

American Society of Clinical Oncology Guideline: Recommendations for Venous Thromboembolism Prophylaxis and Treatment in Patients With Cancer

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A B S T R A C T

Purpose

To develop guideline recommendations for the use of anticoagulation in the prevention and treatment of venous thromboembolism (VTE) in patients with cancer.

Methods

A comprehensive systematic review of the medical literature on the prevention and treatment of VTE in cancer patients was conducted and reviewed by a panel of content and methodology experts. Following discussion of the results, the panel drafted recommendations for the use of anticoagulation in patients with malignant disease.

Results

The results of randomized controlled trials of primary and secondary VTE medical prophylaxis, surgical prophylaxis, VTE treatment, and the impact of anticoagulation on survival of patients with cancer were reviewed. Recommendations were developed on the prevention of VTE in hospitalized, ambulatory, and surgical cancer patients as well as patients with established VTE, and for use of anticoagulants in cancer patients without VTE to improve survival.

Conclusion

Recommendations of the American Society of Clinical Oncology VTE Guideline Panel include (1) all hospitalized cancer patients should be considered for VTE prophylaxis with anticoagulants in the absence of bleeding or other contraindications; (2) routine prophylaxis of ambulatory cancer patients with anticoagulation is not recommended, with the exception of patients receiving thalidomide or lenalidomide; (3) patients undergoing major surgery for malignant disease should be considered for pharmacologic thromboprophylaxis; (4) low molecular weight heparin represents the preferred agent for both the initial and continuing treatment of cancer patients with established VTE; and (5) the impact of anticoagulants on cancer patient survival requires additional study and cannot be recommended at present.

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INTRODUCTION

Venous thromboembolism (VTE) is a major complication of cancer, occurring in 4% to 20% of patients, and is one of the leading causes of death in patients with cancer.¹ The risk of VTE including deep venous thrombosis (DVT) and pulmonary embolism (PE) is increased several-fold in patients with cancer.² Hospitalized patients with cancer and those receiving active therapy seem to be at the greatest risk for development of VTE. In a population-based study, cancer was associated with a 4.1-fold greater risk of thrombosis, whereas the use of chemotherapy increased the risk 6.5-fold.^{2,3} Of all patients with VTE, patients with cancer account for

20%, with patients receiving chemotherapy accounting for as much as 13% of the total burden of VTE.^{4,5} The reported rates of VTE in patients with cancer are believed to be underestimated, given that autopsy rates of VTE can be as high as 50% compared with clinical rates of 4% to 20%.⁶⁻⁸ Furthermore, the burden of VTE in cancer seems to be increasing for uncertain reasons. In a recent analysis of more than 66,000 patients with cancer hospitalized at 120 US academic medical centers, 5.4% developed VTE per hospitalization, increasing by 36% from 1995 to 2002 ($P < .0001$ for trend).¹ Similarly, an analysis of the National Hospital Discharge Survey found that the incidence of VTE increased nearly two-fold from 1980 to 1999.⁹ Vascular toxicity,

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particularly thromboembolism, is a specific toxicity of antiangiogenic drugs. Newer cancer regimens that include thalidomide, lenalidomide, or bevacizumab have reported very high rates of VTE.¹⁰⁻¹³

CONSEQUENCES OF CANCER-ASSOCIATED VTE

The diagnosis of VTE has important clinical implications. In a prospective observational study of ambulatory patients with cancer initiating chemotherapy, venous and arterial thromboembolism together accounted for 9% of deaths.¹ Cancer diagnosed at the same time as, or within 1 year of an episode of VTE, is associated with a three-fold greater mortality at 1 year.¹⁴ Hospitalized patients with VTE have a greater in-hospital mortality rate (odds ratio, 2.01; 95% CI 1.83 to 2.22; $P < .0001$), and this is true of patients both with and without metastatic disease.¹⁵ The risk of fatal PE in patients with cancer undergoing surgery is three-fold greater than in patients without cancer undergoing similar surgery.¹⁶ In addition, VTE recurs three-fold more frequently in cancer patients than in patients who do not have cancer, and requires long-term anticoagulation with a two-fold greater risk of bleeding complications than in patients who do not have cancer.¹⁷ VTE in patients with cancer also consumes health care resources. In a retrospective analysis, the mean length of DVT-attributable hospitalization was 11 days, and the average cost of hospitalization for the index DVT episode was \$20,065 in 2002 US dollars.¹⁸ Reducing VTE in patients with cancer could therefore have a significant impact on morbidity, outcomes, use of health care resources and, above all, mortality. This guideline reviews the evidence base regarding risk factors, prevention, and treatment of VTE in patients with cancer, and provides clinical recommendations based on this evidence. Central venous catheter-associated thrombosis is an important complication of treatment in patients with cancer but is reviewed in a separate American Society of Clinical Oncology (ASCO) guideline on central venous catheters and will not be addressed here.

RISK FACTORS FOR CANCER-ASSOCIATED VTE

The risk of thrombosis differs across various cancer subgroups and over the natural history of the disease. The risk of VTE is highest in the initial period after the diagnosis of malignancy.^{19,20} The association of VTE with specific sites of cancer such as pancreas, stomach, brain, ovary, kidney, and lung, and with the presence of metastatic disease, has been well documented.^{9,15,21-23} Newer studies suggest a strong association with hematologic malignancies, particularly lymphomas.^{15,19}

Patients with cancer receiving active therapy are at a greater risk for VTE. In a population-based study, chemotherapy was associated with a 6.5-fold increased risk of VTE.^{2,3} Studies of newer cancer regimens, particularly those including antiangiogenic agents, have reported very high rates of VTE.¹⁰⁻¹³ Hormonal therapy, particularly tamoxifen, has been associated with an increased risk of VTE. Erythropoiesis-stimulating agents are also associated with an increased risk of VTE; an association of myeloid growth factors with VTE has not been fully established.^{21,24,25} The risk of VTE increases significantly when patients with cancer are hospitalized.²⁶ Patients with cancer undergoing surgery have a two-fold increased risk of postoperative DVT and a three-fold greater risk of fatal PE compared with patients who do not have cancer having similar surgery.¹⁶ Other possible risk factors include a prechemotherapy platelet count $\geq 350,000/\mu\text{L}$ ²¹ and the presence of prothrombotic mutations.^{19,27} A comprehensive list of risk factors associated with VTE in patients with cancer is summarized in Table 1. Although a detailed discussion of the diagnostic process in patients with cancer at risk for VTE is beyond the scope of this guideline, symptomatic patients should be evaluated promptly. Symptoms suggestive of DVT include unilateral calf, leg, or thigh swelling or pain, whereas a diagnosis of DVT is generally based on a lower-extremity Doppler ultrasound. Symptoms suggestive of a PE include shortness of breath, tachypnea, pleuritic chest pain, a

Table 1. Risk Factors for VTE in Patients With Malignant Disease

Patient-related factors
Older age ¹⁵
Race (higher in African Americans; lower in Asian-Pacific Islanders) ²⁰
Comorbid conditions (obesity, infection, renal disease, pulmonary disease, arterial thromboembolism) ^{15,21,26,33}
Prior history of VTE ²⁶
Elevated prechemotherapy platelet count ²¹
Heritable prothrombotic mutations ^{19,34-36}
Cancer-related factors
Primary site of cancer (GI, brain, lung, gynecologic, renal, hematologic) ^{9,15,19-21,23}
Initial 3-6 months after diagnosis ^{19,20,33}
Current metastatic disease ^{15,19,20,23,33,37}
Treatment-related factors
Recent major surgery ^{32,38,39}
Current hospitalization ^{15,26,40}
Active chemotherapy ^{2,23,26,37}
Active hormonal therapy ^{37,41-43}
Current or recent antiangiogenic therapy (thalidomide, lenalidomide, bevacizumab*) ^{11,28-31,44-46}
Current erythropoiesis-stimulating agents ^{21,24}
Presence of central venous catheters ^{32,47-49}

Abbreviation: VTE, venous thromboembolism.

*Bevacizumab is clearly associated with an increased risk of arterial thrombotic events; an association with venous thrombosis is not fully established.

pleural rub, hypoxia, hemoptysis, tachycardia, syncope along with accompanying symptoms, and signs of a DVT or right heart failure. A diagnosis of PE is generally based on a ventilation/perfusion scan or spiral computed tomography scan.

VARIATION IN CLINICAL PRACTICE

Multiple randomized trials in a variety of patient populations have been conducted in the last 30 years demonstrating that primary prophylaxis can reduce DVT, PE, and fatal PE.⁵⁰⁻⁵⁴ The American College of Chest Physicians (ACCP) guidelines on prevention of VTE recommend prophylaxis for acutely ill hospitalized medical or surgical patients with cancer.⁵⁵ Surveys of oncologists, however, show low rates of compliance with thromboprophylaxis.^{56,57} This may be related to under-recognition of prevalent risk factors, concern regarding the risk of bleeding, and lack of awareness of these guidelines within the oncology community. Identification of patients most at risk for VTE followed by institution of effective prophylaxis could have a significant impact on morbidity, delivery of cancer therapy, cancer-related outcomes, use of health care resources and, above all, mortality in patients with cancer.⁵⁸

GUIDELINE QUESTIONS

- (1) Should hospitalized patients with cancer receive anticoagulation for VTE prophylaxis?
- (2) Should ambulatory patients with cancer receive anticoagulation for VTE prophylaxis during systemic chemotherapy?
- (3) Should patients with cancer undergoing surgery receive perioperative VTE prophylaxis?
- (4) What is the best method for treatment of patients with cancer with established VTE to prevent recurrence?
- (5) Should patients with cancer receive anticoagulants in the absence of established VTE to improve survival?

PRACTICE GUIDELINES

Practice guidelines are systematically developed statements that assist practitioners and patients in making decisions about care. Attributes of good guidelines include validity, reliability, reproducibility, clinical applicability, flexibility, clarity, multidisciplinary process, review of evidence, and documentation. Guidelines may be useful in producing better care and decreasing cost. Specifically, utilization of clinical guidelines may provide:

- (1) Improvements in outcomes
- (2) Improvements in medical practice
- (3) A means for minimizing inappropriate practice variation
- (4) Decision support tools for practitioners
- (5) Points of reference for medical orientation and education
- (6) Criteria for self-evaluation
- (7) Indicators and criteria for external quality review
- (8) Assistance with reimbursement and coverage decisions
- (9) Criteria for use in credentialing decisions

In formulating recommendations for the appropriate use of VTE prophylaxis and treatment in patients with cancer, ASCO considered these tenets, emphasizing a review of data from appropriately con-

ducted and analyzed clinical trials. However, it is important to emphasize that guidelines cannot always account for individual variation among patients. They are not intended to supplant physician judgment regarding particular patients or special clinical situations, and cannot be considered inclusive of all proper methods of care or exclusive of other treatments reasonably directed at obtaining the same result. Accordingly, ASCO considers adherence to these guidelines to be voluntary, with the ultimate determination regarding their application to be made by the physician in light of each patient’s circumstances. In addition, these guidelines describe the use of procedures and therapies in clinical practice; they cannot be assumed to apply to the use of these interventions performed in the context of clinical trials, given that clinical studies are designed to evaluate or validate innovative approaches in a disease for which improved management is needed. Because guideline development involves a review and synthesis of the literature, a practice guideline also serves to identify important questions and settings for further research.

METHODS

PANEL COMPOSITION

The ASCO Health Services Committee (HSC) convened an Expert Panel consisting of experts in clinical medicine and research relevant to VTE in patients with cancer including medical and surgical oncology. Academic and community practitioners, an oncology fellow, and a patient representative were also part of the Panel. The Panel members are listed in the Appendix.

LITERATURE REVIEW AND ANALYSIS

Literature search strategy. An exhaustive systematic literature review was performed of randomized clinical trials (RCTs) examining the efficacy and safety of anticoagulation therapy in patients with cancer regarding survival, bleeding complications, and the prevention of VTE. The comprehensive search included the following electronic databases through the end of 2006: MEDLINE, EMBASE, Cancerlit, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, Database of Abstracts of Reviews of Effect, and National Guideline Clearing House. Conference proceedings were searched from 2003 to 2006 (ASCO, American Society of Hematology, International Society of Thrombosis and Hemostasis). References from included articles, relevant excluded reports, and guidelines were searched by hand. In addition, the VTE Panel and other experts from North America and Europe were asked to review identified articles to ensure completeness and provide unpublished results. The literature search had no language restrictions. Subject headings and keywords used in the search process included four major categories, including medical subject headings and text words: venous thromboembolism; anticoagulation including vitamin K antagonists, unfractionated heparin (UFH), and low molecular weight heparin (LMWH); and all malignancies including solid tumors and hematologic malignancies. For RCTs, the recommended search strategy from the Cochrane Collaboration was used.^{59,60} These three major search categories were combined by the Boolean “AND.” The terms utilized within these major search categories were combined by the Boolean “OR.”

Inclusion and exclusion criteria. Included studies had to be RCTs of adult patients with cancer randomly assigned to anticoagulation drug therapy or an appropriate control group. Anticoagulation had to

be with LMWH, UFH, or an oral vitamin K antagonist. Studies were only included if they had VTE or mortality as a priori planned primary or secondary outcomes and described a method of regular patient follow-up to ensure a consistent and identical identification of the outcomes in both study arms. VTE had to be confirmed objectively. Studies were excluded if they were nonrandomized reports, post hoc subgroup analyses, or if they included only patients who did not have cancer. Given the substantial clinical differences, studies of thrombosis prophylaxis related to indwelling catheters were not included in this analysis. Among duplicate publications only the most recent or the most complete report was included.

Data extraction. Two reviewers extracted the data independently on basic study design, patient characteristics, study outcomes, and measures of study quality. Any discrepancies between reviewers were resolved by consensus. Data for analysis were abstracted systematically from the published reports and included authors and citation; category, general type, and stage of malignancy and other demographic patient characteristics; drugs, doses, and schedule of anticoagulation therapy and concomitant interventions; study design (eg, the type of control group [placebo v nonplacebo], appropriate description of randomization, blinding, concealment of therapy, description of patient withdrawals or dropouts, power calculations, and intention to treat analysis); and number of patients initially randomly assigned, the number of patients assessable, and the cumulative proportion experiencing specific outcomes.

Study quality. Overall study quality was evaluated by the method of Moher et al.⁶¹ This scale represents a validated instrument for assessing the quality of RCTs. It evaluates study quality based on appropriate methods of randomization, appropriate description of blinding and treatment concealment, and appropriate description of study withdrawals or dropouts. The possible scoring range is from 0 to 5, with poor quality represented by a score of 2 or less.

CONSENSUS DEVELOPMENT BASED ON EVIDENCE

The entire Panel met twice; additional work on the guideline was completed through a steering group. The purposes of the Panel meetings were to refine the questions addressed by the guidelines and to make writing assignments for the respective guideline sections. All members of the Panel participated in the preparation of the draft guideline document, which was then disseminated for review by the entire Panel. Feedback from external reviewers was also solicited. The content of the guidelines and the manuscript were reviewed and approved by the HSC and by the ASCO Board of Directors before dissemination.

GUIDELINE AND CONFLICTS OF INTEREST

All members of the Expert Panel complied with ASCO policy on conflicts of interest, which requires disclosure of any financial or other interest that might be construed as constituting an actual, potential, or apparent conflict. Members of the Expert Panel completed ASCO's disclosure form and were asked to reveal ties to companies developing products that might be affected by promulgation of the guidelines. Information was requested regarding employment, consultancies, stock ownership, honoraria, research funding, expert testimony, and membership on company advisory committees. The Panel made decisions on a case-by-case basis as to whether an individual's role should be limited as a result of a conflict. No limiting conflicts were identified.

REVISION DATES

At annual intervals, the Panel Co-Chairs and two Panel members designated by the Co-Chairs will determine the need for revisions to the guidelines based on an examination of current literature. If necessary, the entire Panel will be reconvened to discuss potential changes. When appropriate, the Panel will recommend revised guidelines to the HSC and the ASCO Board for review and approval.

RESULTS

SUMMARY OF LITERATURE SEARCH RESULTS

While a limited number of meta-analyses of the value of anticoagulation in patients with cancer have been conducted, most have been limited in their methodology, including poor search and selection strategies, and inclusion of subgroup analyses of the study population with cancer.⁶² Even meta-analyses used to support other clinical guidelines often fail to meet criteria for being truly systematic or of reasonable quality based on Quality of Reporting of Meta-Analyses (QUORUM) criteria.⁶³ The ACCP Conference on Antithrombotic and Thrombolytic Therapy uses a grading system reflecting the perceived strength of the recommendations.⁶⁴ Unfortunately, such guidelines only provide limited information on cancer-associated thrombosis.

Primary prophylaxis. Only three studies of a primary prophylaxis strategy in ambulatory patients with cancer have had VTE as a primary outcome and no meta-analysis of this issue has been completed.

Secondary prophylaxis. The comparative impact of LMWH versus vitamin K antagonists on recurrence of VTE specifically in patients with cancer has been studied in four RCTs, all showing a trend toward a lower risk of recurrent VTE for LMWH.⁶⁵⁻⁶⁸ The comparative impact on cancer-specific mortality of anticoagulants given for VTE has been studied in a number of RCTs, including post hoc analyses of cancer subgroups. A meta-analysis of these studies has been reported by Conti et al.⁶⁹ These investigators found no significant difference in cancer mortality in eight RCTs that compared LMWH and vitamin K antagonists for all patients (odds ratio [OR] = 0.95; 95% CI, 0.73 to 1.23) or limited to patients with cancer (OR = 0.96; 95% CI, 0.73 to 1.25). None of these studies was designed to study cancer-specific mortality. In another meta-analysis of RCTs of VTE patients comparing LMWH and UFH, Hettiarachchi et al⁷⁰ reported a lower 3-month mortality for the subgroup of patients with cancer treated with LMWH compared with those receiving UFH (OR = 0.61; 95% CI, 0.40 to 0.93). Similar results were reported by an earlier meta-analysis.⁷¹

Surgical prophylaxis. A large number of RCTs of prophylactic anticoagulation have been performed in the perioperative and postoperative setting, although few have addressed outcomes specifically in a cancer population. Smorenberg et al⁷² found that, despite a reduction in 3-year mortality in four retrospective studies of prophylactic UFH in resectable GI cancer (OR = 0.65; 95% CI, 0.51 to 0.84), a significant increase in 3-year mortality was found in two prospective RCTs among similar patients (OR = 1.66; 95% CI, 1.02 to 2.71). A recent review of DVT prophylaxis, including subgroup analysis of patients with cancer undergoing surgical procedures, identified 26 studies.⁷³ A significant reduction in DVT was observed in patients

receiving LMWH, whereas no difference was observed between LMWH and UFH. A meta-analysis of RCTs of prolonged LMWH compared with no postoperative prophylaxis in cancer patients undergoing abdominal surgery was reported by Rasmussen et al.^{74,75} The most recent of these meta-analyses identified four RCTs comparing LMWH prophylaxis strategies. Patients receiving LMWH for 4 to 5 weeks after surgery experienced a significantly reduced risk of venographically detected DVT (relative risk [RR] = 0.44; 95% CI, 0.28 to 0.70; *P* = .0005) but not symptomatic VTE (RR = 0.35; 95% CI, 0.06 to 2.22; *P* = .27) compared with those receiving a shorter course.⁷⁵ An individual patient data meta-analysis of the two studies of the LMWH tinzaparin confirmed a reduction in risk with extended prophylaxis.⁷⁶

Anticoagulation as cancer treatment. A number of RCTs of anticoagulation treatment in patients with cancer without a diagnosis of VTE addressed overall or cancer-specific mortality as a primary outcome. No significant impact on 1-year mortality of vitamin K antagonists administered in patients with cancer without VTE was found in a meta-analysis including 1,443 patients in nine disease groups from five separate studies (OR = 0.89; 95% CI, 0.70 to 1.13). However, this meta-analysis was not based on a comprehensive systematic review, it allowed trials in the analysis with a combination of anticoagulants, and it did not address the impact of bleeding complications.⁷² Another meta-analysis by the same authors explored the impact of UFH on survival in patients with cancer.⁶² Only one study was identified as an RCT that studied UFH for more than 7 days.⁷⁷ Two other RCTs investigated UFH given via portal vein infusion continuously for 7 days and found a detrimental effect for UFH compared with control (OR = 1.66; 95% CI, 1.02 to 2.71).^{78,79} In a recently reported meta-analysis, anticoagulation in patients with cancer without recognized VTE was found to decrease 1-year overall mortality significantly, with an RR of 0.905 (95% CI, 0.847 to 0.967; *P* = .003).⁸⁰ The RR for mortality was 0.877 (95% CI, 0.789 to 0.975; *P* = .015) with LMWH, compared with RR = 0.942 (95% CI, 0.854 to 1.040; *P* = .239) with warfarin. Major bleeding episodes occurred less frequently in LMWH patients than in patients receiving warfarin (*P* < .0001).

PREVIOUS GUIDELINES AND CONSENSUS STATEMENTS

ACCP. The ACCP published an evidence-based guideline on antithrombotic and thrombolytic therapy, including chapters on the prevention and treatment of VTE.^{55,81,82} This guideline addresses the broad range of patient indications for the prevention and treatment of VTE, but did not focus specifically on the cancer patient, although selected issues related to patients with cancer were discussed. The current ASCO initiative focuses on the specific issues arising in the patient with cancer, including some new issues that have emerged since the last published ACCP guideline. This provides an opportunity to consider some of these issues in greater detail and provide updated recommendations; it is, therefore, complementary to the effort of the ACCP.

National Comprehensive Cancer Network. The National Comprehensive Cancer Network (NCCN) is a not-for-profit alliance of 20 leading National Cancer Institute–designated cancer centers that develops and disseminates clinical practice guidelines in oncology. The NCCN VTE Panel was convened in 2005 and its guidelines were presented in March 2006. The current version of the recommendations on VTE management (version 2.2006) can be found at http://nccn.org/professionals/physician_gls/PDF/vte.pdf.

Italian Guidelines. Since 2004, the Italian Association of Medical Oncology has published online recommendations to direct the clinical practice of Italian oncologists in the management of VTE in patients with cancer. These recommendations are amended annually and were most recently published in English in 2006.⁸³ The levels of evidence are provided according to a five-point rating system, and the strength of recommendations is assessed on the basis of their relative benefits and risks. The guideline recommendations are comprehensive and focus on six different aspects, including VTE associated with occult cancer, prophylaxis of VTE in cancer surgery, prophylaxis of VTE during chemotherapy or hormonal therapy, prophylaxis of VTE associated with central venous catheters, treatment of VTE in patients with cancer, and anticoagulation and prognosis of cancer.

GUIDELINE RECOMMENDATIONS

1. SHOULD HOSPITALIZED PATIENTS WITH CANCER RECEIVE ANTICOAGULATION FOR VTE PROPHYLAXIS?

Recommendation. Hospitalized patients with cancer should be considered candidates for VTE prophylaxis with anticoagulants in the absence of bleeding or other contraindications to anticoagulation.

Literature review and analysis. The reported frequency of VTE in hospitalized patients with cancer has varied widely, with reported incidences ranging from 0.6% to 18% (Table 2).^{9,15,22,23,85} Patients at particularly high risk for VTE include older patients, patients with cancers of the brain, pancreas, GI tract, ovary, kidney, bladder, lung, and the hematologic malignancies; patients with metastatic disease; and immobilized, neutropenic, and infected patients. Three double-blind, placebo-controlled, multicenter studies of pharmacologic thromboprophylaxis with either LMWH or fondaparinux in acutely ill hospitalized patients have been reported (Table 3).⁸⁶⁻⁸⁸ The three studies differed in their inclusion criteria and patients with cancer constituted only a minority of the enrolled participants. Although each study reported a statistically significant reduction in VTE with pharmacologic prophylaxis, only one study provided outcome data for the cancer subset, which was not statistically significant.^{85,89} Previous studies on medical prophylaxis using UFH 5000 IU given twice daily in acutely ill medical patients failed to demonstrate a significant reduction in fatal PE.⁹⁰ However, other studies utilizing UFH tid (5,000 IU) have indicated efficacy equivalent to LMWH.⁹¹ Analysis of the PREVENT trial data showed that asymptomatic proximal DVT was associated with an increased mortality rate.⁸⁷ Although none

Table 2. Frequency of Venous Thrombosis in Hospitalized Patients With Cancer

Reference	No. of Hospitalizations or Patients	VTE Events	
		No.	%
Levitan et al ^{22*}	1,211,944	7,238	0.6
Sallah et al ²³	1,041	81	7.8
Stein et al ⁹	40,787,000	837,000	2
Khorana et al ^{15†}	66,106	5,272	5.4
Khorana et al ⁸⁴	1,015,598	41,666	4.1

*Medicare claims data base only includes patients age ≥ 65 years.
†Included only patients with cancer with neutropenia.

Table 3. Trials of Anticoagulants for VTE Prophylaxis in Acutely Ill Hospitalized Medical Patients

Reference	Total No. of Patients	Cancer Patients		Placebo Events		Treatment Events		Relative Risk	P	95% CI
		No.	%	No.	%	No.	%			
MEDENOX ^{85,86,89}	579*	72	12.4	43/288 8/41†	14.9 19.5	16/291 3/31†	5.5 9.7	0.37	< .001	0.22 to 0.63
PREVENT ⁸⁷	3,706	190	5.1	73/1,473	4.96	42/1,518	2.77	0.55	.0015	0.38 to 0.8
ARTEMIS ⁸⁸	849‡	131	15.4	34/323	10.5	18/321	5.6	0.47	.029	0.08 to 0.69

Abbreviations: VTE, venous thromboembolism; MEDENOX, Prophylaxis in Medical Patients with Enoxaparin; PREVENT, Prospective Evaluation of Dalteparin Efficacy for Prevention of VTE in Immobilized Patients Trial; ARTEMIS, ARixtra for ThromboEmbolism Prevention in a Medical Indications Study.

*MEDENOX included a 20-mg enoxaparin arm of 287 patients with event rates equivalent to placebo. Number includes only placebo and patients receiving 40-mg treatment.

†Number of patients with cancer treated with placebo and 40-mg treatment arms. Nonstatistical difference $P = .4$.

‡Total patients assessable for safety analysis; only 644 patients were assessable for primary end point.

of the deaths was considered related to VTE, one third of the deaths were due to cancer, suggesting that asymptomatic VTE in the patients with cancer in this study, most likely, was associated with advanced malignancy.⁹²

The 2004 ACCP guidelines strongly recommend (1A) pharmacologic prophylaxis with either low-dose heparin or LMWH for bedridden patients with active cancer.⁵⁵ It should be noted that these recommendations are based on clinical trials in which only a minority of enrollees were patients with cancer. However, even in the absence of clear treatment data in hospitalized patients with cancer, the low complication rates observed with prophylaxis in the major medical trials appear to justify the use of pharmacologic prophylaxis in hospitalized patients with cancer. However, none of the randomized studies discussed here has reported bleeding data specifically in the subgroup of patients with cancer (Table 4).

2. SHOULD AMBULATORY PATIENTS WITH CANCER RECEIVE ANTICOAGULATION FOR VTE PROPHYLAXIS DURING SYSTEMIC CHEMOTHERAPY?

Recommendations

(1) Routine prophylaxis with an antithrombotic agent is not recommended.

(2) Patients receiving thalidomide or lenalidomide with chemotherapy or dexamethasone are at high risk for thrombosis and warrant prophylaxis. Until such time as data are available from RCTs, LMWH or adjusted-dose warfarin (international normalized ratio [INR] ~1.5) is recommended in myeloma patients receiving thalidomide plus chemotherapy or dexamethasone. *This recommendation is based on extrapolation from studies of postoperative prophylaxis in orthopedic surgery and a trial of adjusted-dose warfarin in breast cancer.*

(3) RCTs evaluating antithrombotic agents are needed in patients with multiple myeloma receiving thalidomide or lenalidomide plus chemotherapy and/or dexamethasone.

(4) Research identifying better markers of ambulatory patients with cancer most likely to develop VTE is urgently needed.

Literature Review and Analysis

Low-dose warfarin. There are few data available on the prevention of VTE in ambulatory patients with cancer. In one study, Levine et al⁹³ showed that low-dose warfarin is effective in reducing the rate of thrombosis during chemotherapy. In a double-blind randomized

trial, 311 patients with metastatic breast cancer were given either very low dose warfarin (1 mg for 6 weeks followed by adjusted dose to a target INR of 1.3 to 1.9) or placebo while receiving chemotherapy. The rate of thrombosis was 0.65% in the warfarin arm and 4.4% in the placebo arm, a statistically significant 85% risk reduction in the rate of VTE with no increase in bleeding. On the basis of these results, the number of patients needed to treat to avoid one event is 23.

LMWH. European investigators recently presented data in abstract form from two double-blind, placebo-controlled, RCTs (TOPIC-1 and TOPIC-2) in patients with metastatic breast cancer ($n = 353$) or stage III or IV non-small-cell lung carcinoma ($n = 547$).⁹⁴ Patients were randomly assigned to receive either 6 months of the LMWH certoparin (3,000 anti-factor Xa units daily) or placebo for primary prevention of chemotherapy-associated VTE.⁹⁴ Patients were screened for DVT by ultrasonography every 4 weeks while on study. In patients with breast cancer, there was no observed difference in the rates of VTE (4%), whereas rates of major bleeding complications during 6 months of treatment were 1.7% for the LMWH arm and 0% for the placebo arm. In patients with lung cancer, there was a nonsignificant trend toward effectiveness of LMWH prophylaxis, with VTE rates of 4.5% for the LMWH arm and 8.3% for the placebo arm ($P = .07$). Major bleeding in patients with lung cancer occurred in 3.7% of the LMWH treated patients versus 2.2% in the placebo group. In a post hoc analysis, rates of VTE in patients with stage IV lung cancer who received LMWH were 3.5% compared with 10.1% for those receiving placebo ($P = .03$). Certoparin is not currently available in the United States.

Thalidomide and derivatives. Routine use of prophylaxis in ambulatory patients with cancer receiving chemotherapy is not recommended because of conflicting data from clinical trials, concern about bleeding, the need for laboratory monitoring and dose adjustment, and the relatively low incidence of VTE. However, the risk of VTE in patients receiving thalidomide has been found to range from 17% to 26% in combination with dexamethasone,^{10,28} and from 12% to 28% in combination with other chemotherapy agents including anthracyclines.^{29,30} Recent nonrandomized studies of thalidomide-containing regimens in patients with multiple myeloma have suggested efficacy for prophylactic anticoagulation with LMWH,^{95,96} warfarin 1 mg⁹⁵ and 1.25 mg,⁹⁷ and aspirin.⁹⁸ Rajkumar et al⁹⁹ reported the results of a phase II trial of lenalidomide (an analog of thalidomide) plus dexamethasone in 34 patients with myeloma. Patients received either 80 or

Table 4. Regimens for Prophylaxis/Treatment of VTE in Patients With Cancer

Management	Drug	Regimen*	Estimated Weekly Cost†	Estimated 6-Month Cost†
Prophylaxis				
Hospitalized medical or surgical cancer patients‡	Unfractionated heparin	5,000 U every 8 hours§	\$12.08	\$313.95
	Dalteparin	5,000 U daily	\$152.40	\$3,962.50
	Enoxaparin	40 mg daily	\$154.59	\$4,019.29
	Fondaparinux	2.5 mg daily	\$199.92	\$5,197.92
Treatment of established VTE				
Initial¶	Dalteparin#	100 U/kg every 12 hours	\$426.73	NA
		200 U/kg daily**	\$426.73	NA
	Enoxaparin#	1 mg/kg every 12 hours	\$541.06	NA
		1.5 mg/kg daily**	\$405.79	NA
	Heparin	80 U/kg IV bolus, then 18 U/kg/h IV (adjust level based on PTT†)	\$24.99	NA
	Fondaparinux#	< 50 kg, 2.5 mg daily	\$199.92	NA
		50-100 kg, 5 mg daily	\$399.84	NA
		> 100 kg, 7.5 mg daily	\$599.76	NA
	Tinzaparin	175 U/kg daily	\$198.17	NA
	Long term‡	Dalteparin	200 U/kg daily for 1 month; then 150 U/kg daily	\$334.12
Warfarin		5-10 mg PO daily; adjust dose to INR 2-3	\$4.43	\$115.15

NOTE. Relative contraindications to anticoagulation include, among other conditions: active, uncontrollable bleeding; active cerebrovascular hemorrhage; dissecting or cerebral aneurysm; bacterial endocarditis; pericarditis, active peptic or other GI ulceration; severe, uncontrolled, or malignant hypertension; severe head trauma, pregnancy (warfarin), heparin-induced thrombocytopenia (heparin, LMWH), and epidural catheter placement. Dalteparin (Fragmin; Eisai Inc, Woodcliff Lake, NJ); Enoxaparin (Lovenox; sanofi aventis, Bridgewater, NJ); Fondaparinux (Arixtra; GlaxoSmithKline, Brentford, United Kingdom); Tinzaparin (Innohep; Pharmion, Boulder, CO). Abbreviations: VTE, venous thromboembolism; IV, intravenously; NA, not available; PTT, partial thromboplastin time; LMWH, low molecular weight heparin; PO, orally; INR, international normalized ratio; CMS, Centers for Medicare and Medicaid Services; FUL, Federal Upper Limit.

*All subcutaneously except as indicated.
 †Cost considerations for estimates provided. (1) Cost for injectable drugs is based on Medicare Part B price list effective September 30, 2006 (with no administration fees or other adjustments). (2) Cost estimates for warfarin do not include additional costs for frequent monitoring required to maintain INR in acceptable range. (3) Calculations assume a 70-kg patient. (4) Long-term therapy with dalteparin was calculated as follows: 6-month costs calculated with 1-month start-up + 5-month maintenance. Weekly costs estimated by dividing 6-month cost by 26 weeks. (5) Oral warfarin costs represent ambulatory oral prescriptions. These prices were calculated by using CMS published Medicaid FUL prices. Calculations were as follows: assumed a maximum of 90-day prescription for warfarin using FUL prices per tablet plus a typical dispensing fee of \$4.50 (90-day prescription estimated to be \$57.58). Six-month cost estimate is twice this amount. Weekly cost is estimated by maximum of 90-day prescription for warfarin using FUL prices per tablet plus a typical dispensing fee of \$4.50 (90-day prescription estimated to be \$57.58). Six-month cost estimate is twice this amount. Weekly cost is estimated by dividing 6-month cost by 26 weeks.

§5,000 U every 12 hours has also been used but appears to be less effective.

‡Duration is for length of hospital stay or until ambulatory.

§5,000 U every 12 hours has also been used but appears to be less effective.

||Not approved by the US Food and Drug Administration for this indication.

¶For 5-7 days minimum and until INR is in the therapeutic range for 2 consecutive days if changing to warfarin.

#Significant renal clearance; avoid in patients with creatinine clearance < 35 mL/min or adjust dose based on anti-factorXa levels.

**Optimal dosing unclear in patients > 120 kg.

††PTT range of 1.5 to 2.5× the control value is commonly used. The best approach is to determine the PTT therapeutic range using the local method to correspond to a heparin level of 0.3 to 0.7 U/mL using a chromogenic Xa assay.

‡‡Total duration of therapy depends on clinical circumstances. Treatment for 6 months or longer is usually needed with active cancer.

325 mg of aspirin daily. Although the observed rate of VTE was lower than in a previous study of lenalidomide plus dexamethasone without aspirin prophylaxis, another trial casts doubt on the efficacy of aspirin as an antithrombotic agent in this population.^{100,101} Although similar concerns have arisen with novel antiangiogenic agents such as bevacizumab, the available data on the risk of thrombosis are contradictory, although a consistent increase in bleed risk has been encountered.^{11,31,102,103}

3. SHOULD PATIENTS WITH CANCER UNDERGOING SURGERY RECEIVE PERIOPERATIVE VTE PROPHYLAXIS?

Recommendations

(1) All patients undergoing major surgical intervention for malignant disease should be considered for thromboprophylaxis.

(2) Patients undergoing laparotomy, laparoscopy, or thoracotomy lasting greater than 30 minutes should receive pharmacologic

thromboprophylaxis with either low-dose UFH or LMWH unless contraindicated because of a high risk of bleeding or active bleeding.

(3) Prophylaxis should be commenced preoperatively, or as early as possible in the postoperative period.

(4) Mechanical methods may be added to pharmacologic methods, but should not be used as monotherapy for VTE prevention unless pharmacologic methods are contraindicated because of active bleeding.

(5) A combined regimen of pharmacologic and mechanical prophylaxis may improve efficacy, especially in the highest-risk patients.

(6) Prophylaxis should be continued for at least 7 to 10 days postoperatively. Prolonged prophylaxis for up to 4 weeks may be considered in patients undergoing major abdominal or pelvic surgery for cancer with high-risk features such as residual malignant disease after operation, obese patients, and those with a previous history of VTE.

Literature Review and Analysis

Risk of VTE in surgery. VTE is a common complication in cancer surgical patients.¹⁰⁴ The presence of malignant disease doubles the risk for DVT,¹⁰⁵ with reported incidences of asymptomatic calf vein thrombi at 40% to 80%, proximal-vein thrombi 10% to 20%, PE 4% to 10%, and fatal PE 1% to 5% without perioperative thromboprophylaxis.⁵⁵ Factors influencing the risk of VTE in this setting include advanced age (OR = 2.6), higher stage of disease (OR = 2.7), increasing duration of anesthesia (OR = 4.5), prolonged postoperative immobilization (OR = 4.4), and previous history of VTE (OR = 6.0).³² Up to one fourth of symptomatic thromboembolic events occur after discharge and require readmission to the hospital.¹⁰⁶ Importantly, in an observational study, 40% of VTE events occurred 21 days after surgery and VTE was responsible for 46% of deaths within 30 days after surgery.³² All patients undergoing major surgical intervention for malignant disease (laparotomy, laparoscopy, or thoracotomy lasting greater than 30 minutes) are considered at high risk for the development of VTE. On the other hand, surgery for malignant disease is associated with a greater frequency of bleeding complications, and need for blood transfusion independent of the type of prophylaxis employed.⁹⁵ An assessment of the risk of postoperative bleeding is based on several surgical considerations, including the extent of dissection and the adequacy of intraoperative hemostasis.

VTE prophylaxis in the surgical setting includes mechanical and pharmacologic methods. Mechanical methods overcome venous stasis either passively with graduated compression stockings, or actively with intermittent pneumatic calf compression (IPC) or mechanical foot pumps. Pharmacologic methods of thromboprophylaxis include UFH, LMWHs, fondaparinux (an indirect inhibitor of activated factor Xa), and the vitamin K antagonists.

Mechanical prophylaxis. Recent pooled analyses of studies of all three mechanical methods of thromboprophylaxis, evaluated in different patient populations, indicate that these methods employed as monotherapy for VTE prevention reduce the frequency of DVT by 66%, but only achieve a modest and insignificant reduction of 31% in the frequency of PE.⁹⁷ In a small study, 355 patients were randomly assigned to calf compression or control in trials that reported results for patients with cancer alone.⁹⁸ Rates of DVT decreased from 21% (control) to 12.8% with IPC. Pneumatic calf compression for 5 days has been shown in controlled trials to be of value in reducing VTE in both gynecologic malignancies and intracranial surgery. Its value in reducing VTE in gynecologic malignancy has been demonstrated in a controlled trial in which DVT rates decreased from 34.6% to 12.7% ($P < .005$).¹⁰⁷ Venous thrombosis detected by radioactive fibrinogen uptake decreased from 18.4% to 1.9% ($P = .0051$) in 102 patients undergoing craniotomy for brain tumor, subarachnoid hemorrhage, or subdural hematoma.¹⁰⁸

UFH. Low-dose UFH has been evaluated extensively for both the prevention of postoperative DVT and fatal PE.⁵⁰ Low-dose UFH is administered in a dose of 5,000 units, commencing 2 hours before operation, and continued every 8 hours subcutaneously after surgery. In cancer surgery patients it reduces DVT rates from 22% in controls to 9%.¹⁰⁹ In a meta-analysis of 10 trials with 919 patients with cancer, low-dose UFH prophylaxis reduced DVT rates from 30.6% in the control group to 13.6% in those receiving the active treatment ($P < .001$).⁹⁸ Low-dose UFH is also effective in the prevention of PE, including in those whose operation is undertaken for cancer. Among a subgroup of 953 patients with cancer randomly assigned to low-dose

heparin or control arms in the International Multicenter Trial, low-dose UFH prophylaxis reduced the frequency of PE from 0.8% in the control group to 0.1% in the UFH group.⁵⁰

LMWH. Studies comparing the effects of LMWH and UFH on DVT rates in patients with cancer indicate broadly similar prophylactic efficacies for these two agents.¹¹⁰⁻¹¹² In a large randomized study of more than 600 assessable patients undergoing planned curative abdominal or pelvic surgery for cancer, enoxaparin 40 mg daily and UFH 5,000 U tid were found to be equally efficacious in reducing VTE, with no differences in bleeding events or other complications.¹¹¹ In a large meta-analysis of available randomized trials comparing LMWH, UFH, and placebo or no treatment, LMWH appeared to be as safe and effective as UFH in reducing VTE, in both the general population and a large subgroup of patients with cancer.⁹¹ Another study compared 2,500 v 5,000 U of LMWH in 2,000 patients who underwent surgery, 65% of whom underwent laparotomy for cancer.¹¹² DVT rates decreased from 14.9% in those receiving 2,500 U to 8.5% in those receiving 5,000 U ($P = .001$). This study is the first to demonstrate that increasing the dose of LMWH can improve its thromboprophylactic efficacy in patients with cancer without increasing bleeding complications.¹¹² Potential advantages favoring LMWHs over UFH in cancer surgery prophylaxis include once-daily versus tid injections and a lower risk of heparin-induced thrombocytopenia.

Fondaparinux. Fondaparinux was found to be at least as effective as dalteparin in preventing VTE in an RCT of high-risk abdominal surgery patients.³² Nearly 68% of the 2,048 patients enrolled onto this study had cancer. A post hoc analysis suggested improved efficacy in reducing VTE for fondaparinux versus dalteparin in this large subgroup of patients with cancer.

Combined prophylaxis. A combined regimen of pharmacologic and mechanical prophylaxis may improve efficacy, especially in the highest-risk patients. A Cochrane review of 19 studies showed that low-dose UFH combined with graduated compression stockings was four times more effective for VTE prevention than low-dose UFH alone.¹¹³

Prolonged prophylaxis. Two recent randomized studies suggest that prolonging the duration of prophylaxis up to 4 weeks is even more effective than shorter duration therapy in reducing postoperative VTE.^{114,115} In an RCT, VTE rates were 4.8% in patients receiving enoxaparin for 4 weeks after surgery for abdominal or pelvic cancer versus 12% in patients receiving enoxaparin for 1 week after surgery ($P = .02$).¹¹⁴ In a second randomized study, patients undergoing major abdominal surgery were randomly assigned to receive 4 weeks versus 1 week of dalteparin prophylaxis. VTE rates were 16.3% in the 1-week arm compared with 7.3% in the 4-week prophylaxis arm ($P = .012$).¹¹⁵ More than half of patients in each arm in this second study underwent cancer surgery. There was no increase in bleeding complications associated with prolonged prophylaxis in either study.

Specific surgical populations. Laparoscopic surgery. There are limited data regarding the benefit of thromboprophylaxis in patients undergoing laparoscopic surgery. There are no prospective studies in cancer-specific populations. In a large retrospective study in patients with prostate cancer undergoing laparoscopic radical prostatectomy, the rate of symptomatic VTE was low (0.5%).¹¹⁶ In the absence of prospective data, however, standard prophylactic regimens may be tailored to individual patient risk factors.

Neurosurgery. A randomized trial of 307 patients undergoing neurosurgical procedures showed a significant reduction in VTE with

LMWH and graduated compression stockings combined compared with compression stockings alone.¹¹⁷

Gynecologic oncology. Patients with gynecologic malignancies constitute a high-risk subgroup of surgical patients with cancer and have been studied specifically in clinical trials of both pharmacologic and mechanical thromboprophylaxis. In an RCT involving 185 patients undergoing operation for gynecologic malignancy, 13 of 88 patients (14.8%) receiving low-dose UFH every 12 hours and 12 of 97 patients (12.4%) in the control arm developed VTE, with no significant difference in the incidence of proximal DVT, calf vein thrombosis, or PE.¹¹⁸ However, another study showed that low-dose UFH administered every 8 hours and started before surgery reduced the DVT rate to 4% compared with 19% in the control arm ($P < .001$).¹¹⁹

IPC was equally effective but with no significant complications such as bleeding.¹¹⁹ In a study of patients with gynecologic malignancies undergoing surgery, IPC devices were placed intraoperatively and continued for 5 days.¹⁰⁷ IPC use was associated with a three-fold reduction in VTE. Advantages of IPC devices include safety, ease of use, and lower cost than pharmacologic methods.¹²⁰ Two RCTs and a large retrospective series have found the incidence of VTE to be 1% to 6.5% in a gynecologic oncology patient population treated with low-dose UFH, LMWH, or IPC.¹¹⁹⁻¹²¹ When used during and after major gynecologic surgery, IPC may be as effective as low-dose UFH and LMWH in reducing DVT; unfortunately, most studies have included a small number of patients and these studies have not shown efficacy in lowering the incidence of PE or mortality.¹²⁰⁻¹²² A more intensive prophylaxis regimen consisting of higher or more frequent doses of low-dose UFH or LMWH may be considered in patients with risk factors for IPC failure when used alone, such as age older than 60 years or prior VTE.¹²⁰ Although data are limited in the gynecologic literature on the benefits of using a combination of mechanical and pharmacologic prophylaxis, presence of two of three identified risk factors for failing IPC (age > 60 years, cancer, prior VTE) places patients in the highest risk category for the development of VTE.¹²⁰ A combined approach seems appropriate in the highest-risk patients, and is recommended by the Seventh ACCP Consensus Conference.⁵⁵

4. WHAT IS THE BEST TREATMENT FOR PATIENTS WITH CANCER WITH ESTABLISHED VTE TO PREVENT RECURRENT VTE?

Recommendations

(1) LMWH is the preferred approach for the initial 5 to 10 days of anticoagulant treatment of the cancer patient with established VTE.

(2) LMWH given for at least 6 months is also the preferred approach for long-term anticoagulant therapy. Vitamin K antagonists with a targeted INR of 2 to 3 are acceptable for long-term therapy when LMWH is not available.

(3) After 6 months, indefinite anticoagulant therapy should be considered for selected patients with active cancer, such as those with metastatic disease and those receiving chemotherapy. This recommendation is based on Panel consensus in the absence of clinical trials data.

(4) The insertion of a vena cava filter is only indicated for patients with contraindications to anticoagulant therapy and in those with recurrent VTE despite adequate long-term therapy with LMWH.

(5) For patients with CNS malignancies, anticoagulation is recommended for established VTE as described for other patients with cancer. Careful monitoring is necessary to limit the risk of hemorrhagic complications. Anticoagulation should be avoided in the presence of active intracranial bleeding, recent surgery, pre-existing bleeding diathesis such as thrombocytopenia (platelet count < 50,000/ μ L) or coagulopathy.

(6) For elderly patients, anticoagulation is recommended for established VTE as described for other patients with cancer. Careful monitoring and dose adjustment is necessary to avoid excessive anticoagulation and further increase in the risk of bleeding.

Literature Review and Analysis

Anticoagulant therapy is the preferred approach for most patients with the available agents for VTE prophylaxis and treatment summarized in Table 4 along with estimated costs. However, individual patients may require other modalities, including thrombolysis, thromboembolectomy, and/or placement of an IVC filter. The indications for the use of these additional modalities are essentially the same as for patients who do not have cancer.⁸² Systemic thrombolysis is indicated in selected patients with life-threatening PE, and thrombolysis is indicated for selected patients with massive or nonresolving ileo-femoral thrombosis.

Monotherapy with LMWH. LMWH given for 3 to 6 months is more effective than vitamin K antagonists for preventing recurrent VTE.^{67,123} The risks of LMWH therapy include bleeding complications and osteoporosis. RCTs indicate that the rates of major and overall bleeding with LMWH regimens given for 3 to 6 months are similar to those for patients receiving UFH or LMWH followed by oral vitamin K antagonist therapy.^{65,67,123} Heparin-induced thrombocytopenia and clinically relevant osteoporosis occurred uncommonly. Treatment with subcutaneous LMWH should be given for at least 6 months.⁶⁷ Indefinite treatment should be considered for selected patients with active cancer, such as those with metastatic disease and those receiving chemotherapy, because cancer is a strong continuing risk factor for recurrent VTE. The relative benefits and risks of continuing LMWH beyond 6 months, versus switching to oral vitamin K antagonist therapy, remains a clinical judgment in the individual patient in the absence of clinical trials data. Future studies to evaluate this are necessary.

The CLOT (Randomized Comparison of Low-Molecular-Weight Heparin Versus Oral Anticoagulant Therapy for the Prevention of Recurrent Venous Thromboembolism in Patients with Cancer) study is the largest reported RCT comparing LMWH with vitamin K antagonist therapy in patients with cancer with VTE.⁶⁷ Patients with cancer who had acute, symptomatic proximal DVT, PE, or both, were randomly assigned to receive LMWH (dalteparin 200 IU/kg of body weight subcutaneously once daily for 5 to 7 days) followed by a coumarin derivative for 6 months, or dalteparin alone for an extended period (6 months at 200 IU/kg of body weight once daily for 1 month followed by 150 IU/kg body weight once daily for 5 months). During the 6-month study period, symptomatic, objectively documented recurrent VTE occurred in 27 of 336 patients in the dalteparin-alone group (9%) and in 53 of 336 patients (17%) in the vitamin K antagonist group ($P = .002$), a relative risk reduction of 49%.⁶⁷ Major bleeding occurred in 6% in the dalteparin-alone group and in 4% in the vitamin K antagonist group (not statistically

significant), and corresponding rates of any bleeding were 14% and 19%, respectively.

In the Longitudinal Investigation of Thromboembolism Etiology study, among 200 patients with cancer and acute symptomatic proximal-vein thrombosis observed for 1 year, recurrent VTE occurred in 16 of 100 (16%) patients who received intravenous UFH followed by vitamin K antagonists for 3 months, compared with seven of 100 patients (7%) treated initially and for 3 months with the LMWH tinzaparin (175 U/kg once daily).¹²⁴

In a randomized, open-label multicenter trial, subcutaneous enoxaparin sodium (1.5 mg/kg once a day) was compared with warfarin given for 3 months in 146 patients with VTE and cancer.⁶⁵ Of the 71 assessable patients assigned to receive warfarin, 15 patients (21.1%) experienced one major outcome event defined as major bleeding or recurrent VTE within 3 months compared with seven patients (10.5%) of the 67 assessable patients assigned to receive enoxaparin ($P = .09$). There were six deaths as a result of hemorrhage in the warfarin group compared with none in the enoxaparin group. In an RCT of 122 patients with cancer with acute symptomatic VTE randomly assigned to subcutaneous enoxaparin for up to 180 days versus enoxaparin as initial therapy followed by warfarin, no significant differences in major and minor bleeding rates between treatment groups were reported.¹²⁵ The US Food and Drug Administration recently approved dalteparin sodium for extended treatment of symptomatic VTE to reduce the risk of recurrence of VTE in patients with cancer.^{125a}

Recurrent VTE. Among patients with recurrent VTE despite adequate anticoagulant therapy, the management options include treatment with an alternate anticoagulant regimen (ie, LMWH if the patient had received a vitamin K antagonist) or inserting a vena cava filter. The vena cava filter may be effective for preventing clinically important PE, but data in a cancer-specific population are lacking.¹²⁶ In an 8-year follow-up report of the only randomized study of permanent vena cava filters in the general population, the use of filters reduced the risk of PE, but increased that of DVT and had no effect on survival.¹²⁷ Although less of a concern among patients with extensive cancer and limited life expectancy, consideration should be given to continuing an effective anticoagulant regimen, if it appears safe to do so, to prevent morbidity from recurrent venous thrombosis. The role of removable vena cava filters remains uncertain because of a lack of RCTs evaluating their effectiveness and clinical outcomes. Studies evaluating the use of retrievable filters and the need for concomitant anticoagulant therapy are warranted.

Intracranial malignancy. Patients with cancer with intracranial tumors are at increased risk for thrombotic complications. Anticoagulant therapy is absolutely contraindicated in patients with active intracranial bleeding. In addition, caution is indicated in patients with recent intracranial surgery and those at high risk for falls, pre-existing bleeding diathesis, or poor compliance with medical therapy. However, the presence of an intracranial tumor or brain metastases without evidence of active bleeding is not an absolute contraindication to anticoagulation. Limited data are available regarding the safety and efficacy of antithrombotic therapy in patients with primary or metastatic tumors of the brain who develop concurrent venous thrombosis.¹²⁸⁻¹³³ A high failure rate has been reported with IVC filters, without improved overall survival or reduced intracranial hemorrhage in small retrospective series.¹²⁸⁻¹³⁰ Dose-adjusted UFH and warfarin have been shown to effectively reduce the risk of VTE without

an increase in rates of intracranial bleeding or death and few reported recurrent thromboses.^{128,130-133}

Elderly patients. Elderly patients frequently have concurrent cancer and thrombosis, given that both entities increase with age.¹³⁴ In a large observational study of consecutive patients with VTE, including patients with cancer, fatal bleeding occurred in 0.8% and 0.4% of older and younger patients, respectively (hazard ratio = 2.0; 95% CI, 1.2 to 3.4).¹³⁵ In addition, death from PE occurred in 3.7% of older patients compared to 1.1% for the younger subjects (hazard ratio = 3.6; 95% CI, 2.7 to 4.7). The risk of death due to PE exceeded the incidence of fatal bleeding.¹³⁵ The risk of falls should be considered when anticoagulating an elderly cancer patient.

5. SHOULD PATIENTS WITH CANCER RECEIVE ANTICOAGULANTS IN THE ABSENCE OF ESTABLISHED VTE TO IMPROVE SURVIVAL?

Recommendations

- (1) Anticoagulants are not recommended to improve survival in patients with cancer without VTE.
- (2) Patients with cancer should be encouraged to participate in clinical trials designed to evaluate anticoagulant therapy as an adjunct to standard anticancer therapies.

Literature Review and Analysis

Tumor cells express tissue factor and other procoagulants, and tumors interact with the endothelium, leukocytes, and platelets during invasive growth, dissemination, and formation of metastases. Inhibiting the hemostatic system with UFH or LMWH may alter the biology of cancer and improve survival independent of any direct effect on VTE. Two types of studies have evaluated the value of anticoagulants in patients with cancer as measured by survival in those treated with UFH, LMWH, or vitamin K antagonists.

Evidence from VTE treatment studies. In the first type of trial, patients with cancer with VTE were treated with anticoagulants primarily to prevent recurrent thrombosis, and the effect on survival was a secondary end point. In a retrospective subgroup analysis of a small number of patients with cancer with proximal DVT, those treated with LMWH had a 6-month mortality rate of 7% (one in 15) v 44% (eight in 18) of those treated with UFH ($P = .02$).¹³⁶ Meta-analyses of trials that compared initial VTE therapy with UFH versus LMWH confirmed a survival benefit in patients with cancer randomly assigned to LMWH.^{70,71,137,138} Among nine RCTs, a subgroup analysis of 629 patients with cancer revealed 46 deaths in the LMWH group versus 71 deaths in the UFH group during 3 months of follow-up, for an OR of 0.61 (95% CI, 0.40 to 0.93) in favor of LMWH; this was not attributed to either fatal bleeding or PE. In the CLOT study, overall survival as a secondary outcome was not significantly improved with long-term treatment with an LMWH (dalteparin), compared with short-term treatment with dalteparin followed by long-term treatment with a vitamin K antagonist in patients with cancer with VTE.¹³⁹ However, a post hoc analysis of 150 patients with nonmetastatic disease showed a 12-month survival of 36% in the long-term dalteparin group versus 20% in the short-term dalteparin plus vitamin K antagonist group ($P = .04$). This finding is limited by its post hoc nature, potential imbalance of important prognostic features, and the small number of patients with nonmetastatic disease. These data are provocative but none of these studies was specifically designed to determine the effect of LMWH on survival, and all analyses were performed post hoc.

Evidence from survival studies. Warfarin. The second type of study tested anticoagulants in patients with cancer without thrombosis, with survival as the primary end point. Zacharski et al¹⁴⁰ randomly assigned patients with lung, colon, head and neck, or prostate cancer to standard anticancer therapy versus standard therapy plus warfarin for an average of 26 weeks. There was no difference in overall survival between the two groups. However, among 50 patients with small-cell lung cancer, significant improvements in time to disease progression and in overall survival were observed with warfarin compared with no anticoagulation. In a subsequent study of 328 patients with small-cell lung cancer randomly assigned to chemotherapy alone or to chemotherapy plus warfarin, disease-free survival and overall survival were not statistically improved, although there was a trend favoring warfarin treatment.¹⁴¹ In a Cancer and Leukemia Group B study evaluating warfarin with chemotherapy and radiation therapy in patients with limited-stage small-cell lung cancer, no significant differences were observed in overall, failure-free, or disease-free survival, or in patterns of relapse between the two groups.¹⁴²

UFH. A study of 277 patients with small-cell lung cancer randomly assigned to chemotherapy with or without subcutaneous UFH for 5 weeks reported better complete response rates (37% v 23%; $P = .04$), median survival (317 v 261 days; $P = .01$), and overall survival rates at 1, 2, and 3 years among those receiving UFH.⁷⁷ A subsequent subset analysis showed that the benefit was greater in patients with less extensive disease.

LMWH. In a recent study of 84 patients with small-cell lung cancer randomly assigned to chemotherapy alone or chemotherapy plus dalteparin at a dose of 5,000 U once daily for 18 weeks of chemotherapy, median progression-free survival of 6 and 10 months ($P = .01$) and median overall survival of 8 and 13 months ($P = .01$) were reported in those receiving chemotherapy alone versus chemotherapy plus dalteparin, respectively.¹⁴³ In summary, studies in small-cell lung cancer combining warfarin and chemotherapy and the limited data with UFH or LMWH combined with chemotherapy are of interest but inadequate to base a recommendation upon at this time.

Several other RCTs have evaluated the impact of LMWH therapy on survival in patients with cancer without thrombosis. Kakkar et al¹⁴⁴ conducted an RCT in 385 patients with advanced malignancy assigned to receive either once-daily dalteparin or placebo for 1 year in addition to standard therapy. Although no significant difference in survival was observed overall between the two groups at 1, 2, and 3 years, a post hoc analysis suggested an improved survival with dalteparin in the group of 102 patients who had a better prognosis and were alive 17 months after random assignment. In a study of 304 patients with advanced solid tumors receiving a LMWH (nadroparin), or placebo for 6 weeks with standard therapy, median survival was improved with LMWH (8.0 v 6.6 months; $P = .021$) with a hazard ratio for survival at 1 year of 0.75 (95% CI, 0.59 to 0.96).¹⁴⁵ In a study of 141 patients with advanced breast, colon, lung, or prostate cancer randomly assigned to receive standard therapy alone or in combination with dalteparin daily, no difference in any outcome measures were observed between the two groups, although the small sample size may have led to the study being underpowered.¹⁴⁶

In a recent meta-analysis of the efficacy and safety of anticoagulation in patients with cancer without recognized VTE, 11 RCTs were identified.⁸⁰ Anticoagulants, most notably LMWH, were found to significantly improve overall survival while increasing the risk for

bleeding complications. The authors conclude, based on the limitations of the available data, that the use of anticoagulants in patients with cancer without VTE with the intention of improving survival cannot currently be recommended. Major limitations of the studies include the use of post hoc and subgroup analyses, the heterogeneous patient populations studied, the multiple treatment strategies used, and the small number of patients studied. A significant effect of vitamin K antagonists on survival is unlikely. The impact of anticoagulation on the survival of patients with cancer remains uncertain and warrants further study.

LIMITATIONS OF THE EVIDENCE AND DIRECTIONS FOR FUTURE RESEARCH

Patients with cancer represent a high-risk population for VTE and associated complications including early mortality. The effective and safe prevention of VTE in this population is a laudable goal but remains a challenge in terms of both treatment-associated toxicities and variable evidence from clinical trials, in addition to meta-analyses of such trials. The guideline presented here offers explicit recommendations for the use of anticoagulation and other measures for the prevention of VTE in hospitalized patients with cancer, those receiving cancer chemotherapy on an ambulatory basis, patients with cancer in the perioperative and postoperative period, those with recent prior VTE, and finally, for patients with cancer without an established VTE as a possible adjunct to cancer therapy. Nevertheless, the available data addressing these and related issues are limited. There remains a considerable need for additional research, particularly in the form of large, well-designed, randomized, controlled clinical trials. Systematic reviews and meta-analyses of clinical trials serve a useful purpose in systematically searching for the totality of evidence and, when appropriate, combining the results of smaller and often inconclusive trials. Nevertheless, the quality and validity of meta-analyses are only as valid as those of the individual clinical trials included. Table 5 provides a summary of the Panel Recommendations for VTE.

Prophylaxis in the Various Clinical Settings Considered

Hospitalized patients with cancer should be considered candidates for VTE prophylaxis in the absence of specific contraindications such as active bleeding. As noted above, the recommendations for VTE prophylaxis in hospitalized patients with cancer are based on clinical trials that enrolled, in most cases, only a small proportion of patients with cancer. Although the low complication rates with prophylaxis in the major medical trials appear to justify the use of VTE prophylaxis in hospitalized patients with cancer, none of the randomized studies reported bleeding data specifically in the subgroup of patients with cancer. There are few data available on the prevention of VTE in ambulatory patients with cancer. Although the guideline recommends the use of LMWH or adjusted-dose warfarin in patients receiving thalidomide with chemotherapy or dexamethasone at recognized high risk for VTE, the recommendation is based on nonrandomized studies and extrapolation from randomized studies in other similar high-risk settings. Additional studies are needed to evaluate further the potential risk of VTE and the value of primary prophylaxis in patients receiving novel targeted therapies, particularly the class of antiangiogenic agents. All patients undergoing major surgical intervention for malignant disease should be considered for thromboprophylaxis for at least 7 to 10 days postoperatively. Although prolonged

Table 5. Summary Recommendations and Evidence

Patient Group	Role of VTE Prophylaxis	Evidence
Hospitalized patients with cancer	Patients with cancer should be considered candidates for VTE prophylaxis with anticoagulants (UFH, LMWH, or fondaparinux) in the absence of bleeding or other contraindications to anticoagulation.*	Multiple RCTs of hospitalized medical patients with subgroups of patients with cancer. The 2004 ACCP guidelines strongly recommend (1A) prophylaxis with either low-dose heparin or LMWH for bedridden patients with active cancer.
Ambulatory patients with cancer without VTE receiving systemic chemotherapy	Routine prophylaxis with an antithrombotic agent is not recommended except as noted below. LMWH or adjusted-dose warfarin (INR ~1.5) is recommended in myeloma patients on thalidomide or lenalidomide plus chemotherapy or dexamethasone.	Routine prophylaxis in ambulatory patients receiving chemotherapy is not recommended due to conflicting trials, potential bleeding, the need for laboratory monitoring and dose adjustment, and the relatively low incidence of VTE. This recommendation is based on nonrandomized trial data and extrapolation from studies of postoperative prophylaxis in orthopedic surgery and a trial of adjusted-dose warfarin in breast cancer.
Patients with cancer undergoing surgery	All patients undergoing major surgical intervention† for malignant disease should be considered for thromboprophylaxis with low-dose UFH, LMWH, or fondaparinux starting as early as possible for at least 7-10 days unless contraindicated.* Mechanical methods may be added to anticoagulation in very high risk patients but should not be used alone unless anticoagulation is contraindicated.* LMWH for up to 4 weeks may be considered after major abdominal/pelvic surgery with residual malignant disease, obesity, and a previous history of VTE.	RCTs of UFH and those comparing the effects of LMWH and UFH on DVT rates in patients with cancer indicate broadly similar prophylactic efficacies for these two agents. ^{50,110-112} A Cochrane review of 19 studies. ¹¹³ Recent RCTs suggest that prolonging prophylaxis up to 4 weeks is more effective than short-course prophylaxis in reducing postoperative VTE. ^{114,115}
Treatment of patients with established VTE to prevent recurrence	LMWH is the preferred approach for the initial 5-10 days in cancer patient with established VTE. LMWH for at least 6 months is preferred for long-term anticoagulant therapy. Vitamin K antagonists with a targeted INR of 2-3 are acceptable when LMWH is not available. The CLOT study demonstrated a relative risk reduction of 49% with LMWH v a vitamin K antagonist. ⁶⁷ Dalteparin sodium approved by the FDA for extended treatment of symptomatic VTE to reduce risk of recurrence of VTE in patients with cancer (FDA 2007). Anticoagulation for an indefinite period should be considered for patients with active cancer (metastatic disease; continuing chemotherapy). Inferior vena cava filters are reserved for those with contraindications to anticoagulation or PE despite adequate long-term LMWH.	LMWH for 3 to 6 months is more effective than vitamin K antagonists given for a similar duration for preventing recurrent VTE. ^{67,123} In the absence of clinical trials, benefits and risks of continuing LMWH beyond 6 months is a clinical judgment in the individual patient. Caution is urged in elderly patients and those with intracranial malignancy. Consensus recommendation due to lack of data in cancer-specific populations.
Anticoagulants in the absence of established VTE to improve survival	Anticoagulants are not currently recommended to improve survival in patients with cancer without VTE.	RCTs and meta-analyses of warfarin, UFH, and LMWH have reported encouraging but variable results generally showing clinical benefit only in subgroup analyses. ⁶⁰

Abbreviations: VTE, venous thromboembolism; UFH, unfractionated heparin; LMWH, low molecular weight heparin; RCT, randomized controlled trial; ACCP, American College of Chest Physicians; INR, international normalized ratio; DVT, deep venous thrombosis; PE, pulmonary embolism; CLOT, Randomized Comparison of Low-Molecular-Weight Heparin Versus Oral Anticoagulant Therapy for the Prevention of Recurrent Venous Thromboembolism in Patients with Cancer; FDA, US Food and Drug Administration.

*Relative contraindications to anticoagulation include, among other conditions: active, uncontrollable bleeding; active cerebrovascular hemorrhage; dissecting or cerebral aneurysm; bacterial endocarditis; pericarditis, active peptic or other GI ulceration; severe, uncontrolled or malignant hypertension; severe head trauma, pregnancy (warfarin), heparin-induced thrombocytopenia (heparin, LMWH) and epidural catheter placement.

†Laparotomy, laparoscopy, or thoracotomy lasting > 30 minutes.

prophylaxis for up to 4 weeks may be considered in patients undergoing major abdominal or pelvic surgery for cancer with high-risk features such as obesity, residual cancer, or a previous history of VTE, additional studies are needed to better define the comparative benefits and risks associated with prolonged anticoagulation. LMWH is the preferred approach for both initial and long-term anticoagulant therapy for documented VTE in patients with malignant disease. Al-

though indefinite anticoagulant therapy should be considered for patients with active cancer, including those with metastatic disease or those continuing to receive systemic chemotherapy, this recommendation was based on Panel consensus in the absence of clinical trials data. Additional clinical studies are needed to evaluate the comparative benefits and harms of extended VTE prophylaxis in high-risk patients, including the elderly and those with CNS malignancies.

Finally, anticoagulation cannot currently be recommended to improve survival in patients with cancer without established VTE. However, the results of individual clinical trials and meta-analyses provide conflicting data, which require further investigation. Patients with cancer should be encouraged to participate in clinical trials designed to evaluate anticoagulant therapy as an adjunct to standard anticancer therapies.

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REFERENCES

- Khorana AA, Francis CW, Culakova E: Thromboembolism is a leading cause of death in cancer patients receiving outpatient chemotherapy. *J Thromb Haemost* 5:632-634, 2007
- Heit JA, Silverstein MD, Mohr DN, et al: Risk factors for deep vein thrombosis and pulmonary embolism: A population-based case-control study. *Arch Intern Med* 160:809-815, 2000
- Silverstein MD, Heit JA, Mohr DN, et al: Trends in the incidence of deep vein thrombosis and pulmonary embolism: A 25-year population-based study. *Arch Intern Med* 158:585-593, 1998
- Caine GJ, Stonelake PS, Lip GY, et al: The hypercoagulable state of malignancy: Pathogenesis and current debate. *Neoplasia* 4:465-473, 2002
- Heit JA, O'Fallon WM, Petterson TM, et al: Relative impact of risk factors for deep vein thrombosis and pulmonary embolism: A population-based study. *Arch Intern Med* 162:1245-1248, 2002
- Gomes MP, Deitcher SR: Diagnosis of venous thromboembolic disease in cancer patients. *Oncology (Huntingt)* 17:126-135, 2003; discussion 139-144
- Baron JA, Gridley G, Weiderpass E, et al: Venous thromboembolism and cancer. *Lancet* 351:1077-1080, 1998
- Ottinger H, Belka C, Kozole G, et al: Deep venous thrombosis and pulmonary artery embolism in high-grade non Hodgkin's lymphoma: Incidence, causes and prognostic relevance. *Eur J Haematol* 54:186-194, 1995
- Stein PD, Beemath A, Meyers FA, et al: Incidence of venous thromboembolism in patients hospitalized with cancer. *Am J Med* 119:60-68, 2006
- Cavo M, Zamagni E, Cellini C, et al: Deep-vein thrombosis in patients with multiple myeloma receiving first-line thalidomide-dexamethasone therapy. *Blood* 100:2272-2273, 2002
- Kabbinavar F, Hurwitz HI, Fehrenbacher L, et al: Phase II, randomized trial comparing bevacizumab plus fluorouracil (FU)/leucovorin (LV) with FU/LV alone in patients with metastatic colorectal cancer. *J Clin Oncol* 21:60-65, 2003
- Kuonen BC, Levi M, Meijers JC, et al: Potential role of platelets in endothelial damage observed during treatment with cisplatin, gemcitabine, and the angiogenesis inhibitor SU5416. *J Clin Oncol* 21:2192-2198, 2003
- Shah MA, Ilson D, Kelsen DP: Thromboembolic events in gastric cancer: High incidence in patients receiving irinotecan- and bevacizumab-based therapy. *J Clin Oncol* 23:2574-2576, 2005
- Sørensen HT, Møller M, Olsen JH, et al: Prognosis of cancers associated with venous thromboembolism. *N Engl J Med* 343:1846-1850, 2000
- Khorana AA, Francis CW, Culakova E, et al: Thromboembolism in hospitalized neutropenic cancer patients. *J Clin Oncol* 24:484-490, 2006
- Gallus AS: Prevention of post-operative deep leg vein thrombosis in patients with cancer. *Thromb Haemost* 78:126-132, 1997
- Prandoni P, Lensing AW, Piccioli A, et al: Recurrent venous thromboembolism and bleeding complications during anticoagulant treatment in patients with cancer and venous thrombosis. *Blood* 100:3484-3488, 2002
- Elting LS, Escalante CP, Cooksley C, et al: Outcomes and cost of deep venous thrombosis among patients with cancer. *Arch Intern Med* 164:1653-1661, 2004
- Blom JW, Doggen CJ, Osanto S, et al: Malignancies, prothrombotic mutations, and the risk of venous thrombosis. *JAMA* 293:715-722, 2005
- Chew HK, Wun T, Harvey D, et al: Incidence of venous thromboembolism and its effect on survival among patients with common cancers. *Arch Intern Med* 166:458-464, 2006
- Khorana AA, Francis CW, Culakova E, et al: Risk factors for chemotherapy-associated venous thromboembolism in a prospective observational study. *Cancer* 104:2822-2829, 2005
- Levitani N, Dowlati A, Remick SC, et al: Rates of initial and recurrent thromboembolic disease among patients with malignancy versus those without malignancy: Risk analysis using Medicare claims data. *Medicine (Baltimore)* 78:285-291, 1999
- Sallah S, Wan JY, Nguyen NP: Venous thrombosis in patients with solid tumors: Determination of frequency and characteristics. *Thromb Haemost* 87:575-579, 2002
- Bohlius J, Wilson J, Seidenfeld J, et al: Recombinant human erythropoietins and cancer patients: Updated meta-analysis of 57 studies including 9353 patients. *J Natl Cancer Inst* 98:708-714, 2006
- Barbui T, Finazzi G, Grassi A, et al: Thrombosis in cancer patients treated with hematopoietic growth factors—a meta-analysis: On behalf of the Subcommittee on Haemostasis and Malignancy of the Scientific and Standardization Committee of the ISTH. *Thromb Haemost* 75:368-371, 1996
- Kröger K, Weiland D, Ose C, et al: Risk factors for venous thromboembolic events in cancer patients. *Ann Oncol* 17:297-303, 2006
- Abramson N, Costantino JP, Garber JE, et al: Effect of Factor V Leiden and prothrombin G20210->A mutations on thromboembolic risk in the National Surgical Adjuvant Breast and Bowel

Project Breast Cancer Prevention trial. *J Natl Cancer Inst* 98:904-910, 2006

28. Rajkumar SV, Blood E, Vesole D, et al: Phase III clinical trial of thalidomide plus dexamethasone compared with dexamethasone alone in newly diagnosed multiple myeloma: A clinical trial coordinated by the Eastern Cooperative Oncology Group. *J Clin Oncol* 24:431-436, 2006

29. Zangari M, Anaissie E, Barlogie B, et al: Increased risk of deep-vein thrombosis in patients with multiple myeloma receiving thalidomide and chemotherapy. *Blood* 98:1614-1615, 2001

30. Bennett CL, Angelotta C, Yarnold PR, et al: Thalidomide- and lenalidomide-associated thromboembolism among patients with cancer. *JAMA* 296:2558-2560, 2006

31. Hurwitz H, Fehrenbacher L, Novotny W, et al: Bevacizumab plus irinotecan, fluorouracil, and leucovorin for metastatic colorectal cancer. *N Engl J Med* 350:2335-2342, 2004

32. Agnelli G, Bolis G, Capussotti L, et al: A clinical outcome-based prospective study on venous thromboembolism after cancer surgery: The @RISTOS project. *Ann Surg* 243:89-95, 2006

33. Alcalay A, Wun T, Khatri V, et al: Venous thromboembolism in patients with colorectal cancer: Incidence and effect on survival. *J Clin Oncol* 24:1112-1118, 2006

34. Kennedy M, Andreescu AC, Greenblatt MS, et al: Factor V Leiden, prothrombin 20210A and the risk of venous thrombosis among cancer patients. *Br J Haematol* 128:386-388, 2005

35. Eroglu A, Kurtman C, Ulu A, et al: Factor V Leiden and PT G20210A mutations in cancer patients with and without venous thrombosis. *J Thromb Haemost* 3:1323-1324, 2005

36. Eroglu A, Ulu A, Cam R, et al: Prevalence of Factor V 1691 G-A (Leiden) and prothrombin G20210A polymorphisms and the risk of venous thrombosis among cancer patients. *J Thromb Thrombolysis* 23:31-34, 2007

37. Blom JW, Vanderschoot JP, Oostindier MJ, et al: Incidence of venous thrombosis in a large cohort of 66,329 cancer patients: Results of a record linkage study. *J Thromb Haemost* 4:529-535, 2006

38. Andtbacka RH, Babiera G, Singletary SE, et al: Incidence and prevention of venous thromboembolism in patients undergoing breast cancer surgery and treated according to clinical pathways. *Ann Surg* 243:96-101, 2006

39. Bergqvist D: Risk of venous thromboembolism in patients undergoing cancer surgery and options for thromboprophylaxis. *J Surg Oncol* 95:167-174, 2007

40. Stein PD, Fowler SE, Goodman LR, et al: Multidetector computed tomography for acute pulmonary embolism. *N Engl J Med* 354:2317-2327, 2006

41. Saphner T, Tormey DC, Gray R: Venous and arterial thrombosis in patients who received adjuvant therapy for breast cancer. *J Clin Oncol* 9:286-294, 1991

42. Fisher B, Costantino JP, Wickerham DL, et al: Tamoxifen for prevention of breast cancer: Report of the National Surgical Adjuvant Breast and Bowel Project P-1 Study. *J Natl Cancer Inst* 90:1371-1388, 1998

43. Pritchard KI, Paterson AH, Paul NA, et al: Increased thromboembolic complications with concurrent tamoxifen and chemotherapy in a randomized trial of adjuvant therapy for women with breast cancer: National Cancer Institute of Canada Clinical Trials Group Breast Cancer Site Group. *J Clin Oncol* 14:2731-2737, 1996

44. Rajkumar SV: Thalidomide therapy and deep venous thrombosis in multiple myeloma. *Mayo Clin Proc* 80:1549-1551, 2005

45. Rajkumar SV, Blood E: Lenalidomide and venous thrombosis in multiple myeloma. *N Engl J Med* 354:2079, 2006

46. Knight R, DeLap RJ, Zeldis JB: Lenalidomide and venous thrombosis in multiple myeloma. *N Engl J Med* 354:2079-2080, 2006

47. Lee AY, Levine MN, Butler G, et al: Incidence, risk factors, and outcomes of catheter-related thrombosis in adult patients with cancer. *J Clin Oncol* 24:1404-1408, 2006

48. Tesselar ME, Ouwerkerk J, Nooy MA, et al: Risk factors for catheter-related thrombosis in cancer patients. *Eur J Cancer* 40:2253-2259, 2004

49. Cortelezzi A, Moia M, Falanga A, et al: Incidence of thrombotic complications in patients with haematological malignancies with central venous catheters: A prospective multicentre study. *Br J Haematol* 129:811-817, 2005

50. Prevention of fatal postoperative pulmonary embolism by low doses of heparin: An international multicentre trial. *Lancet* 2:45-51, 1975

51. Collins R, Scrimgeour A, Yusuf S, et al: Reduction in fatal pulmonary embolism and venous thrombosis by perioperative administration of subcutaneous heparin: Overview of results of randomized trials in general, orthopedic, and urologic surgery. *N Engl J Med* 318:1162-1173, 1988

52. Halkin H, Goldberg J, Modan M, et al: Reduction of mortality in general medical in-patients by low-dose heparin prophylaxis. *Ann Intern Med* 96:561-565, 1982

53. Sagar S, Massey J, Sanderson JM: Low-dose heparin prophylaxis against fatal pulmonary embolism. *BMJ* 4:257-259, 1975

54. Sevitt S, Gallagher NG: Prevention of venous thrombosis and pulmonary embolism in injured patients: A trial of anticoagulant prophylaxis with phenindione in middle-aged and elderly patients with fractured necks of femur. *Lancet* 2:981-989, 1959

55. Geerts WH, Pineo GF, Heit JA, et al: Prevention of venous thromboembolism: The Seventh ACCP Conference on Antithrombotic and Thrombolytic Therapy. *Chest* 126:338S-400S, 2004

56. Deitcher SR: Primary prevention of venous thromboembolic events (VTE) in cancer patients: An American survey study. *J Clin Oncol* 22:750s, 2004 (suppl; abstr 8086)

57. Kakkar AK, Levine M, Pinedo HM, et al: Venous thrombosis in cancer patients: Insights from the FRONTLINE survey. *Oncologist* 8:381-388, 2003

58. Kucher N, Koo S, Quiroz R, et al: Electronic alerts to prevent venous thromboembolism among hospitalized patients. *N Engl J Med* 352:969-977, 2005

59. Dickersin K, Scherer R, Lefebvre C: Identifying relevant studies for systematic reviews. *BMJ* 309:1286-1291, 1994

60. Higgins JPT, Green S: *Cochrane Handbook for Systematic Reviews of Interventions* 4.2.5, 2005. <http://www.mrw.interscience.wiley.com/cochrane/clcmr/articles/CMR-7606/frame.html>

61. Moher D, Jadad AR, Nichol G, et al: Assessing the quality of randomized controlled trials: An annotated bibliography of scales and checklists. *Control Clin Trials* 16:62-73, 1995

62. Smorenburg SM, Hettiarachchi RJ, Vink R, et al: The effects of unfractionated heparin on survival in patients with malignancy: A systematic review. *Thromb Haemost* 82:1600-1604, 1999

63. Vigna-Taglianti F, Vineis P, Liberati A, et al: Quality of systematic reviews used in guidelines for oncology practice. *Ann Oncol* 17:691-701, 2006

64. Guyatt G, Schunemann HJ, Cook D, et al: Applying the grades of recommendation for anti-thrombotic and thrombolytic therapy: The Seventh ACCP Conference on Antithrombotic and Thrombolytic Therapy. *Chest* 126:179S-187S, 2004 (3 suppl)

65. Meyer G, Marjanovic Z, Valcke J, et al: Comparison of low-molecular-weight heparin and warfarin for the secondary prevention of venous thromboembolism in patients with cancer: A randomized controlled study. *Arch Intern Med* 162:1729-1735, 2002

66. Deitcher SR, Kessler CM, Merli G, et al: Secondary prevention of venous thromboembolic events (VTE) in patients with active malignancy: A randomized study of enoxaparin sodium alone vs. initial enoxaparin sodium followed by warfarin for a 180-day period. *J Thromb Haemost* 1, 2003 (suppl 1; abstr OC194)

67. Lee AY, Levine MN, Baker RI, et al: Low-molecular-weight heparin versus a coumarin for the prevention of recurrent venous thromboembolism in patients with cancer. *N Engl J Med* 349:146-153, 2003

68. Hull RD, Pineo GF, Brant RF, et al: Self-managed long-term low-molecular-weight heparin therapy: The balance of benefits and harms. *Am J Med* 120:72-82, 2007

69. Conti S, Guercini F, Iorio A: Low-molecular-weight heparin and cancer survival: Review of the literature and pooled analysis of 1,726 patients treated for at least three months. *Pathophysiol Haemost Thromb* 33:197-201, 2003

70. Hettiarachchi RJ, Smorenburg SM, Ginsberg J, et al: Do heparins do more than just treat thrombosis? The influence of heparins on cancer spread. *Thromb Haemost* 82:947-952, 1999

71. Siragusa S, Cosmi B, Piovella F, et al: Low-molecular-weight heparins and unfractionated heparin in the treatment of patients with acute venous thromboembolism: Results of a meta-analysis. *Am J Med* 100:269-277, 1996

72. Smorenburg SM, Vink R, Otten HM, et al: The effects of vitamin K-antagonists on survival of patients with malignancy: A systematic analysis. *Thromb Haemost* 86:1586-1587, 2001

73. Leonardi MJ, McGory ML, Ko CY: A systematic review of deep venous thrombosis prophylaxis in cancer patients: Implications for improving quality. *Ann Surg Oncol* 14:929-936, 2007

74. Rasmussen MS: Preventing thromboembolic complications in cancer patients after surgery: A role for prolonged thromboprophylaxis. *Cancer Treat Rev* 28:141-144, 2002

75. Rasmussen E, Wille-Jorgensen P, Jorgensen LN: Extended out-of-hospital low-molecular-weight heparin prophylaxis against venous thromboembolism in patients after cancer operations: A meta-analysis. *J Thrombosis Haemostasis* 3, 2005 (suppl 1; abstr P2213)

76. Jorgensen LN, Lausen I, Rasmussen MS: Prolonged thromboprophylaxis with low molecular weight heparin (tinzaparin) following major general surgery primarily for cancer: An individual patient data meta-analysis. *J Thromb Haemost* 1, 2005 (suppl 1; abstr P1870)

77. Lebeau B, Chastang C, Brechot JM, et al: Subcutaneous heparin treatment increases survival in small cell lung cancer: "Petites Cellules" Group. *Cancer* 74:38-45, 1994

78. Fielding LP, Hittinger R, Grace RH, et al: Randomised controlled trial of adjuvant chemotherapy by portal-vein perfusion after curative resection

for colorectal adenocarcinoma. *Lancet* 340:502-506, 1992

79. Nitti D, Wils J, Sahmoud T, et al: Final results of a phase III clinical trial on adjuvant intraportal infusion with heparin and 5-fluorouracil (5-FU) in resectable colon cancer (EORTC GITCCG 1983-1987): European Organization for Research and Treatment of Cancer, Gastrointestinal Tract Cancer Cooperative Group. *Eur J Cancer* 33:1209-1215, 1997

80. Kuderer NM, Khorana AA, Lyman GH, et al: A meta-analysis and systematic review of the efficacy and safety of anticoagulants as cancer treatment: Impact on survival and bleeding complications. *Cancer* 110:1149-1161, 2007

81. Hirsh J, Guyatt G, Albers GW, et al: The seventh ACCP guidelines are antithrombotic and thrombolytic therapy: Evidence-based guidelines. *Chest* 126:172S-173S, 2004

82. Büller HR, Agnelli G, Hull RD, et al: Antithrombotic therapy for venous thromboembolic disease: The Seventh ACCP Conference on Antithrombotic and Thrombolytic Therapy. *Chest* 126:401S-428S, 2004 (3 suppl)

83. Mandalà M, Falanga A, Piccioli A, et al: Venous thromboembolism and cancer: Guidelines of the Italian Association of Medical Oncology (AIOM). *Crit Rev Oncol Hematol* 59:194-204, 2006

84. Khorana AA, Francis CW, Culakova E, et al: Frequency, risk factors, and trends for venous thromboembolism among hospitalized cancer patients. *Cancer* 2007 [Epub ahead of print] PMID: 17918266

85. Alikhan R, Cohen AT, Combe S, et al: Risk factors for venous thromboembolism in hospitalized patients with acute medical illness: Analysis of the MEDENOX Study. *Arch Intern Med* 164:963-968, 2004

86. Samama MM, Cohen AT, Darmon JY, et al: A comparison of enoxaparin with placebo for the prevention of venous thromboembolism in acutely ill medical patients: Prophylaxis in Medical Patients with Enoxaparin Study Group. *N Engl J Med* 341:793-800, 1999

87. Leizorovicz A, Cohen AT, Turpie AG, et al: Randomized, placebo-controlled trial of dalteparin for the prevention of venous thromboembolism in acutely ill medical patients. *Circulation* 110:874-879, 2004

88. Cohen AT, Davidson BL, Gallus AS, et al: Efficacy and safety of fondaparinux for the prevention of venous thromboembolism in older acute medical patients: Randomised placebo controlled trial. *BMJ* 332:325-329, 2006

89. Alikhan R, Cohen AT, Combe S, et al: Prevention of venous thromboembolism in medical patients with enoxaparin: A subgroup analysis of the MEDENOX study. *Blood Coagul Fibrinolysis* 14:341-346, 2003

90. Gärdlund B: Randomised, controlled trial of low-dose heparin for prevention of fatal pulmonary embolism in patients with infectious diseases: The Heparin Prophylaxis Study Group. *Lancet* 347:1357-1361, 1996

91. Mismetti P, Laporte-Simitsidis S, Tardy B, et al: Prevention of venous thromboembolism in internal medicine with unfractionated or low-molecular-weight heparins: A meta-analysis of randomised clinical trials. *Thromb Haemost* 83:14-19, 2000

92. Vaitkus PT, Leizorovicz A, Cohen AT, et al: Mortality rates and risk factors for asymptomatic deep vein thrombosis in medical patients. *Thromb Haemost* 93:76-79, 2005

93. Levine M, Hirsh J, Gent M, et al: Double-blind randomised trial of a very-low-dose warfarin for prevention of thromboembolism in stage IV breast cancer. *Lancet* 343:886-889, 1994

94. Haas SK: Prevention of venous thromboembolism with low-molecular-weight heparin in patients with metastatic breast or lung cancer: Results of the TOPIC Studies. *J Thromb Haemost* 3, 2005 (suppl 1; abstr OR059)

95. Kakkar AK, Haas S, Wolf H, et al: Evaluation of perioperative fatal pulmonary embolism and death in cancer surgical patients: The MC-4 cancer substudy. *Thromb Haemost* 94:867-871, 2005

96. Kearon C, Hirsh J: Management of anticoagulation before and after elective surgery. *N Engl J Med* 336:1506-1511, 1997

97. Roderick P, Nicholson T, Armitage A, et al: An evaluation of the costs, effectiveness and quality of renal replacement therapy provision in renal satellite units in England and Wales. *Health Technol Assess* 9:1-178, 2005

98. Clagett GP, Reisch JS: Prevention of venous thromboembolism in general surgical patients: Results of meta-analysis. *Ann Surg* 208:227-240, 1988

99. Rajkumar SV, Hayman SR, Lacy MQ, et al: Combination therapy with lenalidomide plus dexamethasone (Rev/Dex) for newly diagnosed myeloma. *Blood* 106:4050-4053, 2005

100. Dimopoulos M, Weber D, et al: Evaluating oral lenalidomide (Revlimid) and dexamethasone versus placebo and dexamethasone in patients with relapsed or refractory multiple myeloma. *Haematologica* 90:160, 2005

101. Zonder JA, Barlogie B, Durie BG, et al: Thrombotic complications in patients with newly diagnosed multiple myeloma treated with lenalidomide and dexamethasone: Benefit of aspirin prophylaxis. *Blood* 108:403, 2006

102. Miller KD, Chap LL, Holmes FA, et al: Randomized phase III trial of capecitabine compared with bevacizumab plus capecitabine in patients with previously treated metastatic breast cancer. *J Clin Oncol* 23:792-799, 2005

103. Johnson DH, Fehrenbacher L, Novotny WF, et al: Randomized phase II trial comparing bevacizumab plus carboplatin and paclitaxel with carboplatin and paclitaxel alone in previously untreated locally advanced or metastatic non-small-cell lung cancer. *J Clin Oncol* 22:2184-2191, 2004

104. Kakkar AK, Williamson RC: Thromboprophylaxis in malignant disease. *Br J Surg* 82:724-725, 1995

105. Kakkar VV, Howe CT, Nicolaidis AN, et al: Deep vein thrombosis of the leg: Is there a "high risk" group? *Am J Surg* 120:527-530, 1970

106. Huber O, Bounameaux H, Borst F, et al: Postoperative pulmonary embolism after hospital discharge: An underestimated risk. *Arch Surg* 127:310-313, 1992

107. Clarke-Pearson DL, Synan IS, Hinshaw WM, et al: Prevention of postoperative venous thromboembolism by external pneumatic calf compression in patients with gynecologic malignancy. *Obstet Gynecol* 63:92-98, 1984

108. Turpie AG, Gallus A, Beattie WS, et al: Prevention of venous thrombosis in patients with intracranial disease by intermittent pneumatic compression of the calf. *Neurology* 27:435-438, 1977

109. Gallus AS, Hirsh J, O'Brien SE, et al: Prevention of venous thrombosis with small, subcutaneous doses of heparin. *JAMA* 235:1980-1982, 1976

110. Comparison of a low molecular weight heparin and unfractionated heparin for the prevention of deep vein thrombosis in patients undergoing ab-

dominal surgery: The European Fraxiparin Study (EFS) Group. *Br J Surg* 75:1058-1063, 1988

111. Efficacy and safety of enoxaparin versus unfractionated heparin for prevention of deep vein thrombosis in elective cancer surgery: A double-blind randomized multicentre trial with venographic assessment—ENOXACAN Study Group. *Br J Surg* 84:1099-1103, 1997

112. Bergqvist D, Burmark US, Flordal PA, et al: Low molecular weight heparin started before surgery as prophylaxis against deep vein thrombosis: 2500 versus 5000 Xal units in 2070 patients. *Br J Surg* 82:496-501, 1995

113. Wille-Jørgensen P, Rasmussen MS, Andersen BR, et al: Heparins and mechanical methods for thromboprophylaxis in colorectal surgery. *Cochrane Database Syst Rev* 4:CD001217, 2003

114. Bergqvist D, Agnelli G, Cohen AT, et al: Duration of prophylaxis against venous thromboembolism with enoxaparin after surgery for cancer. *N Engl J Med* 346:975-980, 2002

115. Rasmussen GS, Jørgensen LN, Wille-Jørgensen P, et al: Prolonged prophylaxis with dalteparin to prevent late thromboembolic complications in patients undergoing major abdominal surgery: A multicenter randomized open-label study. *J Thromb Haemost* 4:2384-2390, 2006

116. Secin FP, Jiborn T, Bjartell AS, et al: Multi-institutional study of symptomatic deep venous thrombosis and pulmonary embolism in prostate cancer patients undergoing laparoscopic or robot-assisted laparoscopic radical prostatectomy. *Eur Urol* [Epub ahead of print on June 11, 2007]

117. Agnelli G, Piovello F, Buoncristiani P, et al: Enoxaparin plus compression stockings compared with compression stockings alone in the prevention of venous thromboembolism after elective neurosurgery. *N Engl J Med* 339:80-85, 1998

118. Clarke-Pearson DL, Synan IS, Dodge R, et al: A randomized trial of low-dose heparin and intermittent pneumatic calf compression for the prevention of deep venous thrombosis after gynecologic oncology surgery. *Am J Obstet Gynecol* 168:1146-1153, 1993; discussion 1153-1154

119. Clarke-Pearson DL: Prevention of venous thromboembolism in gynecologic surgery patients. *Curr Opin Obstet Gynecol* 5:73-79, 1993

120. Clarke-Pearson DL, Dodge RK, Synan I, et al: Venous thromboembolism prophylaxis: Patients at high risk to fail intermittent pneumatic compression. *Obstet Gynecol* 101:157-163, 2003

121. Maxwell GL, Synan I, Dodge R, et al: Pneumatic compression versus low molecular weight heparin in gynecologic oncology surgery: A randomized trial. *Obstet Gynecol* 98:989-995, 2001

122. Ginzburg E, Cohn SM, Lopez J, et al: Randomized clinical trial of intermittent pneumatic compression and low molecular weight heparin in trauma. *Br J Surg* 90:1338-1344, 2003

123. Tsai AW, Cushman M, Rosamond WD, et al: Coagulation factors, inflammation markers, and venous thromboembolism: The Longitudinal Investigation of Thromboembolism Etiology (LITE). *Am J Med* 113:636-642, 2002

124. Hull RD, Pineo GF, Brant RF, et al: Long-term low-molecular-weight heparin versus usual care in proximal-vein thrombosis patients with cancer. *Am J Med* 119:1062-1072, 2006

125. Deitcher SR, Kessler CM, Merli G, et al: Secondary prevention of venous thromboembolic events in patients with active cancer: Enoxaparin alone versus initial enoxaparin followed by warfarin for a 180-day period. *Clin Appl Thromb Hemost* 12:389-396, 2006

- 125a.** Department of Health and Human Services: Lovenox. www.fda.gov/cder/ogd/rld/20164s36.pdf
- 126.** Decousus H, Leizorovicz A, Parent F, et al: A clinical trial of vena caval filters in the prevention of pulmonary embolism in patients with proximal deep-vein thrombosis: Prevention du Risque d'Embolie Pulmonaire par Interruption Cave Study Group. *N Engl J Med* 338:409-415, 1998
- 127.** Eight-year follow-up of patients with permanent vena cava filters in the prevention of pulmonary embolism: The PREPIC (Prevention du Risque d'Embolie Pulmonaire par Interruption Cave) randomized study. *Circulation* 112:416-422, 2005
- 128.** Levin JM, Schiff D, Loeffler JS, et al: Complications of therapy for venous thromboembolic disease in patients with brain tumors. *Neurology* 43:1111-1114, 1993
- 129.** Olin JW, Young JR, Graor RA, et al: Treatment of deep vein thrombosis and pulmonary emboli in patients with primary and metastatic brain tumors: Anticoagulants or inferior vena cava filter? *Arch Intern Med* 147:2177-2179, 1987
- 130.** Schiff D, DeAngelis LM: Therapy of venous thromboembolism in patients with brain metastases. *Cancer* 73:493-498, 1994
- 131.** Ruff RL, Posner JB: Incidence and treatment of peripheral venous thrombosis in patients with glioma. *Ann Neurol* 13:334-336, 1983
- 132.** Altschuler E, Moosa H, Selker RG, et al: The risk and efficacy of anticoagulant therapy in the treatment of thromboembolic complications in patients with primary malignant brain tumors. *Neurosurgery* 27:74-76, 1990; discussion 77
- 133.** Choucair AK, Silver P, Levin VA: Risk of intracranial hemorrhage in glioma patients receiving anticoagulant therapy for venous thromboembolism. *J Neurosurg* 66:357-358, 1987
- 134.** Bates SM, Ginsberg JS: Clinical practice: Treatment of deep-vein thrombosis. *N Engl J Med* 351:268-277, 2004
- 135.** López-Jiménez L, Montero M, Gonzalez-Fajardo JA, et al: Venous thromboembolism in very elderly patients: Findings from a prospective registry (RIETE). *Haematologica* 91:1046-1051, 2006
- 136.** Prandoni P, Lensing AW, Buller HR, et al: Comparison of subcutaneous low-molecular-weight heparin with intravenous standard heparin in proximal deep-vein thrombosis. *Lancet* 339:441-445, 1992
- 137.** Dolovich LR, Ginsberg JS, Douketis JD, et al: A meta-analysis comparing low-molecular-weight heparins with unfractionated heparin in the treatment of venous thromboembolism: Examining some unanswered questions regarding location of treatment, product type, and dosing frequency. *Arch Intern Med* 160:181-188, 2000
- 138.** Gould MK, Dembitzer AD, Doyle RL, et al: Low-molecular-weight heparins compared with unfractionated heparin for treatment of acute deep venous thrombosis: A meta-analysis of randomized, controlled trials. *Ann Intern Med* 130:800-809, 1999
- 139.** Lee AY, Rickles FR, Julian JA, et al: Randomized comparison of low molecular weight heparin and coumarin derivatives on the survival of patients with cancer and venous thromboembolism. *J Clin Oncol* 23:2123-2129, 2005
- 140.** Zacharski LR, Henderson WG, Rickles FR, et al: Effect of warfarin anticoagulation on survival in carcinoma of the lung, colon, head and neck, and prostate: Final report of VA Cooperative Study #75. *Cancer* 53:2046-2052, 1984
- 141.** Chahinian AP, Propert KJ, Ware JH, et al: A randomized trial of anticoagulation with warfarin and of alternating chemotherapy in extensive small-cell lung cancer by the Cancer and Leukemia Group B. *J Clin Oncol* 7:993-1002, 1989
- 142.** Maurer LH, Herndon JE II, Hollis DR, et al: Randomized trial of chemotherapy and radiation therapy with or without warfarin for limited-stage small-cell lung cancer: A Cancer and Leukemia Group B study. *J Clin Oncol* 15:3378-3387, 1997
- 143.** Altinbas M, Coskun HS, Er O, et al: A randomized clinical trial of combination chemotherapy with and without low-molecular-weight heparin in small cell lung cancer. *J Thromb Haemost* 2:1266-1271, 2004
- 144.** Kakkar AK, Levine MN, Kadziola Z, et al: Low molecular weight heparin, therapy with dalteparin, and survival in advanced cancer: The fragmin advanced malignancy outcome study (FAMOUS). *J Clin Oncol* 22:1944-1948, 2004
- 145.** Klerk CP, Smorenburg SM, Otten HM, et al: The effect of low molecular weight heparin on survival in patients with advanced malignancy. *J Clin Oncol* 23:2130-2135, 2005
- 146.** Sideras K, Schaefer PL, Okuno SH, et al: Low-molecular-weight heparin in patients with advanced cancer: A phase 3 clinical trial. *Mayo Clin Proc* 81:758-767, 2006

Appendix

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