Deep Vein Thrombosis: A Concise Review of Contemporary Interventional Strategies

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Abstract

Deep vein thrombosis (DVT) and its long term sequelae, particularly post thrombotic syndrome (PTS), pose substantial challenges to global public health. Traditionally, anticoagulation has served as the cornerstone of DVT management, aimed principally at preventing thrombus propagation and pulmonary embolism (PE). However, anticoagulation alone often fails to fully lyse existing thrombi and does not reliably prevent disabling PTS in all patients. PTS develops in approximately 40–50% of patients following proximal DVT, despite adequate anticoagulation, highlighting the substantial long-term impact of residual venous obstruction. To address this therapeutic gap, a various endovascular (interventional) strategies have emerged, designed to actively remove thrombus, restore venous patency, and improve long term outcomes. This review seeks to provide a thorough and up to date examination of interventional DVT therapies, including catheter directed thrombolysis (CDT), ultrasound-assisted catheter-directed thrombolysis (EKOS), pharmaco-mechanical thrombectomy (PMT), iliac vein stenting, and the use of inferior vena cava (IVC) filters. We review the mechanisms, clinical evidence, efficacy, safety and key results (e.g. from the ATTRACT trial), and discuss criteria for patient selection. In addition, we synthesize recommendations from major professional society guidelines and preview emergent technologies and future directions in DVT interventional therapy, with the aim of providing clinicians with a reference for individualized decision making in DVT management. Current evidence suggests that interventional therapy is beneficial primarily for carefully selected individuals—particularly those with acute iliofemoral DVT, severe symptoms, or high thrombus burden—rather than being universally indicated for all DVT patients.

Keywords: Deep Vein Thrombosis, endovascular therapy, peripheral intervention, Catheter-Directed Thrombolysis , Pharmacomechanical Thrombectomy

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1. Introduction

1.1 Epidemiology and Clinical Impact of Deep Vein Thrombosis

Deep vein thrombosis (DVT) remains a major, preventable cause of morbidity and mortality worldwide. Venous thromboembolism (VTE), comprising DVT and pulmonary embolism (PE), is estimated to affect about 1 in 1,000 individuals annually and results in 60,000 to 100,000 deaths per year[1]. DVT accounts for roughly two-thirds of VTE events[1,2]. These statistics underscore the substantial public health burden posed by DVT and emphasize the urgency of developing effective treatment and preventive approaches — the focus of this review.

1.2 Challenge of Post Thrombotic Syndrome

Post thrombotic syndrome (PTS) is a common, long term complication of DVT, occurring in 20-50% of patients even after standard anticoagulation therapy[3]. Among these, 5-10% may develop severe PTS, including venous ulcers[4,5]. Clinically, PTS manifests with chronic leg pain, swelling, heaviness, skin changes (e.g. hyperpigmentation, lipodermatosclerosis), and venous ulcers, significantly impairing quality of life and incurring higher health care costs[4,5]. The Villalta scale is the standardized and widely adopted clinical scoring system used to diagnose and grade the severity of PTS, and it remains the reference tool in major clinical studies[6]. Even if anticoagulation reaches the accepted standard for preventing thrombus extension and PE, the high incidence of PTS reveals an unmet need in DVT therapy: namely, the inability of anticoagulants alone to reliably prevent long term venous dysfunction[7]. Anticoagulants address systemic coagulation but do little to eliminate established thrombi or prevent venous valvular injury and remodeling, thereby justifying more aggressive interventional approaches aimed at reducing PTS risk[8,9].

1.3 Limitations of Anticoagulation Alone

While standard anticoagulation is effective at halting further thrombosis and reducing PE risk, its capacity to dissolve established thrombi is limited, and its effect in preventing valvular damage and venous wall scarring is minimal[10]. Anticoagulants function by suppressing coagulation pathways to impede further clot extension rather than actively lysing thrombus. Incomplete recanalization is a key mechanism contributing to chronic venous obstruction and subsequent venous hypertension, serving as a major driver of PTS development[11]. Hence, patients remain at risk of permanent venous insufficiency and PTS. This limitation highlights a therapeutic gap, particularly in preserving long term venous health, and supports the rationale for adjunctive therapies.

1.4 Theoretical Basis for Interventional Treatments

Interventional treatments, such as catheter directed thrombolysis (CDT) and pharmaco-mechanical thrombectomy (PMT), aim to rapidly remove or debulk thrombus via minimally invasive techniques, restore venous patency, alleviate acute symptoms more swiftly, and potentially protect venous valves from secondary injury, thereby reducing the incidence and severity of PTS[10]. Mechanistic evidence from animal and imaging-based human studies demonstrates that early thrombus clearance can preserve venous valve function by reducing inflammation, fibrosis and leaflet thickening during the early phase of thrombus organization[12]. These approaches adopt a more proactive strategy, targeting the long term sequelae of DVT and compensating for the shortcomings of anticoagulation-only strategies.

1.5 Beyond Anticoagulation, the Role of Interventional Strategy

Early thrombus removal therefore represents a mechanistically rational complement to anticoagulation[12]. While anticoagulants prevent propagation, they do not reverse existing obstruction. Mechanical thrombectomy offers rapid debulking without reliance on fibrinolytic

agents, potentially addressing the unmet need for restoring venous patency in selected patients[13].

2. Pathophysiology of DVT and PTS

2.1 Revisiting Virchow's Triad

Virchow's triad — venous stasis, endothelial injury, and a hypercoagulable state — remains the foundational framework for understanding DVT risk[1]. Among these, venous stasis is often viewed as a crucial contributor, though it rarely suffices alone to provoke thrombosis[1,14]. Clinical circumstances associated with DVT — such as surgery, trauma, malignancy, prolonged immobility, or pregnancy — link back to one or more elements of the triad[1,14]. Tissue factor is believed to play a pivotal role in initiating thrombogenesis[1,14,15]. A concise review of DVT pathogenesis helps illuminate therapeutic targets and patient risk stratification.

2.2 Mechanisms Underlying PTS Development

PTS is thought to arise from sustained venous hypertension, which in turn results from valvular incompetence and ongoing obstruction or fibrosis in the venous lumen[3]. After an acute DVT event, if the vein fails to recanalize effectively, persistent obstruction and remodeling of the venous wall can ensue[3,11]. Simultaneously, the inflammatory response accompanying DVT contributes directly to valve destruction[3,16]. Beyond these classical elements, inflammatory mediators such as interleukin-6 (IL-6), tumor necrosis factor-α (TNF-α), and matrix metalloproteinases (MMPs) play critical roles in vein wall remodeling. These molecules promote leukocyte recruitment, extracellular matrix degradation, and fibrosis, ultimately contributing to chronic venous dysfunction[16-18]. These pathologic changes raise venous pressure, triggering tissue edema, lipodermatosclerosis and potentially tissue hypoxia and venous ulceration[3]. The inflammatory reaction is not merely secondary, but plays an active role in valve damage and PTS progression[3,14,16]. This suggests that thrombus removal alone may not fully reverse valve damage, and that adjunctive anti inflammatory strategies or extremely prompt thrombus clearance (to shorten the inflammatory period) may be necessary components of therapy. Evidence suggests that the therapeutic time window for valve preservation is limited; thrombus older than approximately 14 days is associated with increased organization, fibrosis and irreversible leaflet damage. Additionally, residual venous obstruction exceeding 50% or persistent reflux detected on duplex ultrasonography is strongly predictive of subsequent PTS development and may help stratify patients at higher risk[19].

3. Anticoagulation: The Foundation of DVT Management

Current standard DVT therapy historically involves vitamin K antagonists (VKAs, e.g. warfarin), with bridging by heparin or low molecular weight heparin in the initial phase. In recent years, direct oral anticoagulants (DOACs) have gained favor owing to convenience and a favorable safety profile, and have been validated in large-scale trials as suitable alternatives to warfarin in many contexts[1,20-22].

Robust evidence from contemporary randomized trials supports the use of DOACs as first-line therapy. The AMPLIFY trial demonstrated that apixaban was non-inferior to LMWH/warfarin for VTE treatment and significantly reduced major bleeding[23]. Similarly, the EINSTEIN program established rivaroxaban as an effective single-drug approach for acute DVT, offering comparable efficacy with a more favorable bleeding profile[24].

For non–cancer-associated VTE, guidelines generally favor DOACs (e.g. dabigatran, rivaroxaban, apixaban, edoxaban) over VKAs. In cancer-associated VTE, low molecular-weight heparin (LMWH) has traditionally been first-line over VKAs or DOACs, though newer guidelines increasingly incorporate DOAC options in certain

patients[25]. Regarding treatment duration, in surgery-provoked proximal DVT, three months of anticoagulation is typical; for proximal DVT or PE provoked by transient risk factors, three months is also standard, with modifications in regimen intensity depending on bleeding risk[25,26]. For a first unprovoked VTE, patients at high bleeding risk are often treated for three months; those at low or moderate bleeding risk may warrant indefinite anticoagulation[25,26].

Although this review focuses on interventional therapy, it is essential to emphasize that anticoagulation remains the backbone of DVT care, and every patient undergoing interventional therapy must remain on anticoagulation. The ease and safety of DOACs may indirectly raise the bar for justifying invasive procedures: if anticoagulation alone becomes safer and more convenient, then the decision to proceed to invasive therapy demands stronger justification, thereby underscoring the need for rigorous patient selection. Post-thrombotic surveillance with duplex ultrasonography — especially following cessation of anticoagulation — may help identify individuals with ongoing obstruction who are at higher risk of developing PTS and may benefit from closer follow-up[27].

4. Interventional Treatment Strategies for DVT

4.1 Catheter Directed Thrombolysis (CDT)

4.1.1 Mechanism and Procedural Overview

CDT is a minimally invasive endovascular technique in which a catheter is advanced, under imaging guidance (typically fluoroscopy), directly into or adjacent to the thrombus. A relatively low-dose thrombolytic agent (commonly recombinant tissue plasminogen activator, rt-PA or Urokinase) is infused slowly and continuously[10]. The targeted delivery is intended to increase local drug concentration and thrombolysis efficiency while minimizing systemic exposure and bleeding risk.

4.1.2 Clinical Evidence: Thrombolysis, Venous Patency & PTS Prevention

Compared with anticoagulation alone, CDT may achieve more rapid venous patency and improve relief of acute symptoms (e.g. pain, swelling)[10]. Crucially, by reducing thrombus burden and reducing valve injury from prolonged obstruction and inflammation, CDT is postulated to lower the incidence and severity of PTS[4,5,10]. Patients with a longer life expectancy and those with iliofemoral DVT (IFDVT) appear to derive the greatest benefit from CDT[10]. Some studies suggest that achieving $\geq$90% thrombus removal is associated with minimal residual PTS risk[28]. Given the anatomical importance of the iliac and femoral veins, thrombosis in these segments often carries a higher risk of severe PTS than more distal DVT, and thus may benefit most from aggressive intervention[28]. A balanced interpretation of the evidence is important, as not all trials have demonstrated clear clinical benefit with CDT. The ATTRACT trial, the largest RCT to date, did not show a significant reduction in overall PTS compared with anticoagulation alone, although a potential benefit was observed in the iliofemoral DVT subgroup[29]. Earlier data from CAVENT suggested a reduction in long-term PTS, whereas the CAVA trial reported neutral findings[30,31]. These discrepancies highlight that the benefit of CDT is likely patient-specific, influenced by thrombus location, symptom duration, and technique. Accordingly, CDT should be considered selectively in well-chosen patients rather than applied universally.

4.1.3 Contraindications, Safety and Complications

CDT is contraindicated in patients with active bleeding, recent major surgery, intracranial pathology, uncontrolled hypertension, or other major bleeding risks, and careful assessment of risk–benefit balance is essential prior to initiation. The principal risk of CDT lies in bleeding, particularly intracranial hemorrhage, though this is rare[10,28]. Other bleeding complications

(e.g. access-site hematomas, gastrointestinal bleeding) must also be considered. The exact rate of major bleeding remains to be fully defined by randomized controlled trials[10,28,32].

4.2 EKOS: Ultrasound-Assisted Catheter-Directed Thrombolysis

4.2.1 Mechanism and Concept Overview

The dense collagen structure within thrombi hinders the penetration and efficacy of thrombolytic agents by concealing plasminogen activation sites[33]. As a result, successful fibrinolysis largely depends on the drug's ability to reach these sites[33,34].

The EKOS catheter system addresses this limitation through high-frequency, low-power ultrasound, which disrupts the fibrin matrix and exposes plasminogen receptors. This enhances the permeability of the thrombus and facilitates deeper drug penetration via acoustic microstreaming, improving lytic efficiency while allowing for reduced dosage and lower bleeding risk[33-35].

4.2.2 Clinical Evidence

Clinical data derived from multi-center experiences have demonstrated that ultrasound-assisted thrombolysis is a safe and effective treatment modality for deep vein thrombosis (DVT). Moreover, this technique significantly reduces overall infusion time, increases the likelihood of complete thrombus resolution, and is associated with a lower incidence of bleeding complications[33,34]. Registry data provide real-world insights into the performance of EKOS. Previous study reported high technical success and symptomatic improvement with significantly reduced thrombolytic doses compared with conventional CDT[33]. However, the results of the BERNUTIFUL study, published in 2015, demonstrated that when treating deep vein thrombosis (DVT), EKOS-assisted thrombolysis and conventional catheter-directed thrombolysis showed no statistically significant differences in thrombolysis duration, thrombolytic drug dosage, or bleeding rates[36]. Larger and more definitive clinical trials are needed to further address this question.

4.2.3 Comparison with Traditional CDT and Pharmaco-mechanical Thrombectomy

Comparison with Conventional CDT:

Ultrasound-assisted thrombolysis requires a lower dose of thrombolytic agents and results in a shorter thrombolysis duration, compared to conventional CDT (Table 1)[33,34,37].

Advantages over Pharmaco-mechanical Thrombectomy:

Ultrasound-assisted thrombolysis enables single-modality treatment without causing hemolysis or endothelial injury. It reduces peripheral embolization risk, effectively dissolves valve-protected thrombi, and shortens catheter lab time[37,38].

4.3 Pharmaco-mechanical Thrombectomy

4.3.1 Technical Approaches and Device Options

Pharmaco-mechanical thrombectomy (PMT), also called pharmaco-mechanical catheter-directed

Table 1. Comparison Between EKOS and Conventional CDT

	Urokinase		Alteplase(t-PA)		Reteplase(r-PA)	
	EKOS (n=14)	CDT (n=38)	EKOS (n=9)	CDT (n=32)	EKOS (n=22)	CDT (n=12)
Median Drug Dose	2.02 MU	4.36 MU	14.0 mg	21.6 mg	6.9 U	21.4 U
Median Infusion Time	19.3 hr	40.6 hr	18.0 hr	30.8 hr	24.0 hr	24.3 hr

thrombolysis (PCDT), combines mechanical methods (such as thrombus aspiration, maceration, or mechanical disruption) with local thrombolytic infusion[10]. One of the commonly used devices is the AngioJet™ system, which uses high-velocity saline jets to create suction and fragment thrombus, while simultaneously delivering thrombolytic agents[23]. The concept behind PMT is to debulk or disrupt thrombus mechanically, thereby reducing the required dose or duration of thrombolytic therapy and potentially lowering bleeding risk[10,39]. These approaches also hold promise for shortening procedural time and reducing cost[10,39].

4.3.2 Relative Efficacy and Safety (PMT vs. CDT and anticoagulation alone)

A systematic review and meta-analysis comparing AngioJet PMT to CDT showed that the PMT group had significantly greater symptomatic improvement (mean difference, MD = 6.31) and a lower overall complication rate (odds ratio, OR = 0.51), though no significant difference in grade II/III thrombus removal rates was found (Table 2)[32]. Using adjunctive thrombolytic agents during PMT facilitates thrombus extraction and may reduce overall treatment time[23]. These results suggest that in select settings, PMT may offer a more favorable risk-benefit profile relative to CDT, particularly in early symptom relief and complication reduction. Device-specific limitations include the risk of hemolysis — particularly reported with rheolytic systems such as AngioJet — which can lead to transient hemoglobinuria or, in rare cases, acute kidney injury. Additionally, PMT devices may be associated with higher procedural costs compared with standard CDT, potentially influencing institutional or regional adoption.

4.3.3 Insights from the ATTRACT Trial

The ATTRACT (Acute Venous Thrombosis: Thrombus Removal with Adjunctive Catheter-Directed Thrombolysis) trial is a landmark randomized controlled study enrolling 692 patients with acute proximal DVT, comparing PMT (primarily with AngioJet plus adjunctive thrombolysis) combined with anticoagulation vs. anticoagulation alone. The primary endpoint was incidence of PTS (Villalta score ≥ 5) over 6 to 24 months. The results revealed no statistically significant difference: 47% (PMT) vs. 48% (control), $p = 0.56$[29].

However, in secondary endpoints, the PMT group experienced more rapid relief of leg pain and swelling, and among those who did develop PTS, the severity was lower. These benefits were particularly notable in the iliac-femoral DVT subgroup[40]. Safety analysis revealed a higher rate of major bleeding within 10 days in the PMT group (1.7% vs. 0.3%, $p = 0.049$). No significant difference in VTE recurrence over 24 months was observed[29].

The negative primary outcome of ATTRACT tempered enthusiasm for universal adoption of PMT, but the observed benefits in secondary endpoints and subgroup analyses, especially for symptomatic, extensive iliac-femoral DVT, suggest that selected patients may still derive meaningful benefit — if willing to accept a modestly increased bleeding risk. The discrepancy between ATTRACT's neutral primary outcome and earlier observational or smaller series suggesting PTS benefit underscores the critical role of large, well-powered randomized trials in shaping practice, and also highlights the limitations of surrogate endpoints (such as percentage of thrombus removal) that may not always translate to clinically meaningful outcomes (e.g. PTS prevention). Additionally, constraints in the Villalta scale as a PTS measurement tool must be recognized[29]. In sum, ATTRACT does not negate the value of PMT, but rather refines its indications and underscores the importance of individualized decision-making. Table 3 provides a comparative framework outlining patient-specific factors that guide the selection among CDT, PMT and conservative anticoagulation. These criteria incorporate thrombus location, symptom duration, bleeding risk, anatomical burden, and the urgency of symptom relief, thereby enhancing the clinical

Table 2. Comparison Between CDT and PMT

Feature	**Catheter Directed Thrombolysis (CDT)**	**Pharmaco-mechanical Thrombectomy (PMT, e.g. AngioJet)**
Mechanism	Infusion of thrombolytic agents.	Mechanical thrombus disruption +/– thrombolytic infusion.
Early postoperative deep vein patency	As reference	Significantly higher rates of early postoperative deep vein patency (MD = 7.73, 95% CI: 3.29-12.17, p = 0.0006).
Thrombus removal grade II/III	As reference	No differences (OR = 1.30, 95% CI: 0.95-1.77, p = 0.10).
Symptom improvement	Beneficial	Significantly better vs. CDT (MD = 6.31, 95% CI: 1.82-10.80, p = 0.006).
Changes in thigh circumference before and after treatment	As reference	No difference (MD = 0.01, 95% CI: −0.80-0.83, p = 0.97).
PTS incidence	As reference	Lower rates of PTS incidence (OR = 0.56, 95% CI: 0.36-0.88, p =0.01).
Complications / adverse events	As baseline	Lower bleeding risk (OR = 0.51, 95% CI: 0.31-0.83, p = 0.0007).
Procedure time	Longer (continuous infusion)	Shorter
Typical thrombolytic dose	Relatively high	Lower dose (MD = −145.33, 95% CI: −164.28-126.38, p < 0.00001) and shorter infusion time (MD = −2.35, 95% CI: −2.80- −1.90), p < 0.00001).
Hospital stay	As reference	Compared to CDT: shorter days (MD = −3.13, 95% CI: −3.81- −2.45, p < .00001).

* MD=mean difference

Reference: A systematic review and meta-analysis of the relative safety and efficacy of treating lower extremity deep vein thrombosis via pharmacomechanical thrombectomy and catheter-directed thrombolysis. Vascular, 2025. 33(4): p. 910-923. Tian, Z., et al.

Table 3. Patient-specific factors guiding selection among CDT, PMT and conservative anticoagulation

Clinical Factor	Conservative Anticoagulation	Catheter-Directed Thrombolysis (CDT)	Pharmaco-mechanical Thrombectomy (PMT)
Ideal Patient Profile	Distal DVT; high bleeding risk; mild-to-moderate symptoms.	Acute iliofemoral DVT <14 days; low bleeding risk; good functional status.	Acute iliofemoral DVT <14 days requiring rapid debulking; severe symptoms or phlegmasia.
Primary Therapeutic Goal	Prevent thrombus propagation.	Restore venous patency; reduce thrombus burden; preserve valves.	Rapid clot removal; reduce thrombolytic dosing and infusion time.
Symptom Duration	Any duration.	Best outcomes <14 days.	Optimal <14 days; diminished benefit with chronic clot (>14 days).
Anatomical Considerations	Distal DVT; limited thrombus burden.	Iliofemoral, extensive thrombus requiring lytic penetration.	Iliofemoral DVT with high burden; when CDT is insufficient or too slow.
Bleeding Risk	Standard for patients with high risk of bleeding.	**Requires Low Risk.** Significantly **increases** the risk of major bleeding compared to anticoagulation alone. Requires intensive monitoring.	**Better Than CDT.** Utilizes **lower lytic doses** to remove clot, resulting in a **lower bleeding risk**, compared to CDT. Moderate risk is often acceptable.
Need for Rapid Symptom Relief	Not urgent.	Moderate.	High — PMT provides fastest debulking.
Limitations	No thrombus removal; higher Post-Thrombotic Syndrome (PTS) risk.	Bleeding risk; ICU-level monitoring.	Device-specific complications, cost.
Evidence Basis	DOAC RCTs (AMPLIFY, EINSTEIN).	Observational studies; ATTRACT CDT subset.	Subgroup benefits in ATTRACT (iliofemoral DVT).

applicability of decision-making for interventional vs. non-interventional strategies.

4.4 Iliac Vein Stenting for Underlying Obstructive Lesions

4.4.1 Indications: May–Thurner Syndrome and Chronic Post-thrombotic Obstruction

Iliac vein stenting is primarily used to treat underlying anatomic or chronic obstructive lesions contributing to DVT or PTS. May–Thurner syndrome (right common iliac artery compressing the left common iliac vein) is one such anatomical variant and a recognized risk factor for left-sided DVT[41,42]. Chronic post-thrombotic stenosis or occlusion refers to residual venous narrowing after DVT that impairs venous return and contributes significantly to PTS[43].

In patients with acute or subacute DVT, when significant stenosis is identified after thrombus removal, concurrent stenting may be considered. In chronic symptomatic venous obstruction (even without active thrombosis), stenting is also a viable therapeutic option. The stent provides mechanical scaffolding to maintain patency of the compressed or narrowed segment, improving symptoms and potentially preventing recurrent DVT.

4.4.2 Technique and Long Term Patency

Following balloon angioplasty of the stenotic segment, a self-expanding metal stent is typically deployed[41,42]. Intravascular ultrasound (IVUS) has become integral to assessing the degree of compression or stenosis, optimizing stent placement and sizing, and confirming wall apposition.

Several meta-analyses report favorable long-term patency rates: at one year, for non-thrombotic lesions (e.g. straightforward May–Thurner), primary patency is ~96%, and secondary patency is ~99%; for acute thrombotic DVT post thrombectomy and stenting, primary patency is ~87%, and secondary patency is ~89%; for chronic post-thrombotic obstruction, primary patency is ~79%, and secondary patency ~94%[43]. Other studies show 6 month primary patency of 96-97% in both post-thrombotic and non-thrombotic lesions[44]. The higher patency seen when stenting is performed shortly after thrombus removal (compared to chronic lesions) suggests a "window of opportunity" before significant fibrotic remodeling sets in. This supports the rationale of routinely employing IVUS during interventional DVT therapy to detect and treat underlying compressive lesions when appropriate. Both covered and bare-metal venous stents are used in clinical practice. Comparative data suggest that primary patency rates are generally similar in these two categories; however, covered stents may offer benefits in preventing early recoil or restenosis in highly compressed or post-thrombotic lesions[45]. Following iliac vein stenting, most experts recommend maintaining therapeutic anticoagulation for 6-12 months, especially in post-thrombotic disease, to promote stent patency and reduce the risk of re-thrombosis[46].

4.5 Inferior Vena Cava (IVC) Filters

4.5.1 Current Indications and Guideline Recommendations

The most universally accepted indication for IVC filters is in patients with VTE (DVT or PE) who have absolute contraindications to anticoagulation (e.g. active bleeding, or exceedingly high bleeding risk)[25]. Other debated indications include anticoagulation failure (i.e. PE occurring despite therapeutic anticoagulation) or large PE in the setting of extensive residual DVT and high risk of embolization (Table 4)[25,47-49].

However, major guidelines (e.g. CHEST, ASH) strongly recommend against routine placement of IVC filters in patients who can receive anticoagulation[21,25]. Filters are not substitutes for anticoagulation.

4.5.2 Filter Types (Permanent vs. Retrievable)

Clinically, filters are broadly categorized into permanent and retrievable types. Retrievable

Table 4. IVC Filters: Indications and Complications

Accepted indications	1. Acute proximal DVT or PE with absolute contraindication to anticoagulation. 2. Anticoagulation failure (rare) . 3. Massive PE with high embolic risk and contraindication or limitation to anticoagulation.
Major long-term complications	1. Recurrent or new DVT (often at or above the filter level). 2. Filter thrombosis / caval occlusion. 3. Filter migration (to the heart or pulmonary arteries). 4. Caval wall perforation (by filter struts). 5. Filter fracture and fragment embolization. 6. PTS due to IVC obstruction.
Considerations for retrieval	7. FDA recommends prompt removal when PE risk subsides or anticoagulation is possible.

filters are designed to provide temporary PE protection and be removed once the risk subsides or anticoagulation becomes feasible, thereby mitigating long-term filter-related complications[47]. The benefits of retrievable filters, however, depend on successful retrieval.

4.5.3 Controversies, Complications, and Retrieval Challenges

The U.S. Food and Drug Administration (FDA) has issued warnings about long-term complications of IVC filters, recommending prompt retrieval of retrievable filters once PE risk abates or anticoagulation becomes feasible[47].

Long-term complications of IVC filters include recurrent or new DVT (paradoxical to the device's purpose), filter thrombosis or occlusion, filter migration (potentially to the heart or pulmonary arteries), caval wall perforation, filter fracture, and embolization of filter fragments[47,49]. Paradoxically, filters may themselves act as foci for thrombosis[49]. In response to safety concerns, the U.S. Food and Drug Administration (FDA) has issued safety communications recommending retrieval of temporary or retrievable filters as soon as protection from pulmonary embolism is no longer required — typically within 30-60 days — to minimize device-related complications[50].

Despite the recommendation for retrieval, only about one-third of retrievable filters are actually removed in practice[47]. A meta-analysis reported that IVC filter use is associated with reduced PE risk but increased DVT risk, with no significant effect on all-cause mortality[49]. The low retrieval rates reflect not only device limitations but also systemic issues in patient follow-up and care coordination. Addressing these issues demands improved hospital protocols, enhanced patient education, and interdepartmental communication to reduce preventable harm.

5. Patient Selection for Endovascular DVT Intervention

Deciding whether a DVT patient should undergo endovascular intervention is complex and must integrate thrombus characteristics, patient clinical conditions, and a balanced risk-benefit assessment. Widely accepted indications for thrombus removal (e.g. CDT or PMT) include acute, extensive proximal DVT with severe symptoms such as limb swelling and

pain, especially when involving iliofemoral or femoropopliteal segments[51].

Symptom duration is a major determinant: acute DVT (symptoms < 14 days) and subacute DVT (15-28 days) are more amenable to intervention, whereas chronic DVT (> 28 days) often features organized, fibrotic thrombus resistant to mechanical or pharmacologic disruption[51]. Given that temporal definitions may differ slightly among various studies, detailed discussion on this aspect is beyond the scope of this paper.

Ideal candidates typically are younger, have longer life expectancy, fewer comorbidities, and present with proximal, symptomatic, acute DVT[10]. In cases of phlegmasia cerulea dolens (a limb-threatening DVT), aggressive intervention should be considered regardless of age to salvage the limb[48].

Given the bleeding risks associated with many interventions (particularly those involving thrombolytics), a careful assessment of bleeding risk is imperative; only patients with low bleeding risk should be considered for thrombolytic-based procedures[21].

Shared decision-making is crucial in this process. Treatment decisions should reflect not only anatomical and physiological considerations but also the patient's values, tolerance for procedural risk, functional goals, and expectations regarding symptom improvement.

In summary, optimal candidates are those who stand to lose the most from PTS (younger, active, longer life expectancy, with extensive iliofemoral DVT) while incurring minimal procedural risk (low bleeding risk, few comorbidities). This risk-benefit stratification is central to decision-making.

6. Review of Current Major Society Guideline Recommendations

Various professional societies across vascular surgery, hematology and pulmonology have issued evidence-based guidelines for DVT management. Key themes and differences are summarized below:

Overall Trends

- Anticoagulation is universally the foundation of DVT therapy (agreed across all guidelines).
- For non–cancer-associated VTE, DOACs are typically preferred over VKAs[25].
- Routine use of interventional thrombectomy or thrombolysis in unselected DVT patients is generally not recommended (e.g. ASH, CHEST), largely due to findings from the ATTRACT trial[21,48].
- When interventional therapy is used, it should be done selectively.

Interventional Therapy Recommendations

- **American Society of Hematology (ASH, 2020)**: For most proximal DVTs, anticoagulation alone is preferred over thrombolysis. In patients with limb-threatening DVT, or in younger patients with low bleeding risk and iliofemoral DVT, thrombolysis (especially CDT rather than systemic thrombolysis) may be considered[48].
- **CHEST (2021 update)**: For PE, thrombolysis is only recommended in hypotensive patients or in those clinically deteriorating with low bleeding risk; if thrombolysis fails or bleeding risk is high, catheter-based thrombectomy may be used. The guidelines do not extensively detail thrombolysis in DVT, but the direction post ATTRACT aligns with ASH — favoring selective application[21]. Earlier CHEST editions had been less supportive of routine use of elastic compression stockings for PTS prophylaxis[22,25].
- **European Society for Vascular Surgery (ESVS, 2021)**: If early thrombus removal is undertaken, the subsequent duration of anticoagulation should be at least as long as that in non interventional therapy. The guidelines otherwise echo similar cautious endorsement of interventional therapy[52].
- **2025 ESVM Guidelines on interventional treatment of venous thromboembolism**: This guideline recommends that catheter-based

therapy (CBT), preferably using mechanical thrombectomy, should be considered for acute DVT with severe iliofemoral/iliocaval symptoms, and is recommended or considered for high-risk or deteriorating intermediate-high-risk PE, mandating the involvement of vascular experts and multidisciplinary teams at specialized centers[53].

IVC Filter Recommendations

- Across major guidelines (e.g. CHEST, ASH), IVC filters should not be routinely used in patients who can tolerate anticoagulation[21,48].
- The use of filters is tightly restricted to VTE patients with absolute contraindications to anticoagulation.

While major international guidelines uniformly endorse anticoagulation as the first-line therapy for acute proximal DVT, including iliofemoral disease, they differ in how permissive they are toward early thrombus removal in selected patients. European vascular societies are somewhat more open to offering catheter-directed or pharmaco-mechanical interventions in carefully chosen individuals with anatomically extensive, symptomatic iliofemoral DVT, reflecting a stronger emphasis on preserving long-term venous function and potentially mitigating severe post-thrombotic morbidity. By contrast, North American guidelines generally adopt a more conservative stance, discouraging routine use of catheter-based therapies and highlighting the

Table 5. Summary of Major Societies' Recommendations for DVT Interventional Therapy

Society (Year)	Recommendation for DVT Thrombolysis / PMT (Patient Criteria, Strength)	Recommendation for IVC Filters (Patient Criteria, Strength)
ASH (2020)[2]	In most proximal DVTs, anticoagulation is preferred over thrombolysis. Consider in younger, low bleeding risk patients with iliofemoral DVT or threatened limb. CDT preferred over systemic thrombolysis.	Anticoagulation preferred. Filter use only when anticoagulation contraindicated.
CHEST (2021)[22]	Similar to ASH; emphasizes selective use.	Against concurrent use with anticoagulation.
ESVS (2021)[52]	If early thrombus removal is done, maintain at least equivalent anticoagulation duration.	Similar constraints, with emphasis on safe patient selection.
ESVM (2025)[53]	Catheter-based therapy (CBT), preferably using mechanical thrombectomy, should be considered for acute DVT with severe iliofemoral/iliocaval symptoms, and is recommended or considered for high-risk or deteriorating intermediate-high-risk PE.	Routine IVC filter placement is not recommended (Class III, Level A) for acute DVT or PE; however, placement may be considered (Class IIb) for patients with acute proximal DVT and/or PE who have contraindications to therapeutic dose anticoagulation or disease progression despite such treatment, mandating the involvement of a vascular expert (Class I).

Recommendation strengths are not always explicitly graded in all summaries.

neutral primary outcomes and increased bleeding risk observed in trials such as ATTRACT as a rationale to restrict interventions to highly selected patients with severe symptoms and low bleeding risk. Across regions, these nuanced differences underscore the need for individualized care pathways that integrate patient-specific anatomy, symptom burden, comorbidity profile, bleeding risk, and preferences when applying guideline recommendations to clinical decision-making.

7. Emerging Technologies and Future Directions

The interventional DVT landscape is rapidly evolving, with the aim of enhancing efficacy, reducing risk, and expanding suitable patient populations.

7.1 Novel Thrombectomy Devices

Recent device innovations are trending toward more effective mechanical thrombectomy capable of completing thrombus removal in a single procedure with minimal or no use of thrombolytics, thereby lowering bleeding risk[54].

- **Inari FlowTriever® / ClotTriever® (Inari Medical)**: Large-lumen aspiration and/or mechanical thrombectomy systems, capable of removing substantial thrombus without fibrinolytic agents. This may obviate the need for ICU monitoring post-procedure[55]. The Protrieve™ sheath offers intra procedural embolic protection[56]. These systems are applicable to both DVT and PE[55,56].
- **Aspirex®S (Straub/BD)**: A rotational mechanical thrombectomy device. The P MAX study reported a procedural success rate of 97.5% and a 24-month primary patency of 77.9%[54,57].
- **Penumbra Indigo® system (Penumbra)**: A continuous aspiration thrombectomy device. In the EXTRACT-PE study, its safety and efficacy in PE were demonstrated; it is adaptable to different vessel sizes and relatively user-friendly[54].
- **AngioJet™ (Boston Scientific)**: Although established, this system continues to be refined and combined with adjunctive approaches. Some reports indicate thrombus removal rates up to 85%, with shorter procedure time, compared to CDT[54].

These newer devices — especially those that minimize or eliminate thrombolytic use — directly address the main limitation of early interventional therapies (i.e., bleeding risk, as underscored by the ATTRACT trial). If they can achieve equal or superior thrombus clearance and reduce PTS incidence while maintaining greater safety, they may fundamentally change the risk-benefit calculus and broaden the applicability of interventional therapy. However, their long-term effectiveness and head-to-head comparisons with conventional approaches require confirmation in large randomized trials. Recent prospective data from the completed CLOUT registry (Inari) and the STRIDE study (Penumbra) are beginning to provide important real-world and longer-term outcome evidence for mechanical thrombectomy platforms, and ongoing follow-up and successor trials are expected to further refine the role of these interventions in future practice. Table 6 summarizes the devices currently used for thrombus removal in DVT, as reported in the literature reviewed[54-56].

Nevertheless, several challenges remain. Device costs can be substantial, and successful implementation requires procedural expertise and familiarity with device-specific nuances—representing a notable learning curve for interventionalists. Moreover, outcome reporting across trials remains heterogeneous, highlighting the need for standardized endpoints such as 12-month stent patency, degree of thrombus clearance, functional improvement, and validated patient-reported outcomes[58].

7.2 Role of Artificial Intelligence and Personalized Medicine

In the future, artificial intelligence (AI) may assist intraoperative decision-making via real-time data analytics, optimizing device selection, procedure planning, or risk stratification[58].

Table 6. Overview of Selected Emerging Thrombus Removal Devices

Device (Manufacturer)	Mechanism	Thrombolytic Use	Key Reported Outcomes	Notable Features / Advantages
Inari FlowTriever® / ClotTriever®	Large-lumen aspiration / mechanical disruption.	None	High thrombus clearance in single procedure; possibly avoids ICU stay.	Applicable to DVT and PE; optional embolic protection with Protrieve™.
Aspirex®S (BD/ Straub)	Rotational mechanical thrombectomy.	None	Procedural success: 97.5%, 24-month primary patency: 77.9% (P MAX).	Effective in acute/ subacute DVT.
Penumbra Indigo®	Continuous aspiration	None	In PE: improved RV/ LV ratio (EXTRACT-PE); limited DVT data (technical success rate: ~60%).	Versatile catheter sizing for various vessels.
AngioJet™	Jet-mediated aspiration + fragmentation	Adjunctive thrombolytics	Up to ~85% removal in some reports; shorter procedure than CDT.	Widely used, continually evolving.

Custom-designed thrombus removal devices tailored to individual patient anatomy or thrombus characteristics also represent a potential frontier[59]. Future research should aim to clearly define personalized strategies based on thrombus location, burden, chronicity and patient-specific risk variables[59].

8. Conclusions and Key Considerations for Clinical Practice

Deep vein thrombosis is a common vascular disorder whose sequela, post thrombotic syndrome, seriously impairs patient quality of life. Anticoagulation remains the foundational therapy for DVT but is often insufficient to prevent PTS effectively. Interventional treatments — including CDT, PMT, and iliac vein stenting — offer potential benefits in carefully selected patients, particularly those with acute, extensive (e.g. iliofemoral) DVT and severe symptoms. The goal of intervention is both symptomatic relief and mitigation of long-term PTS burden.

The ATTRACT trial, by failing to show a significant reduction in overall PTS incidence, tempered enthusiasm for routine interventional therapy. However, its findings highlight that certain patient subgroups — especially those with more extensive disease and younger age — may still derive benefit, albeit at a somewhat elevated bleeding risk. Thus, patient selection is critical, and the decision to intervene must carefully balance risks and benefits.

Use of IVC filters should remain highly restricted, reserved mainly for patients who cannot undergo anticoagulation. The landscape of DVT intervention is evolving favorably, especially with the advent of new mechanical thrombectomy devices that reduce or eliminate the need for fibrinolytics, potentially improving the safety profile of intervention. Yet their long-term outcomes and comparative effectiveness remain to be established via rigorous trials.

The paradigm for DVT treatment is shifting

from a largely uniform approach toward a more personalized strategy. With the maturation of mechanical thrombectomy devices and the incorporation of AI-assisted patient selection tools, DVT intervention may shift from a niche approach to a tailored mainstream therapy for carefully chosen individuals. Future decisions will increasingly rely on integrated evaluation of thrombus characteristics, symptom burden, risk of PTS, procedural risks (especially bleeding), and patient preferences. Future multicenter registries and prospective studies are essential to define long-term cost-effectiveness, durability of venous patency, and the true impact of early thrombus removal on prevention of post-thrombotic syndrome. Clinicians should stay abreast of advances, adhere to evidence based guidelines, and support high-quality clinical research to continually optimize DVT patient outcomes. Looking ahead, more precise risk stratification tools and results from trials of newer, safer technologies will be pivotal in further advancing DVT interventional therapy.

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