standard risk (SR) MM patients; aspirin 75 mg vs apixaban 2.5 mg/	2 SR (both randomized to apixaban); 8h (4 randomized to enoxaparin; 4 randomized	0 thrombotic events; 0 major

Another randomized controlled trial, AVERT and CASSINI,[51,52] demonstrated the benefits of apixaban and rivaroxaban for primary VTE prevention in outpatients with intermediate to high-risk cancer. In a cohort of 305 NDMM patients, those treated with (carfilzomib + lenalidomide) KRd showed greater efficacy in thrombus prevention with rivaroxaban compared to aspirin (ASA), with VTE rates of 16% and 5%, respectively. Furthermore, there were no reports of increased bleeding risk.[53] Among NDMM patients receiving IMiD treatment, the safety and efficacy of apixaban for thrombus prevention for at least six months have been confirmed in four recent trials, involving a total of 306 patients.[54–57] In the pooled data, two VTE events (0.6%) and three major bleeding events (1%) were reported. These results have not been validated against another method of VTE prevention in randomized trials. One group compared the incidence of thromboembolic complications before and after the implementation of routine thrombus prevention with apixaban 2.5 mg twice daily in IMiD patients. Before the protocol change, the VTE rate in ASA patients was 20.7%, and in patients receiving prophylactic dose LMWH, it was 7.4%. However, after the practice change following 2014 and within six months of treatment initiation, no VTE events occurred.[55]

The data regarding the use of DOACs for the prevention of multiple myeloma mainly comes from a retrospective study. In a study involving 37 cases of multiple myeloma, patients receiving warfarin or apixaban twice daily during first-line treatment or relapse showed that no DVT events were observed in the warfarin group, while there was 1 case in the apixaban group.[58] The aforementioned study has demonstrated that DOACs have been investigated for VTE primary prevention in MM patients undergoing IMiD treatment, showing good safety and efficacy.[13,14]

While DOACs such as apixaban and rivaroxaban have demonstrated favorable outcomes in recent clinical studies, low molecular weight heparin (LMWH) remains an important prophylactic option, especially in patients with contra-indications to DOACs or those undergoing short-term high-risk therapies. LMWH is supported by earlier clinical experience and remains recommended in some international guidelines for thromboprophylaxis in cancer patients, including MM, particularly during the initiation of IMiD-based regimens[41,59.] It is often preferred in hospitalized patients or those with impaired renal function, where the use of DOACs may be limited.

Although DOACs have shown encouraging results in MM-related thrombosis prevention, it is important to acknowledge their limitations. Firstly, the majority of clinical evidence supporting DOACs comes from small-sample or observational studies, with a lack of large-scale randomized controlled trials specific to MM populations. Secondly, DOACs are partially eliminated by the kidneys, raising concerns for patients with impaired renal function, which is common in MM. Thirdly, potential drug–drug interactions, particularly with P-glycoprotein and CYP3A4 substrates used in MM treatment regimens, may affect DOAC plasma levels and efficacy. Therefore, careful patient selection and renal function monitoring are essential when using DOACs for thromboprophylaxis.[51,52]

Non-Pharmacological Prevention

Intermittent pneumatic compression (IPC) devices are an effective non-pharmacological approach for the prevention of VTE. They periodically apply pressure to the calves or feet to promote venous blood return and improve blood circulation, thereby reducing the risk of thrombus formation.[58] Relevant research evidence: Numerous studies have

shown that IPC is effective in VTE prevention. A meta-analysis revealed that IPC can significantly reduce the incidence of DVT and PE in hospitalized patients.[59]

Advances in the Treatment of Deep Vein Thrombosis

Anticoagulation Therapy

Anticoagulant therapy is the cornerstone of deep vein thrombosis (DVT) treatment, aimed at preventing thrombus extension, promoting thrombus dissolution, reducing the risk of thrombus recurrence, and preventing serious complications such as pulmonary embolism (PE). Currently, commonly used anticoagulants mainly include traditional anticoagulants and novel oral anticoagulants (NOACs/DOACs).[60,61]

Thrombolytic Therapy

Thrombolytic therapy is a treatment method that quickly dissolves blood clots using thrombolytic drugs such as urokinase, streptokinase, and recombinant tissue plasminogen activator (rt-PA), restoring vascular patency and improving limb circulation and pulmonary function.[60]

Indications and special applications: 1. Thrombolytic therapy is primarily suitable for the following situations: 2. Acute massive pulmonary embolism with hemodynamic instability; 3. Acute limb artery embolism severely threatening limb viability; 4. Iliac-femoral venous thrombosis with severe symptoms unresponsive to conservative treatment.

In patients with multiple myeloma, the occurrence of deep vein thrombosis may be related to the hypercoagulable state of the disease itself and treatment-related factors. For MM patients with extensive pulmonary embolism or severe limb venous thrombosis, and when anticoagulant therapy is ineffective, thrombolytic therapy can be considered, with a comparison of different thrombolytic agents and protocols (Table 4).

Future Research Directions

Development of New Anticoagulant Drugs

Traditional anticoagulants, such as warfarin and low molecular weight heparin, have some limitations in clinical use. Warfarin requires frequent monitoring of INR (International Normalized Ratio) to adjust the dosage and is easily affected by food and drugs, leading to a higher risk of bleeding. Low molecular weight heparin, although more convenient to use, still requires injection and carries risks such as heparin-induced thrombocytopenia (HIT). Therefore, the development of more efficient and safer specific anticoagulants is of great significance.[62]

In recent years, the emergence of direct oral anticoagulants (DOACs) has provided new options for the prevention and treatment of VTE. DOACs include direct thrombin (IIa) inhibitors (such as dabigatran) and factor Xa inhibitors (such as rivaroxaban, apixaban, and edoxaban). These medications have the following advantages: convenient oral administration, no

Table 4 Comparison of Different Thrombolytic Drugs and Regimens

Thrombolytic Drugs	Advantage	Disadvantage	Major Complications
Urokinase	Relatively low price, Rich experience in using	The thrombolytic effect is relatively weak, requiringcontinuous intravenous infusion and is prone to produce	Bleeding, Allergic reactions
Streptkinase	Low price, Widely used	The thrombolysis effect is weak, the antigenicity is strong, and it is easy to produce antibodies, which may	Bleeding, Allergic reactions, Hypotension
rt-PA(alteplase)	Strong thrombolysis effect, high specificity, and difficult to produce antibodies	Expensive, short half-life, and continuous intravenous drip	Bleeding, Cerebral bleeding
TNK-tPA (Tenelepse)	Single intravenous bolus injection, easy to use, and the thrombolysis effect is similar to rt-PA	Expensive, short half-life, and continuous intravenous drip	Bleeding, Cerebral bleeding

need for routine monitoring of coagulation function, rapid onset of action, and a lower risk of intracranial hemorrhage compared to warfarin. Apixaban has been approved for the treatment of acute VTE and for reducing the risk of recurrent VTE after initial treatment. It is hoped to be a promising option for oral VTE prevention in patients with multiple myeloma.

Published studies have evaluated the effectiveness and safety of DOACs in high-risk patients. Some studies indicate that, compared to warfarin or low molecular weight heparin, DOACs have similar or superior efficacy in preventing IMiD treatment-related VTE, and that the bleeding risk is comparable or lower. However, caution is still needed when assessing the interactions of DOACs with other treatment methods (such as chemotherapy and targeted therapy). Therefore, it is recommended to closely monitor patients' coagulation function and bleeding conditions when using combination therapy, and to adjust the dosage of DOACs as necessary.

Personalized Medicine and Artificial Intelligence

Artificial intelligence (AI) technologies, such as machine learning and deep learning, demonstrate great potential in predicting VTE risk. Traditional risk assessment models are often based on limited clinical variables, and the accuracy of predictions needs improvement. AI models can more accurately identify high-risk patients and reduce missed diagnoses by analyzing large volumes of multidimensional data, including genomics, clinical characteristics, lifestyle factors, and imaging data.

For example, AI models can analyze patients' gene expression profiles to identify genetic variations associated with coagulation function, inflammatory responses, and vascular endothelial function, thereby predicting their risk of VTE. In addition, AI models can integrate patients' clinical data, such as age, gender, weight, medical history, and medication usage, as well as lifestyle factors like smoking, drinking, and exercise habits, for a comprehensive assessment. Based on this information, AI models can develop personalized prevention strategies for each patient, such as selecting appropriate anticoagulant medications, adjusting dosages, and optimizing treatment courses.

AI technology can also play a role in dynamically monitoring patient status and adjusting treatment plans. For example, AI models can analyze indicators such as D-dimer levels, platelet counts, and prothrombin time, updating the VTE risk score in real time and adjusting the dosage of anticoagulants or switching medications based on changes in risk. Additionally, AI models can predict the efficacy and safety of different anticoagulants based on the patient's response to treatment and adverse reactions, thereby providing doctors with more informed medication recommendations.

However, when applying AI technology, it is also necessary to pay attention to some challenges, such as data privacy protection and algorithm transparency. To protect patients' privacy, strict data encryption and desensitization measures need to be taken. To improve algorithm transparency, interpretable AI models need to be developed, allowing doctors to understand the AI's decision-making process and to verify and adjust it.

Long-Term Follow-up Plan and Data Collection

Long-term follow-up is crucial for assessing the recurrence rate of DVT, the efficacy of medications, and the quality of life of patients. Through long-term follow-up, DVT recurrence or progression can be detected timely, the efficacy and safety of anticoagulants can be evaluated, and the quality of life of patients can be understood.

A reasonable follow-up plan should include the following:

Follow-up frequency: Determine the follow-up frequency based on the patient's VTE risk and changes in their condition. For high-risk patients, the follow-up frequency should be increased to timely identify any issues.

Monitoring indicators: Monitor the patient's D-dimer levels, platelet count, prothrombin time, and other indicators, as well as imaging examination results.

Quality of life assessment: Regularly assess the patient's quality of life to understand their physical functions, mental state, and social functions.

Data collection and management should be standardized. It is recommended to establish a unified electronic health record system to collect patients' clinical data, laboratory data, imaging data, and follow-up data. In addition, it is also necessary to clean, organize, and analyze the data for subsequent research and applications.

Utilizing big data technology to mine the value of follow-up data can provide a basis for optimizing DVT management. For example, big data analysis can be used to identify risk factors for DVT recurrence, predict the efficacy and safety of anticoagulant medications, and develop more personalized treatment plans.

A study conducted in the Klang River Basin of Malaysia showed that the incidence of venous thromboembolism (VTE) in newly diagnosed patients with multiple myeloma is 10.2%. Female gender, ECOG performance status score ≥2, and recent orthopedic surgery are independent risk factors for VTE. Therefore, individualized thrombus prevention strategies are crucial, and further real-world studies are needed to optimize anticoagulant regimens.[63]

Venous thromboembolism (VTE) (including deep vein thrombosis and pulmonary embolism) is a major cause of morbidity and mortality in cancer patients. Arterial thromboembolism, including myocardial infarction and stroke, is also commonly present in cancer patients. Certain cancers (including pancreatic cancer, gastric cancer, and multiple myeloma) have a higher incidence rate.[64]

Conclusion Section

Currently, venous thromboembolism (VTE) in patients with multiple myeloma (MM), including deep vein thrombosis (DVT) and pulmonary embolism (PE), has become an important clinical issue. Research has mainly focused on the pathophysiological mechanisms of VTE, risk assessments, prevention, and treatment strategies. The academic community is increasingly concerned with identifying high-risk factors for VTE in MM patients, as well as optimizing thromboprophylaxis and treatment protocols to improve patient prognosis and quality of life.[65]

The pathophysiological mechanisms of multiple myeloma and deep vein thrombosis are complex, involving the cumulative effects of various factors. The pro-coagulative state related to MM, inflammatory responses, and treatment factors such as immunomodulatory agents (IMiDs) may all increase the risk of venous thromboembolism (VET). The pro-coagulative state occurs due to the release of pro-coagulant substances by tumor cells, the activation of the coagulation system by inflammatory responses, and IMiDs may affect coagulation balance through multiple pathways.

The SAVED and IMPEDE-VTE risk assessment models have improved discrimination performance, making them the best current tools for VTE risk assessment. However, their performance is not ideal, and better tools need to be developed to provide effective thromboprophylaxis information for MM patients. Existing scientific data cannot fully confirm the best regimen for pharmacological prevention and treatment of venous thromboembolism (VTE) in patients with multiple myeloma (MM); DOAC is merely the most acceptable drug under current research, and the most recent data is promising, but lacks direct comparisons, necessitating more rigorous thromboprophylaxis strategies.

In patients with multiple myeloma, a framework for early identification and intervention should be established to take measures before the occurrence of thrombosis. Early identification and intervention can reduce the incidence of VTE, improve patient survival rates, and enhance quality of life. A continuous patient feedback mechanism needs to be established to optimize intervention strategies and assess their effectiveness, ensuring the best treatment outcomes. Patient feedback can help clinicians understand the effectiveness of preventive and therapeutic measures and adjust plans in a timely manner to improve treatment efficacy.

Disclosure

The authors report no conflicts of interest in this work.

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