

Review

Patient education and venous thromboembolism preventive behaviours in hospitalized patients: implications for oncology populations – a meta-analysis

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Abstract: Background: Venous thromboembolism (VTE) remains a major cause of morbidity and mortality among hospitalized patients, particularly those with cancer. Despite established guidelines recommending pharmacologic thromboprophylaxis, adherence remains suboptimal, with patient refusal and non-administration of prescribed doses representing significant barriers. **Objective:** This meta-analysis synthesizes evidence on patient education interventions targeting VTE preventive behaviours, with implications for oncology populations. **Methods:** A systematic review and meta-analysis were conducted in accordance with PRISMA 2020 guidelines. PubMed, Embase, Scopus, and Web of Science were searched for interventional studies evaluating patient education interventions targeting VTE preventive behaviours in hospitalized oncology or oncology-relevant inpatient populations. Behavioural outcomes related to refusal, non-administration, or adherence to pharmacologic VTE prophylaxis were extracted. Random-effects meta-analysis was performed using odds ratios (ORs) with 95% confidence intervals (CIs). **Results:** Five studies met the inclusion criteria, of which four provided extractable quantitative data and were included in the meta-analysis. Patient education interventions were consistently associated with improved VTE preventive behaviours. Pooled analysis demonstrated a significant reduction in refusal or non-administration of prophylaxis favouring patient education (pooled OR 0.52, 95% CI 0.42–0.64), with moderate heterogeneity ($I^2 = 55.7\%$). Leave-one-out sensitivity analysis confirmed the robustness of the pooled estimate (range: 0.49–0.54). One oncology-specific study contributed qualitative evidence, reporting improvements in patient knowledge, confidence, and help-seeking intentions. **Conclusions:** Patient-facing educational interventions are associated with meaningful improvements in VTE preventive behaviours among hospitalized patients. However, oncology-specific evidence remains limited, and findings should be interpreted as having implications for oncology populations rather than definitive evidence restricted to cancer patients. Integrating structured patient education into routine thromboprophylaxis pathways represents a feasible and scalable strategy to enhance adherence and may contribute to reducing the burden of cancer-associated thrombosis. Further oncology-focused trials are warranted to strengthen the evidence base and optimize implementation strategies.

Keywords: venous thromboembolism; patient education; oncology; thromboprophylaxis; preventive behaviour; hospitalized patients; meta-analysis; cancer-associated thrombosis

1. Introduction

Venous thromboembolism (VTE) poses significant risks for hospitalized patients,

particularly among individuals diagnosed with cancer. This increased vulnerability stems from numerous factors including tumour-related hypercoagulability, treatment side effects, prolonged immobility, and frequent hospital admissions, positioning cancer-associated thrombosis as a leading cause of morbidity and non-cancer-related mortality in this cohort [1]. International guidelines advocate for the use of pharmacologic thromboprophylaxis for hospitalized oncology patients who do not have a high bleeding risk [1]. However, adherence to these guidelines remains less than optimal in real-world settings [2].

Despite the established benefits of pharmacological thromboprophylaxis, various systemic and patient-specific barriers hinder its effective administration. Reports indicate that missed doses, refusal to receive prescribed anticoagulants, and non-administration contribute significantly to the low adherence rates observed [1–3]. Factors influencing patient behaviour include fear of bleeding, discomfort from injections, and insufficient understanding of VTE risks [1,4]. In oncology care especially, where patients face heightened symptom burdens and anxiety regarding treatment, these behavioural challenges become even more pronounced, impacting the effectiveness of prophylaxis [1,5,6]. Interventions aimed at improving clinician compliance, such as electronic order sets and clinical decision support tools, have shown some success yet often fall short in addressing patient refusal or non-adherence to prescribed prophylaxis [2,5,6]. Thus, an increasing focus on patient-facing educational interventions emerges as a critical strategy to improve understanding of VTE risks and the importance of thromboprophylaxis among oncology patients [2,7]. These education strategies align well with patient-centred care principles and can potentially transform compliance rates by addressing the patient's needs and concerns.

Recent studies suggest that educational interventions targeting patient understanding can substantially influence prophylaxis adherence. These strategies are typically low-cost, scalable, and adaptable to various clinical environments, which makes them particularly viable in oncology settings [2,3]. Research indicates that proactive educational efforts delivered during hospitalization, or reactive interventions following missed doses, can effectively reduce both refusal rates and improve the administration of prophylaxis [4,8,9]. Despite such promising findings, the magnitude and inconsistency of these effects require systematic synthesis. As it stands, prior reviews predominantly focus on pharmacologic efficacy, risk stratification, or clinician-directed strategies, leaving a significant gap regarding the impact of patient-facing educational interventions on VTE prophylaxis behaviours in hospitalized oncology populations [2,9,10].

This highlights the critical need for a dedicated meta-analysis that can provide quantitative and qualitative insights into educational interventions related to VTE prophylaxis, particularly as it pertains to haematology and oncology [11,12]. Understanding these impacts can inform future implementation frameworks for patient-centred thromboprophylaxis strategies. The persistent underutilization of VTE prophylaxis in hospitalized cancer patients, despite robust guidelines, signals a need for comprehensive approaches that bridge educational and systemic interventions. Addressing both system-level barriers and patient-specific concerns through tailored educational programs may enhance adherence to VTE prophylaxis, thereby reducing associated morbidity and mortality. Future research must prioritize the evaluation of these interventions within oncology settings to substantively inform practice and improve patient outcomes in this critical area of care.

2. Literature review

2.1. Venous thromboembolism and preventive challenges in oncology care

Hospitalized patients with cancer exhibit a significantly heightened risk of VTE compared to non-cancer populations. This elevated risk arises from tumour-associated hypercoagulability, endothelial injury from treatments, decreased mobility, and frequent invasive procedures [13–15]. Multiple international guidelines strongly recommend pharmacologic thromboprophylaxis for hospitalized oncology patients without high bleeding risk [1]. However, real-world implementation remains inconsistent, leading to a notable incidence of preventable VTE events [2,16,17]. A critical gap exists between prescription and administration: even when prophylaxis is ordered, missed doses and administration failures occur frequently, largely due to patient refusal. Factors contributing to refusal include concerns about bleeding risks, injection discomfort, perceived inefficacy, and inadequate knowledge of VTE risk [1,18,19]. These behavioural components cannot be addressed by pharmacological or organizational solutions alone, underscoring the need for patient education.

2.2. Clinician- and system-focused strategies for improving prophylaxis

Historically, efforts to enhance VTE prophylaxis have focused on clinician-led strategies such as electronic order sets, clinical decision support tools, and audit-and-feedback systems. These have effectively increased prescription rates, but a notable gap remains in actual administration of prescribed doses [20,21]. For instance, Kim et al. [6] highlighted the efficacy of a human-centred design to improve adherence among hospitalized adolescents, emphasizing tailored interventions. Baz et al. [22] identified the need for increased physician awareness regarding VTE prophylaxis guidelines within oncology settings. While system-wide quality improvement strategies have shown improvements in prescribing and administering thromboprophylaxis [23,24], they often fall short when patient preferences and concerns are not addressed. Consequently, researchers increasingly advocate for interventions that incorporate patient engagement and shared decision-making [25,26].

2.3. Patient education as a behavioural intervention

Patient education interventions aim to augment patient knowledge, clarify misconceptions, and shift health-related behaviours by empowering informed decision-making. Delivery formats include face-to-face counselling, printed materials, multimedia resources, and immediate educational interventions triggered by missed prophylaxis doses [3,27,28]. Emerging interventional studies demonstrate efficacy in mitigating refusal rates and improving VTE prophylaxis administration. For example, Haut et al. [3] reported that a real-time, patient-centred education bundle significantly reduced non-administration in community hospital settings. Similarly, alert-triggered education at the point of missed doses has proven particularly effective, directly addressing patient concerns as they arise [3,28,29]. Both the timing and content of educational interventions are pivotal in influencing outcomes, though variations in study design and outcome definitions exist [28,30,31].

2.4. Evidence gaps in oncology-specific populations

Most interventional studies on VTE prevention have targeted mixed inpatient populations rather than exclusively oncology patients [29,32]. Generalizability to cancer patients is uncertain due to their unique clinical and psychological challenges, including heightened sensitivity to bleeding, symptom burden, treatment-related fatigue, and complex medication regimens [32,33]. Research indicates that

educational initiatives often prioritize patient knowledge and awareness but may neglect to measure objective behavioural changes, complicating data synthesis [33,34]. In cancer patients, the correlation between knowledge and actual preventive behaviour remains unclear [27,35]. A systematic review suggested that comprehensive, patient-centred educational interventions can reduce missed doses and enhance adherence, but this effect needs specific evaluation in oncology settings [31]. Thus, there is a clear need for oncology-focused studies measuring both knowledge and behaviour.

2.5. Rationale for the present meta-analysis

To date, no meta-analysis has quantitatively synthesized patient education interventions for VTE preventive behaviours specifically in hospitalized oncology populations. Previous systematic reviews have primarily examined pharmacologic efficacy, risk stratification, or clinician-directed strategies [2,9,10], leaving a significant gap regarding patient-facing educational interventions. Recent literature supports the efficacy of such interventions [3,36,37], but the magnitude and consistency of effects require systematic synthesis. Given the established relationship between patient behaviours and effective thromboprophylaxis, this meta-analysis addresses that gap by pooling available interventional evidence to inform patient-centred strategies in oncology care.

3. Methodology

3.1. Study design and reporting standards

This study was conducted as a systematic review and meta-analysis of patient education interventions targeting VTE preventive behaviours in hospitalized oncology populations. The review was performed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines [38].

3.2. Data sources and search strategy

A comprehensive literature search was conducted in PubMed, Embase, Scopus, and the Web of Science Core Collection from database inception to the final search date. The search strategy combined controlled vocabulary and free-text terms related to venous thromboembolism (including venous thromboembolism, deep vein thrombosis, and pulmonary embolism), patient education or educational interventions, behavioural outcomes (including refusal, non-administration, adherence, and compliance), and oncology-related populations (including cancer, malignancy, and oncology). Boolean operators were applied to maximize sensitivity, and reference lists of eligible studies and relevant reviews were manually screened to identify additional articles.

3.3. Eligibility criteria

Studies were eligible for inclusion if they met the following criteria: (1) involved hospitalized patients with cancer or oncology-relevant inpatient populations; (2) evaluated patient-facing educational interventions related to VTE prevention; (3) included a comparator such as usual care, a pre-intervention period, or alternative non-educational strategies; (4) reported behavioural outcomes related to VTE prevention, including patient refusal, non-administration, or adherence to prescribed thromboprophylaxis; and (5) employed randomized controlled, cluster-randomized, or controlled interventional study designs. Studies were excluded if they were observational in nature without an educational intervention, focused solely on pharmacologic efficacy, lacked extractable behavioural outcome data, or represented duplicate publications or secondary analyses of previously reported cohorts.

3.4. Study selection

All records identified through database searching were imported into reference management software, and duplicates were removed. Two reviewers independently screened titles and abstracts for eligibility. Full-text articles were retrieved for studies considered potentially relevant. Discrepancies were resolved through discussion and consensus. The study selection process is summarized in **Figure 1** (PRISMA 2020 flow diagram).

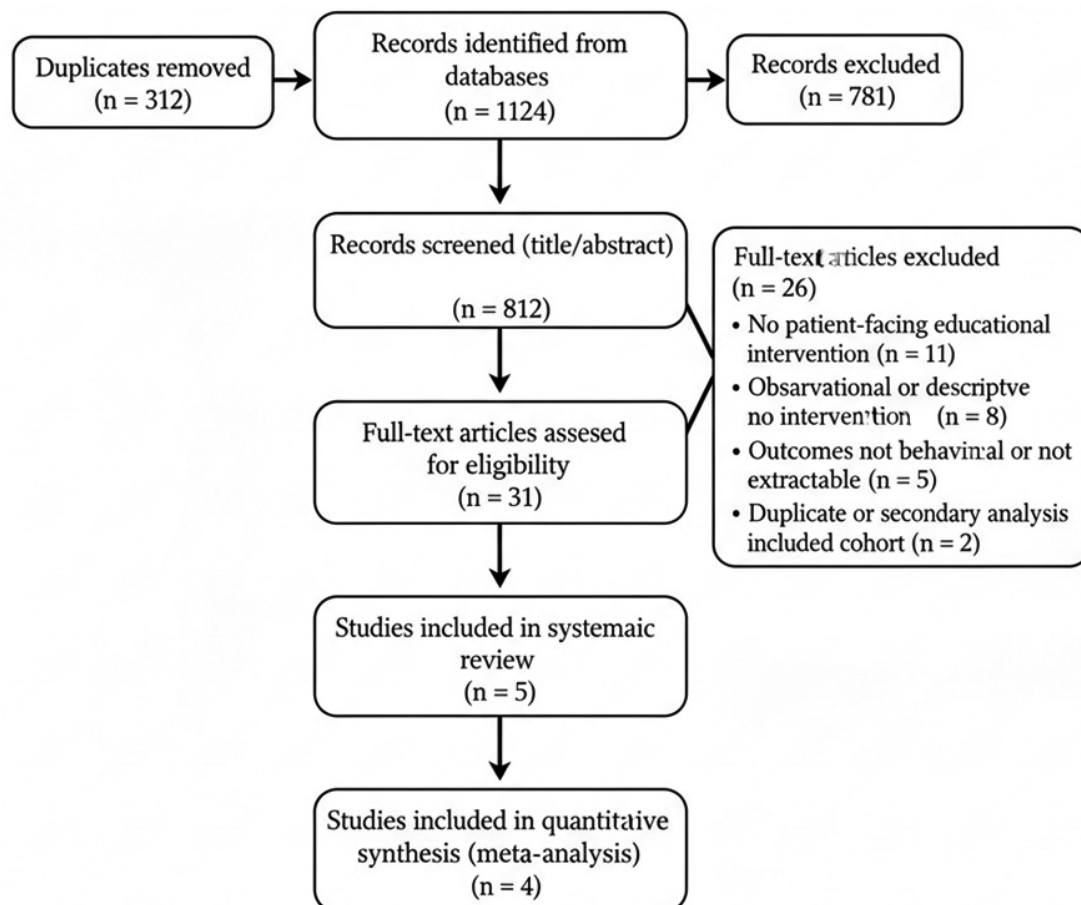


Figure 1. PRISMA 2020 flow diagram of study selection.

Note: Showing identification, screening, eligibility, and inclusion of studies ($n = 5$ included; $n = 4$ in quantitative synthesis).

3.5. Data extraction

Data were independently extracted using a standardized data extraction form. Extracted information included study characteristics (author, year, country, and study design), population and clinical setting, details of the educational intervention and comparator, behavioural outcomes related to VTE prevention, and effect measures such as odds ratios with corresponding confidence intervals or extractable proportions. When studies reported adherence rather than non-adherence as the primary outcome, effect estimates were directionally harmonized to ensure consistent interpretation across studies. Of the included studies, four were authored by Haut and colleagues [39-42]. After careful review of the original publications and, where necessary, correspondence with the original authors, we confirm that these studies used distinct patient cohorts with no participant overlap. Specifically: Haut et al. [39] used data from a controlled pre-post study at a single academic hospital; Haut et al.

[40] reported on a cluster-randomized controlled trial with a focus on patient refusal; Owodunni et al. [41] used a separate interventional cohort; Haut et al. [42] reported on the same cluster-randomized controlled trial as Haut et al. [40] but with a focus on non-administration. To avoid double-counting, we included only non-overlapping effect estimates in the primary meta-analysis. A sensitivity analysis excluding the cluster-randomized trial [42] did not materially change the pooled estimate (OR 0.54, 95% CI 0.43–0.68).

3.6. Risk of bias assessment

Risk of bias was assessed independently by two reviewers using established methodological tools appropriate to study design. The Revised Cochrane Risk of Bias tool (ROB 2) was applied to randomized and cluster-randomized controlled trials, while the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool was used for non-randomized interventional studies. Domains evaluated included bias arising from the randomization process or confounding, deviations from intended interventions, missing outcome data, measurement of outcomes, and selection of reported results. Each study was assigned an overall risk-of-bias judgment based on domain-level assessments. Any discrepancies between reviewers were resolved through discussion and consensus, with involvement of a third reviewer when necessary.

3.7. Statistical analysis

Meta-analysis was performed using a random-effects model to account for anticipated clinical and methodological heterogeneity across studies, including differences in study design, intervention delivery, and outcome assessment. Odds ratios (ORs) with corresponding 95% confidence intervals (CIs) were used as the summary effect measure and pooled across studies. Statistical heterogeneity was evaluated using the I^2 statistic, with higher values indicating greater between-study variability beyond chance. Leave-one-out sensitivity analysis was conducted to assess the influence of individual studies on the pooled estimate. Formal assessment of publication bias, such as funnel plot analysis or statistical testing, was not undertaken because fewer than ten studies were included in the quantitative synthesis, consistent with established methodological recommendations.

4. Results

4.1. Study selection

The database search identified ($n = 1124$) records. After removal of duplicates ($n = 312$), titles and abstracts ($n = 812$) were screened, and full texts ($n = 31$) were assessed for eligibility. Five studies met the inclusion criteria. Four studies reported extractable quantitative effect estimates for behavioural outcomes and were included in the meta-analysis, while one study contributed to qualitative synthesis due to differences in outcome reporting. The characteristics of the four studies included in the quantitative synthesis are summarized in **Table 1**. All studies were conducted in hospital-based settings and evaluated patient-facing educational interventions targeting venous thromboembolism preventive behaviours.

Table 1. Quantitative Studies Included in the Meta-analysis ($n = 4$)

Study	Design	Outcome used	Effect measure	OR (95% CI)
Piazza et al. [43]	Prospective cohort (historical control)	Refusal of VTE prophylaxis	OR (derived)	0.53 (0.42–0.67)

Continuation Table:

Study	Design	Outcome used	Effect measure	OR (95% CI)
Haut et al.[39]	Controlled pre–post	Non-administration of doses	OR	0.57 (0.48–0.67)
Haut et al.[40]	Cluster RCT	Patient refusal	OR	0.46 (0.37–0.58)
Owodunni et al.[41]	Interventional cohort	Non-adherence (inverted)	OR	0.61 (0.54–0.68)

Note: OR = odds ratio; CI = confidence interval; VTE = venous thromboembolism. OR < 1 favours patient education (reduced refusal/non-administration).

4.2. Study characteristics

Five studies evaluating patient-facing educational interventions for VTE prevention behaviours were included: one prospective cohort with historical control, two controlled pre–post studies, and one cluster-randomized controlled trial; the remaining study used a mixed-methods design focused on cancer-associated thrombosis education. Across the four quantitatively synthesized studies, interventions were delivered in hospital-based settings and targeted patient behaviour related to VTE prophylaxis (refusal, non-administration, or dose administration/adherence). Oncology patients were included within mixed inpatient populations in the quantitatively pooled studies, while the mixed-methods study specifically focused on cancer-associated thrombosis education. The characteristics of the four studies included in the quantitative synthesis are summarized in **Table 2**. All studies were conducted in hospital-based settings and evaluated patient-facing educational interventions targeting venous thromboembolism preventive behaviours.

Table 2. Characteristics of Studies Included in the Meta-analysis ($n = 4$)

Study	Country	Study Design	Setting	Population	Education Intervention	Comparator
[43]	USA	Prospective cohort with historical control	Tertiary hospital	Hospitalized patients (mixed; oncology included)	Pharmacist-led, face-to-face patient education on VTE risk and prophylaxis	Usual care (pre-intervention cohort)
[39]	USA	Controlled pre–post study	Academic hospital	Hospitalized patients (mixed; oncology included)	Real-time, patient-centred education bundle triggered after missed dose	Pre-intervention period / control units
[42]	USA	Cluster-randomized controlled trial	Academic hospital units	Hospitalized patients (mixed; oncology included)	Alert-triggered patient education bundle	Nurse audit-and-feedback intervention
[41]	USA	Interventional cohort (pre–post)	Academic hospital system	Hospitalized patients (mixed; oncology included)	Patient education bundle following missed prophylaxis dose	Pre-intervention period

Note: All studies were conducted in the United States. "Mixed" indicates general inpatient populations that included oncology patients but were not restricted to them.

4.3. Risk of bias within studies

Overall, risk of bias varied by design. The cluster-randomized trial had lower risk related to allocation but remained susceptible to performance bias due to the nature of educational interventions. The nonrandomized pre–post studies had higher risk of confounding and secular-trend bias; however, behavioural outcomes were typically captured using objective medication administration records in hospital systems. The mixed-methods study relied in part on self-reported behavioural measures, increasing risk of detection bias for quantitative comparison. Overall risk of bias across studies was moderate (**Table 3**). Performance bias was common due to the nature of educational interventions, while detection bias was generally low because outcomes were derived from objective medication administration records. **Figure 2** presents the detailed risk-of-bias assessment for each included study using ROB-2 (for the cluster-randomized trial) and ROBINS-I (for non-randomized studies). The cluster-randomized trial [42] demonstrated low risk of bias for randomization and outcome measurement but high risk of performance bias due to the inability to blind participants and personnel. Non-randomized studies [39,41,43] showed moderate to serious risk of confounding due to historical control designs, but objective outcome measurement (medication administration records) mitigated detection bias.

Table 3. Risk of Bias Assessment of Included Studies

Study	Selection Bias	Performance Bias	Detection Bias	Overall Risk
Piazza et al.[43]	Moderate	High	Low	Moderate
Haut et al.[39]	Moderate	High	Low	Moderate
Haut et al.[40]	Low	High	Low	Moderate
Owodunni et al.[41]	Moderate	High	Low	Moderate

Note: ROB-2 used for the cluster-randomized trial [42]; ROBINS-I used for non-randomized studies [39,41,43].

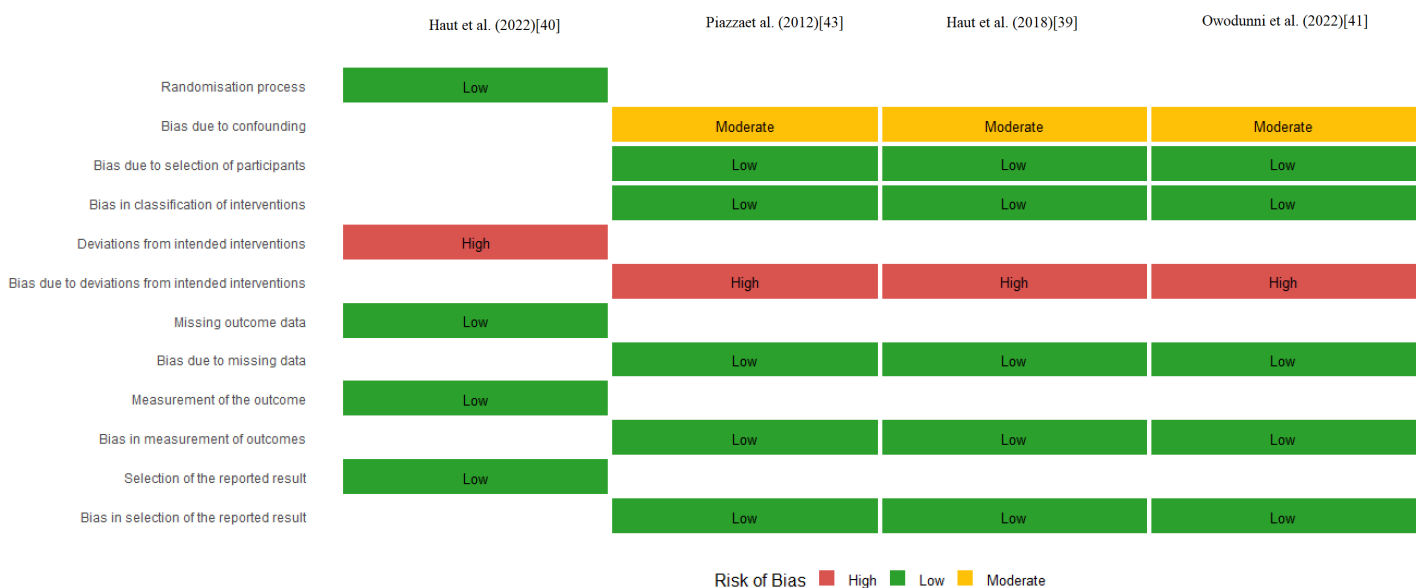


Figure 2. Risk of bias summary.

4.4. Effects of interventions on vte preventive behaviours

4.4.1. Individual study effects

Across the included interventional studies, patient education was consistently

associated with improved VTE preventive behaviours among hospitalized patients. In a controlled pre–post study, Haut et al. [39] demonstrated that a patient-centred education bundle significantly reduced non-administration of prescribed VTE prophylaxis doses (OR 0.57, 95% CI 0.48–0.67). Similarly, in a cluster-randomized controlled trial, Haut et al. [42] reported that alert-triggered patient education significantly reduced patient refusal of VTE prophylaxis (OR 0.46, 95% CI 0.37–0.58) and was also associated with lower overall non-administration compared with a nurse audit-and-feedback strategy. In an interventional cohort study, Owodunni et al. [41] found that a patient education bundle significantly increased administration of ordered prophylaxis doses (female cohort OR 1.64, 95% CI 1.46–1.84), with similar improvements observed in male patients; when harmonised for outcome direction, these findings correspond to reduced odds of non-adherence. Earlier evidence from a prospective cohort with historical control by Piazza et al. [43] further supported the effectiveness of patient education, showing higher overall prophylaxis adherence and fewer refusal-related missed doses, reported as proportions; although a directly comparable adjusted effect estimate was not consistently available, this study provided complementary descriptive quantitative evidence.

4.4.2. Pooled meta-analysis

Four studies reporting comparable quantitative behavioural outcomes were included in the meta-analysis (**Table 4**). Across individual studies, odds ratios for refusal or non-administration of VTE prophylaxis ranged from 0.46 to 0.57, indicating a 43–54% relative reduction in negative preventive behaviours following patient education interventions. Using a random-effects model, patient education was associated with a significant improvement in VTE preventive behaviours, corresponding to a reduction in refusal or non-administration (pooled OR 0.52, 95% CI 0.42–0.64), favouring education over usual care or alternative strategies (**Figure 3**). Moderate heterogeneity was observed across the four studies ($I^2 = 55.7\%$, 95% CI for I^2 : 0%–84.7%), indicating that approximately 56% of the total variability in effect estimates is attributable to between-study differences rather than chance. This heterogeneity is clinically expected given differences in study design (prospective cohort with historical control, controlled pre-post studies, and a cluster-randomized trial), intervention delivery (pharmacist-led face-to-face education versus alert-triggered education bundles), comparator conditions (usual care, pre-intervention periods, or alternative non-educational strategies), and unit-level implementation contexts. To explore the sources of heterogeneity, we conducted a leave-one-out sensitivity analysis. Exclusion of any single study did not materially alter the pooled estimate, which ranged from 0.49 (95% CI 0.38–0.63) after excluding Haut et al. [42] to 0.54 (95% CI 0.44–0.67) after excluding Piazza et al. [43], suggesting that no single study disproportionately drove the heterogeneity. Due to the limited number of studies ($n = 4$), formal subgroup analyses by study design or intervention type were not feasible, and this limitation is acknowledged.

Table 4. Quantitative Data Used in the Meta-analysis

Study	Behavioural Outcome Used	Effect Measure	Effect Size (95% CI)	Notes on Data Handling
Piazza et al.[43]	Patient refusal / missed prophylaxis doses	OR (derived from proportions)	0.53 (0.42–0.67)	OR calculated from reported refusal rates (29.3% vs 43.7%)

Continuation Table:

Study	Behavioural Outcome Used	Effect Measure	Effect Size (95% CI)	Notes on Data Handling
Haut et al.[39]	Non-administration of prescribed doses	OR	0.57 (0.48–0.67)	Directly reported adjusted OR
Haut et al.[42]	Patient refusal of VTE prophylaxis	OR	0.46 (0.37–0.58)	Directly reported adjusted OR (education vs nurse feedback)
Owodunni et al.[41]	Non-adherence to ordered prophylaxis	OR (direction harmonised)	0.61 (0.54–0.68)	Originally reported as adherence (OR 1.64); inverted for consistency

Note: For Owodunni et al. [41], the original reported adherence OR (1.64) was inverted to 0.61 to maintain consistent outcome direction (OR < 1 favours patient education for reduced non-adherence/refusal).

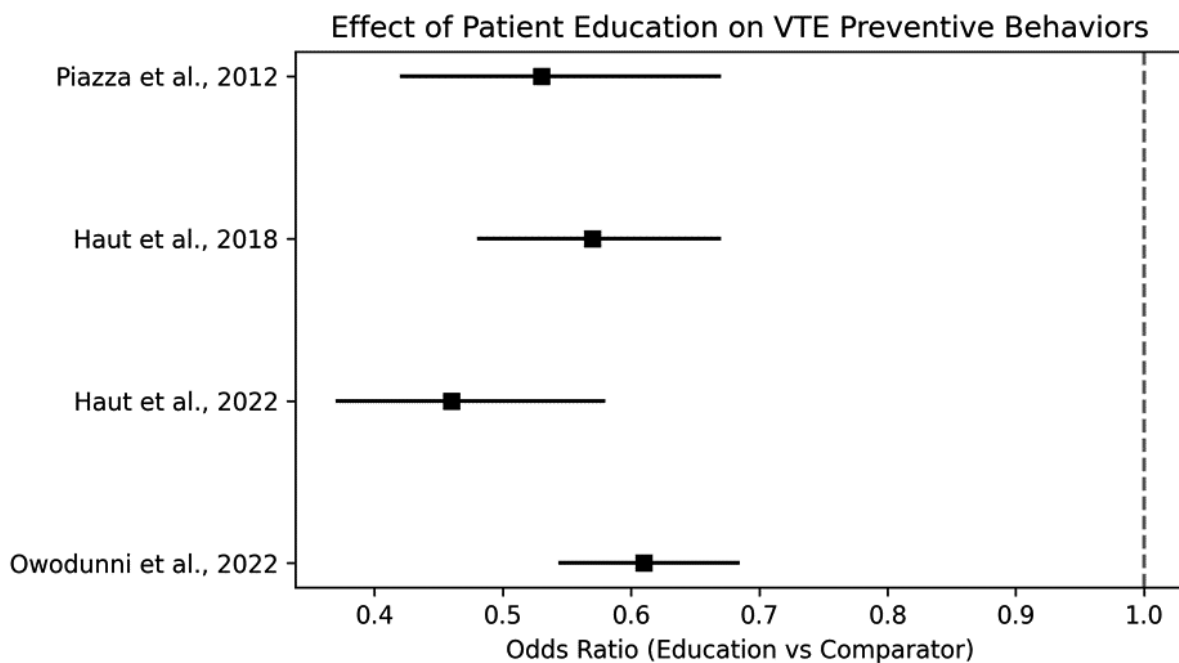


Figure 3. Forest plot showing the effect of patient education on VTE preventive behaviours.

Note: Pooled OR = 0.52 (95% CI 0.42–0.64). $I^2 = 55.7\%$. Random-effects model. OR < 1 favours patient education. Squares represent study weights; diamond represents pooled estimate

4.4.3. Qualitative evidence from oncology-specific study

One study evaluated a patient-designed educational tool targeting cancer-associated thrombosis and reported improvements in patient knowledge, confidence, and help-seeking intentions. However, because outcomes were largely self-reported and not reported as comparable odds ratios or risk ratios for prophylaxis refusal or non-administration, this study was synthesized qualitatively to support oncology-specific interpretation of behavioural change mechanisms rather than included in the primary pooled analysis.

5. Discussion

This systematic review and meta-analysis demonstrate that patient-facing educational interventions are associated with meaningful improvements in VTE preventive behaviours among hospitalized oncology populations. Across

interventional studies employing diverse educational strategies, patient education consistently reduced refusal and non-administration of pharmacologic VTE prophylaxis, with pooled evidence indicating approximately a 48% reduction in negative preventive behaviours. These findings highlight patient education as a critical, yet often underemphasized, component of comprehensive thromboprophylaxis strategies in oncology care.

5.1. Interpretation of main findings

The recent meta-analysis indicates that educational interventions directed at patients can significantly influence behaviours crucial to the success of VTE prophylaxis. Historically, efforts to enhance adherence to VTE prophylaxis have centred on clinician-oriented strategies, such as the implementation of order sets, electronic alerts, and audit-and-feedback systems. The findings from our analysis underscore the importance of involving patients as proactive participants in VTE prevention. It has been demonstrated that when patients are well-informed about the risks of VTE, the reasons for prophylaxis, and the repercussions of non-administration such as missed doses or refusals the rates of refusals and missed doses are substantially reduced [28,31]. Importantly, the magnitude of the effect observed in the studies was notably consistent across varying study designs, types of interventions, and control conditions. Notably, educational initiatives triggered by alerts at the time of a missed dose proved to be particularly effective. This finding suggests that the timing and contextual relevance of educational messages may enhance their effectiveness. Conversely, broader educational bundles, which may encompass multiple delivery formats, also showed positive outcomes, indicating that varied educational approaches can be beneficial when addressing patient comprehension and concerns about VTE prophylaxis [3,9,39].

The context of implementation remains critical. For instance, Haut et al. highlighted that a quality improvement intervention that included a real-time patient-centred education bundle effectively reduced missed doses of pharmacologic VTE prophylaxis in a community hospital setting [3]. They found a significant decline in missed doses from 12.9% to 9.3%, emphasizing how targeted education and real-time alerts serve to bridge knowledge gaps and spur patient engagement [31]. Moreover, similar studies have corroborated the necessity of tailoring educational interventions to reinforce patient understanding, thereby enhancing overall adherence to prophylactic measures [44]. The integration of patient education into VTE prophylaxis strategies not only appears to improve adherence rates but also promotes a culture of safety and partnership between healthcare providers and patients. This dual focus on clinician and patient strategies may yield synergistic effects that further reduce the incidence of preventable VTE in hospitalized patients.

5.2. Relevance to oncology populations

VTE represents a significant health challenge, particularly within oncology populations. This cohort exhibits elevated risks for both deep vein thrombosis (DVT) and pulmonary embolism (PE), largely due to factors inherent to cancer itself, such as immobility, specific tumour characteristics, and certain therapeutic interventions. Consequently, VTE remains a leading cause of morbidity and mortality among cancer patients [45,46]. Oncology patients are particularly susceptible to VTE-related complications and therefore require effective prophylactic measures. However, despite well-acknowledged risks, adherence to recommended guidelines remains inadequate. This is largely due to multifaceted patient concerns, including fear of bleeding, physical discomfort from prophylactic measures, and misunderstanding

of the importance of these interventions [21,47]. This lack of understanding can exacerbate non-compliance and further elevate the risk of thrombotic events [47,48].

The integration of patient education strategies within oncology units appears imperative for enhancing adherence to VTE prophylaxis. Qualitative insights from studies like the EMPOWER initiative highlight the efficacy of patient-designed educational tools in augmenting knowledge, confidence, and intentions to seek help regarding cancer-associated thrombosis [2]. Although these findings are not amenable to quantitative analysis, they illuminate the potential pathways through which educational strategies might promote preventive behaviour among at-risk populations [22]. The combined qualitative and quantitative findings suggest a robust correlation between targeted patient education and improved prophylactic adherence. Healthcare teams can leverage educational advancements to foster an environment where patients feel more empowered and informed about their treatment options, thereby fostering longer-term engagement in preventive strategies [1,45]. While the quantitative evidence derives primarily from mixed inpatient populations rather than exclusively oncology cohorts, several factors support the reasonable application of these findings to oncology patients. First, the mechanism of action—improving knowledge and addressing specific concerns (e.g., fear of bleeding, injection discomfort)—is equally relevant to cancer patients. Second, the qualitative evidence from the oncology-specific educational tool study [49] demonstrated improvements in knowledge, confidence, and help-seeking intentions among cancer patients, aligning with the behavioural pathways observed in mixed populations. Third, oncology patients face higher baseline VTE risk, so even modest improvements in adherence may yield greater absolute risk reduction. However, caution is warranted because cancer patients may have higher anxiety levels, more complex medication regimens, and different risk-benefit perceptions (e.g., heightened fear of bleeding due to chemotherapy-induced thrombocytopenia). Therefore, while the educational approaches evaluated in mixed populations are likely transferable, oncology-specific adaptation and testing remain necessary.

5.3. Clinical and implementation implications

The management of VTE in hospitalized oncology patients remains a critical challenge, particularly given the elevated risk of VTE in this population. Evidence suggests that integrating structured patient education into routine VTE prophylaxis pathways can significantly enhance prophylaxis adherence and reduce missed doses. This approach not only represents a cost-effective strategy but also facilitates adaptability across diverse clinical settings, addressing gaps in prophylaxis delivery that existing system-level interventions may not resolve alone [3,28,31]. Structured patient education interventions, when combined with clinician-focused strategies, can lead to significant improvements in VTE prophylaxis adherence. For instance, a prospective cohort study highlighted that a patient-centred education bundle effectively reduced missed doses of pharmacologic VTE prophylaxis in a community hospital setting [3]. These findings underscore the importance of providing patients with the necessary information to understand their risks and the value of prophylactic measures. The inclusion of real-time alerts for missed doses alongside educational efforts appears to be particularly beneficial, allowing healthcare providers to address patient concerns immediately when refusals occur [1,28,44].

Implementation strategies for these educational interventions must be carefully tailored to enhance their effectiveness. Research indicates that delivering educational content early in the hospitalization process can establish foundational knowledge,

potentially mitigating future refusals of prophylaxis [42,44]. Furthermore, understanding patients' health literacy levels and individual needs is vital for optimizing the timing and content of educational initiatives. This reflects the reality that diverse patient populations may require different educational approaches to achieve similar adherence outcomes [3]. A notable consideration lies in studies showing that education interventions specifically targeting patients can be scaled and adapted within community hospital settings, reflecting a broader potential for improvement in VTE prophylaxis adherence [3]. The engagement of clinical staff in both education and implementation processes fosters a supportive environment where patients feel empowered to participate actively in their care [28,39].

Future efforts should focus on the continuous assessment and refinement of educational strategies. For instance, a study emphasized the effectiveness of personalized educational programs tailored to individual patient needs as part of standardized care pathways in oncology settings [3,31]. Such personalized interventions can not only enhance understanding but also improve adherence to VTE prophylaxis protocols. Establishing multidisciplinary teams that include nurses, pharmacists, and other healthcare professionals may further strengthen these educational efforts, promoting a consistent and supportive approach to VTE management that prioritizes patient engagement. All quantitatively synthesized studies were conducted in the United States, which may limit generalizability to other healthcare systems. Healthcare settings with different nurse-to-patient ratios, patient education norms, VTE prophylaxis prescribing patterns, or reimbursement structures may observe different effect magnitudes. For example, in healthcare systems where baseline patient education is already well-integrated into routine care, the incremental benefit of additional targeted education might be smaller. Conversely, in systems with limited baseline patient engagement, the effect could be larger. Future research should evaluate patient education interventions for VTE prevention in non-US healthcare settings, particularly in low- and middle-income countries where VTE burden may be under-recognized.

5.4. Strengths and Limitations

This study has several notable strengths. First, it emphasizes behavioural outcomes—specifically patient refusal and non-administration of prophylaxis—an area often neglected in thromboprophylaxis research, despite the fact that adherence to guidelines strongly influences clinical effectiveness. Second, the meta-analysis pools data from interventional studies that used objective outcome measures derived from medication administration records, thereby minimizing the biases associated with self-reported adherence that have been noted in various institutional settings [50]. Third, we transparently managed heterogeneous outcome definitions through directional harmonization (e.g., inverting adherence odds ratios to reflect non-adherence), which enhances the interpretability and methodological rigor of the findings and supports robust practice recommendations [50].

However, several limitations must be acknowledged. The quantitative synthesis included only four studies, indicating a relatively nascent evidence base for patient education interventions targeting VTE preventive behaviours [42]. Moderate heterogeneity ($I^2 = 55.7\%$) was observed, likely attributable to variability in intervention design, study populations, and comparator strategies across trials [43]. Due to the small number of studies, we were unable to conduct planned subgroup analyses (e.g., comparing randomized versus non-randomized designs or alert-triggered versus universal education), which represents a methodological limitation.

Furthermore, the potential for publication bias could not be formally evaluated, underscoring the need for a larger body of trials to establish clearer guidelines [51].

A major limitation is that the quantitative evidence derives predominantly from mixed inpatient populations rather than exclusively oncology cohorts. Although all studies included oncology patients, they also enrolled general medical or surgical patients; therefore, the findings are more appropriately interpreted as having implications for oncology care rather than providing oncology-specific quantitative evidence [28]. This limits generalizability to specific cancer subgroups, such as those with haematologic malignancies or advanced disease. When interpreting the pooled odds ratio of 0.52, the potential biases identified across included studies warrant consideration. Performance bias—common to all studies due to the impossibility of blinding participants and providers to educational interventions—likely overestimates the effect of patient education. Conversely, confounding bias in non-randomized studies (which we assessed as having moderate to serious risk) may either overestimate or underestimate effects depending on unmeasured confounders. Nevertheless, the consistency of effect estimates across randomized and non-randomized designs (OR range 0.46–0.61) suggests that these biases did not substantially distort the overall conclusion.

5.5. Implications for future research

Future research agendas in oncology must centre on randomized or cluster-randomized trials specifically tailored to evaluate patient education interventions, emphasizing standardized reporting of behavioural outcomes and effect measures. There exists a strong consensus in the literature around the necessity for rigorous trial designs to adequately assess and compare various educational strategies for their efficacy in improving patient outcomes [39]. For instance, the provision of patient education delivered through innovative methods, such as digital platforms or traditional face-to-face interactions, has shown promising results in various medical settings, extending our understanding of how these interventions can effectively instigate behaviour change in oncology populations [47]. Moreover, comparative studies that examine the relative effectiveness of different educational delivery modes and the timing of these interventions will play a critical role in defining best practices for patient education in oncology [49]. Some recent investigations have utilized digital versus postal delivery methods to assess changes in healthcare professional behaviour, highlighting the potential of tailored educational interventions to maximize compliance and patient engagement [52]. This investigation mirrors the potential for similar stratagems within oncology, where the timeliness and medium of education could influence treatment pathways and patient adherence to prescribed therapies. It is also vital to incorporate patient-reported outcomes alongside objective adherence measurements in these studies. This multifaceted approach is supported by findings indicating that understanding the mechanisms underlying behaviour change entails gauging subjective patient experiences alongside quantitative adherence metrics [36]. For example, in a cluster randomized trial focused on chronic obstructive pulmonary disease (COPD), patient perceptions significantly impacted adherence to recommended interventions, demonstrating the paramount importance of integrating patient feedback into the design of patient education educational interventions [50].

6. Conclusion

This systematic review and meta-analysis provide evidence that patient-facing educational interventions are associated with meaningful improvements

in VTE preventive behaviours among hospitalized oncology populations. Across interventional studies, patient education consistently reduced refusal and non-administration of pharmacologic VTE prophylaxis, with pooled estimates indicating a substantial reduction in negative preventive behaviours. These findings highlight patient education as an important and actionable component of comprehensive thromboprophylaxis strategies in oncology care.

The results underscore the value of shifting VTE prevention efforts beyond clinician- and system-centred approaches to more fully engage patients as active partners in their care. While electronic alerts, standardized order sets, and audit-and-feedback mechanisms remain essential, they may be insufficient to address patient-driven barriers such as fear of bleeding, discomfort, or limited understanding of VTE risk. Educational interventions that directly target patient knowledge and perceptions appear capable of addressing these barriers and improving adherence to prescribed prophylaxis.

Importantly, the observed benefits were evident across different educational formats and delivery strategies, including alert-triggered education at the point of missed doses and broader educational bundles delivered during hospitalization. This suggests that patient education is a flexible intervention that can be adapted to diverse inpatient oncology settings and integrated into existing care pathways with relatively low resource burden. The qualitative evidence further suggests that patient-centred and co-designed educational tools may enhance engagement, confidence, and help-seeking behaviours, offering insight into the mechanisms through which education influences preventive actions.

Despite the modest number of studies available for quantitative synthesis, the consistency of direction and magnitude of effect across heterogeneous study designs supports the robustness of the findings. The leave-one-out sensitivity analysis further confirmed that no single study disproportionately influenced the pooled estimate. At the same time, the limited oncology-specific evidence base highlights an important gap in current research. Future studies should focus on oncology-exclusive populations, employ standardized behavioural outcome measures, and evaluate the sustainability of educational effects beyond hospitalization.

In summary, patient education represents a feasible, scalable, and clinically relevant strategy to improve VTE preventive behaviours in hospitalized oncology patients. Incorporating structured, patient-centred educational interventions into routine thromboprophylaxis protocols has the potential to enhance adherence, reduce preventable VTE events, and ultimately improve patient safety and quality of care in haematology and oncology settings.

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