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Impact of a risk-stratified thromboprophylaxis protocol on the incidence of postoperative venous thromboembolism and bleeding*

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Short title: Impact of a risk-stratified thromboprophylaxis model

Summary

Efforts to reduce postoperative venous thromboembolism are challenging due to significant heterogeneity in thromboprophylaxis practice. As a result, a 'one-size-fits-all' approach that accounts for surgery-specific risk, but fails to account for patient-level variation, is often adopted by healthcare networks. Updated clinical practice guidelines have advocated an individualised risk-stratified approach that balances the risk:benefit ratio associated with thromboprophylaxis; however, there are limited data confirming effectiveness of these recommendations on the incidence of postoperative venous thromboembolism and bleeding. We developed the surgical-thrombo-embolism-prevention protocol, a novel risk-stratified algorithm that classified patients into low-, intermediate-, and high-risk profiles according to surgical procedure and patient baseline medical risk. Expert-endorsed risk-specific thromboprophylaxis strategies were then applied. A staged quality improvement program was developed to implement the protocol. We postulated that compliance with the protocol would reduce postoperative venous thromboembolism rates without increasing the incidence of postoperative bleeding. Between June 2013 and March 2018, we evaluated the efficacy, safety and sustainability of this risk-stratified approach in 24,953 surgical admissions at a dedicated cancer centre. By final implementation, program compliance was 91%. Postoperative venous thromboembolism rates reduced from 3.1 per 1000 surgical admissions to 0.6 per 1000 surgical admissions (relative risk reduction 79%; $p < 0.005$). Postoperative bleeding rates also declined from 10.0 per 1000 surgical admissions to 6.3 per 1000 surgical admissions (relative risk reduction 37%; $p = 0.02$). Sustained improvement was evident more than three years after implementation. Implementation of the surgical-thrombo-embolism-prevention protocol significantly reduced the incidence of postoperative venous thromboembolism supporting its validation at other institutions.

Postoperative venous thromboembolism (VTE) remains an important cause of morbidity and mortality [1]. Approximately 2–13 in every 1000 elective surgical admissions in Australia develop a symptomatic postoperative VTE and this is associated with a 10% case fatality rate [2-4]. Prevention of VTE remains a worldwide priority safety initiative, with the Agency for

Healthcare Research and Quality ranking this the number-one patient safety practice for hospitals [5]. However, despite the widespread availability of updated clinical practice guidelines and implementation of a number of national and international quality improvement initiatives, the rates of symptomatic VTE and VTE-related deaths have not declined [6]. The reasons for this are multifactorial and include: poor adoption and implementation of clinical practice guidelines; significant heterogeneity in surgical and patient comorbid risk; and clinician uncertainty with regards to the choice and duration of application of optimal thromboprophylaxis strategies [7-10]. This variable risk then needs to be balanced against the risks and benefits associated with mechanical and/or pharmacological thromboprophylaxis.

An individualised risk-stratified approach to postoperative VTE prevention was proposed over 25 years ago [11]. This method has found little traction in the acute care setting and a population-based 'one-size-fits-all' approach, accounting for procedure-related risk is applied commonly due to its ease of adoption and avoidance of the need for complex risk-assessment algorithms [12]. However, this approach does not take into account the competing aims and risks of anticoagulant medication for VTE prevention and bleeding, nor does it address patient-specific risks. We aimed to assess the impact of an individualised risk-stratified decision support algorithm on the incidence of postoperative VTE and bleeding rates through the implementation of a multi-stage quality improvement initiative led by peri-operative physicians, including anaesthetists, pharmacists and haematologists.

Method

Between June 2013 and March 2018, we developed and implemented a four-stage quality improvement program at the Peter MacCallum Cancer Centre, Melbourne, Australia. Ethical approval was obtained from the hospital's human research and ethics committee and requirement for written informed consent was waived.

All surgical admissions were enrolled over the four stages of the project. This included adult patients from a broad spectrum of cancer surgery specialties including: head and neck; breast; endocrine; pulmonary; upper gastrointestinal; hepatobiliary; colorectal; genitourinary; sarcoma; and plastic/reconstructive surgery. Patients underwent minor diagnostic or definitive therapeutic procedures. Implementation followed known quality

improvement methodology using the Institute for Healthcare Improvement's plan-do-study-act (PDSA) model [13]. Figure 1 outlines the design and implementation stages.

After completion of a baseline audit, we developed the surgical-thrombo-embolism-prevention (STEP) quality improvement program. The development strategy involved a multidisciplinary approach which included haematology, anaesthesia, surgery, pharmacy, nursing and other stakeholders.

The Agency for Healthcare Research and Quality has developed a set of internationally recognised patient safety indicators that measure the quality of healthcare provided by institutions using readily available administrative data [14]. These patient safety indicators have been adapted to the Australian healthcare system using codes from the 10th revision of the International Statistical Classification of Disease Australian Modification (ICD-10-AM) [15]. Potential postoperative VTE and bleeding events were identified using ICD-10-AM codes assigned for each episode of care and extracted from the hospital's administrative data warehouse that reports to the Victorian admitted episodes dataset (this collects demographic, clinical and administrative details for all episodes of care at Victorian healthcare organisations). For episodes of care that met ICD-10-AM criteria for postoperative VTE and/or bleeding, we undertook a medical record review by trained abstractors to identify true episodes of postoperative VTE and/or bleeding based on strict and explicit diagnostic and exclusion criteria (supplementary material, Table S1). Postoperative VTE was diagnosed if a new thrombus was identified in the lower or upper venous systems, and/or within the pulmonary circulation using specific imaging modalities. Postoperative bleeding followed definitions set by the International Society of Thrombosis and Haemostasis and excluded any intra-operative bleeding event [16]. True positive patient episodes then defined our postoperative VTE and bleeding events and rates.

Stage 1: Baseline prevalence rate and planning

Between June 2013 and July 2014, we evaluated the incidence of postoperative VTE and bleeding rates for all surgical admissions to establish a comparative baseline rate. Synchronously, we conducted a prospective system analysis audit over one month in August 2013 that observed surgical thromboprophylaxis practice. This revealed significant heterogeneity in practice within and across the institution, absence of a formalised risk assessment process, significant underutilisation of mechanical and pharmacological thromboprophylaxis, and no measures to extend thromboprophylaxis beyond discharge.

A steering group was established, consisting of expert clinicians and stakeholders, which identified key targets for intervention including: development of a risk-stratified thromboprophylaxis protocol; education of patients and professional groups in the rationale and planned implementation of the protocol; and a stipulation that all thromboprophylaxis decisions should be made by senior medical staff.

The STEP protocol consisted of a risk-assessment tool and decision-making algorithm and provided risk-category specific thromboprophylaxis recommendations including: type (mechanical, pharmacological); time of initiation; and duration of application of interventions. The risk-assessment model defined the risk profile for the specific patient interaction and included both patient comorbid disease and surgical category risks. The initial step assessed the procedural VTE risk to determine the surgical risk profile (low, intermediate or high) which was then combined with the patient's medical risk profile to generate an overall VTE risk profile. The surgical risk profile considered the duration of surgery and the extent of tissue injury. Surgical duration < 45 min was considered as low VTE risk, non-major surgery $\geq$ 45 min was classified as intermediate VTE risk and major surgery $\geq$ 45 min was classified as high VTE risk (including major abdominopelvic surgeries). Procedures meeting low, intermediate, and high VTE surgical risk classification were also defined. The medical risk was simplified to a VTE risk score based on 13 validated risk factors. Each risk factor was given a weighted risk score from 0.5 to 2 according to published odds ratios (Table 1). A score $\geq$ 2 or escalated the surgical risk profile from low- to intermediate-risk or from intermediate- to high-risk.

The surgical and medical risk profiles together determined the overall VTE risk classification as low, intermediate or high-risk profiles. Figure 2 summarises the STEP protocol. Intermediate and high-risk profiles received intraoperative intermittent pneumatic compression devices such as sequential compression devices (SCDs) and thromboembolic deterrent stockings (TEDs). For high-risk patients pharmacological thromboprophylaxis was added, which was started intra-operatively or within 6 h postoperatively. Pharmacological thromboprophylaxis was continued for at least 28 days for patients having major abdominopelvic surgery and at least 7 days for all other major surgery. Low- and intermediate-risk profile patients that were admitted to hospital received pharmacological thromboprophylaxis only for the duration of their hospital admission (in-patient pharmacological thromboprophylaxis). Low molecular weight heparin was used for pharmacological thromboprophylaxis, with a once daily dosing regimen based on patient

weight: < 50 kg enoxaparin 20 mg; 50-120 kg enoxaparin 40mg; and > 120 kg enoxaparin 60 mg. The dose was reduced by 50% if the patient's creatinine clearance was < 30 ml.min⁻¹. Haematology was consulted for patients on dialysis. Contraindications to thromboprophylaxis were also defined (Supplementary Table S2).

Stage 2: Initial implementation

Following completion of the baseline prevalence audit, initial implementation began in August 2014. The steering group attended surgical, anaesthetic, pharmacy and nursing meetings to introduce the initiative and identify a launch date. Hospital-wide education began in earnest and occurred through face-to-face tutorials, educational material and webmail quizzes. Expectations of care were outlined including the need for risk assessment for all surgical patients; this was mandated at the surgical time-out and incorporated into the World Health Organization (WHO) surgical safety checklist. In addition, the overall risk profile, time of initiation of pharmacological thromboprophylaxis balanced against the risk of postoperative bleeding, and other risk-specific interventions were reconfirmed at the end of the procedure as part of the surgical sign-out. To improve patient awareness of postoperative VTE, targeted educational brochures and risk assessment questionnaires were provided at the time of surgical booking. Daily postoperative rounds were conducted by clinical pharmacists to assess and enhance compliance with the STEP protocol. Post-discharge thromboprophylaxis prescriptions were signed off by clinical pharmacists and prescribed according to the minimal recommended durations. Patients were provided with education with regards to the risk of postoperative VTE and self-administration techniques for enoxaparin. Discharge bundles consisting of educational material and sharps disposal bin were also provided.

To measure compliance a four-week prospective audit was conducted assessing the accuracy of risk assessment and compliance with risk-specific interventions for all surgical admissions. Updates on performance were disseminated to staff, and staff were able to provide feedback to the steering group regarding issues with implementation.

Stage 3: Gap analysis

Following initial implementation, a gap analysis was undertaken to identify barriers affecting successful uptake. These included: high staff turnover that necessitated frequent education;

maintaining awareness of the STEP quality improvement program with current staff; human errors in protocol interpretation; incorrect documentation of in-patient drug charts; and time pressures associated with risk assessment at the surgical time-out. Consequently, targeted interventions were developed and included an e-learning module that newly appointed staff were required to complete during induction. In-patient medication charts were modified to include a section on VTE prophylaxis and protocol recommendations for individual risk profiles.

In order to minimise protocol interpretation errors the steering group developed a decision support smartphone application. The application included a set of questions that were completed by point-of-care users, including the type of surgery and medical risk factors. This then generated an overall risk profile and provided risk appropriate recommendations, including dosing of pharmacological thromboprophylaxis. The STEP protocol application (CLOTS®) was available from online application stores and could be downloaded onto iOS and Android platforms.

A nurse-initiated risk assessment program was introduced, which provided nursing staff from the day surgery assessment unit with education and an electronic tablet for use of the CLOTS application. Nursing staff then generated a summary printout of the patient's risk profile and thromboprophylaxis recommendations which was then used by clinicians at the time-out phase to inform risk assessment and thromboprophylaxis. Protocol awareness was maintained through seminars and research day presentations.

Stage 4: Final implementation

Final implementation occurred between January 2017 and March 2018 after successful institution of targeted interventions. A prospective compliance audit and an audit of accuracy of the nurse-initiated risk assessment program was conducted over a one-month period for all surgical admissions. In addition, the impact of interventions on postoperative VTE and bleeding rates were assessed.

Key outcome data were analysed at the following time points: baseline pre-implementation (June 2013 - July 2014); initial implementation (August 2014 - December 2014); gap analysis (January 2015 - December 2016); and final implementation (January 2017 - March 2018). Compliance rates with the program were assessed prospectively using convenience sampling over one month period in 2014 (initial implementation) and 2017 (final implementation).

Statistical quality control p-charts were used to track postoperative VTE rates during study implementation, with rates (events per 1000 surgical admissions) reported quarterly and variable-width upper and lower confidence limits calculated per quarter. As postoperative VTE and bleeding rates were relatively small, we used the Fisher's exact test to compare proportions of patients with VTE and bleeding during the baseline and final implementation phases; these were reported in terms of relative risk reduction (RRR) with Altman's method for 95%CI. All statistical tests were two-sided and conducted as a significance level of 0.05. Statistical analysis was performed using Stata version 12.1 (StataCorp LP, College Station, TX, USA).

Results

Data were collected from 24,953 surgical admissions (Table 2). Of these, 23,206 (93%) were elective surgical admissions. The mean (SD) hospital length of stay was 3.4 (7.6) days. Of all admissions, 6155 (25%) stayed > 24 h, with a median (IQR [range]) hospital duration of stay of 7 (2-12 [1-239]) days. Surgical activity during the various program stages of baseline, initial implementation, gap analysis and final implementation were 407, 498, 463 and 413 admissions per month, respectively. Among the cohort, 21,677 (87%) patients underwent a low- or intermediate-VTE risk procedure, with 3908 (16%) patients having a VTE risk score ≥ 2 which escalated their VTE risk profile.

The rate of VTE risk assessment at final implementation was 231/232 (99%) patients. The accuracy rate of the nurse-initiated risk assessment program was 213/232 (92%) patients. Compliance with VTE prophylaxis management increased from 166/242 (69%) patients during initial implementation to 211/232 (91%) patients during the final implementation stage (RR [95%CI] 0.29 [0.18-0.45]; $p < 0.0001$). The use of extended pharmacological thromboprophylaxis in patients undergoing major abdominopelvic surgery increased from 1/11 (9%) at baseline to 12/12 (100%) by the final implementation stage (RR [95%CI] 0.04 [0.00-0.67]; $p = 0.025$). Utilisation of sequential compression devices in intermediate- and high-risk patients increased from 55/117 (47%) patients at baseline to 121/133 (91%) patients after final implementation (RR [95%CI] 0.16; [0.08-0.28]; $p < 0.0001$). Following full implementation of the program the postoperative VTE rate reduced from 3.1 per 1000 (20/6491) surgical admissions at baseline to 0.6 per 1000 (4/6195) surgical admissions (relative risk reduction (RRR) [95%CI] 79% [39%-93%]; $p < 0.005$). Sustained improvement was evident more than three years after initial implementation (Fig. 3). Postoperative

bleeding rates also significantly reduced from baseline to the final implementation stages (10.0 (65/6491) per 1000 surgical admissions vs. 6.3 (39/6195) per 1000 surgical admissions respectively; (RRR [95%CI] 37% [6%-58%]; $p = 0.02$) (Table 3)).

Discussion

Implementation of this stepped quality improvement program demonstrated a significant reduction in both postoperative VTE and bleeding rates in a high-risk cancer surgery population. Before this program began, our baseline postoperative VTE and bleeding rates were comparable to administrative database studies by Assareh et al. (2–13 VTE events per 1000 elective surgical admissions) and that reported by the Australian Institute of Health and Welfare on postoperative haemorrhage (4–18 per 1000 surgical admissions) [3, 5-6, 17].

A number of programs have focused on improving risk assessment and prescription of prophylaxis for hospitalised patients with varying degrees of success. Scaglione et al. evaluated the impact of implementing a hospital guideline using educational interventions and found that VTE rates reduced significantly two years after implementation (odds ratio (OR) [95%CI] 0.7 [0.6–0.8]) [18]. By contrast Liu et al. evaluated the impact of the Australian National Inpatient Medication Chart initiative and found that despite an increase in surgical VTE prophylaxis prescriptions and adherence rates, this did not translate to a significant reduction in VTE rates (RR [95%CI] 0.9 [0.5-1.6]) [19]. Another study using a mandatory computerised clinical decision support tool for VTE prevention in hospitalised trauma patients also did not significantly decrease VTE rates but did reduce preventable harm (defined as VTE in patients not-ordered guideline-appropriate prophylaxis) [20].

International survey data repeatedly demonstrates that up to 50% of patients still do not receive appropriate VTE prophylaxis [9]. A leading cause for this relates to the uncertainty of appropriate risk assessment, and incongruence between the risk level and prescribed prophylaxis. Inadequate risk assessment has been shown to predict future VTE events [21]. The STEP protocol used a risk-assessment model that took into account both the procedural (surgical) and medical (co-morbid disease) risk of the individual patient to generate an overall VTE risk profile. Moreover, it also considered real-time surgical haemostasis at the surgical time-out and sign-out decision points. This assessment drove an individualised and risk-stratified VTE prevention strategy that was appropriate for the specific surgical

interaction. The 2013 Quality Systems Assessment data estimated that only 40% of patients are assessed for VTE risk on admission, and only 70% of those at risk receive appropriate prophylaxis [22]. Our protocol enforced risk assessment before the surgical intervention, and this occurred in greater than 99% of patients, thereby achieving a quality measure set by the Care Quality Commission in the United Kingdom [23].

We implemented VTE prophylaxis at the commencement of surgery, and pharmacological thromboprophylaxis (when required) was initiated at or within 6 h of termination of surgery. This initiation time frame, coupled with the surgical sign-out discussion at the end of the procedure, aimed to balance the risk-benefit between VTE prevention and postoperative bleeding, and may explain the observed reduction in postoperative bleeding rates.

Most attempts to improve care have focused primarily on medication prescription rather than the whole process of care [24]. We achieved improved protocol adherence through an active implementation strategy that identified barriers to improvement. Targeted interventions served to maintain awareness of the program and improve on previous innovations. Integrating VTE risk assessment into the WHO surgical safety checklist acted as an active reminder for clinicians to address risk and follow protocol recommendations. Active audits and feedback to clinicians and other healthcare professionals encouraged further improvement. The use of an electronic decision tool through development of the CLOTS smartphone application aimed to reduce human error in protocol interpretation and improve adherence to risk-specific recommendations. Modifying the in-patient medication chart to include a visual reminder for nursing staff and clinicians to adhere to protocol recommendations further improved compliance rates. Finally, the STEP quality improvement program engaged all relevant healthcare teams from the peri-operative to the post-discharge phase. This ensured that VTE prevention was at the forefront of surgical care throughout the patient's surgical journey.

We acknowledge limitations within this study. Our outcome data were screened from ICD-10-AM diagnostic codes and therefore our results are influenced by coding accuracy. While some studies have found that the positive predictive value (PPV) of diagnostic codes for postoperative VTE has ranged from 29% to 79% [25-26], a more recent validation study confirmed that using administrative data ICD codes for VTE screening has a high PPV (89% 95%CI 67%-99%) and thus is a powerful tool for true positive case finding [27]. The authors concluded that these tools could be used to flag potential cases from large volume of

admissions for verification through chart reviews, as was done in our study. Coding accuracy can also impact detection of postoperative bleeding. Previous studies have detected a true incidence of postoperative bleeding in 56-80% of flagged records using discharge codes [28-29]. More recently, Utter et al. found that 93% of cases involved an accurately coded event, but only 70% (PPV 78% 95%CI 58–90%) represented true postoperative bleeding, with false positives due to inclusion of intra-operative bleeding [30]. There are inherent limitations associated with quality improvement methodology, in particular selection bias for patients and operative treatments, which are determined by hospital case mix. We delivered a suite of interventions and improvements over time. We were unable to assess the impact of any one element of the program that had the greatest benefit on reducing VTE rates. We deliberately used the Hawthorne effect to modify hospital culture and drive improved compliance and this might explain the rapid fall in VTE rates after initial implementation. A significant drop in VTE rates was also noted following the integration of the protocol's risk-specific recommendations into the in-patient drug chart. In addition, we were unable to assess patient compliance after hospital discharge; however, patients were provided with educational material and advice from staff at discharge. Finally, this project reports a single-centre experience. Our study cohort included predominantly elective day-case surgical admissions with a high proportion of low- and intermediate-risk procedures, and the observed improvements may not be reproducible at other centers with a higher risk population.

In summary, we developed a quality improvement program led by anaesthetic peri-operative physicians, with multidisciplinary input that included haematologists and pharmacists. The program was patient-centred with an ongoing multimodal implementation strategy. We provided data comparing a risk-stratified response to postoperative VTE prophylaxis side by side with data on bleeding complications. It has been estimated that best practice prophylaxis can reduce the incidence of VTE by up to 70% [24]. Our quality improvement initiative resulted in an almost 80% reduction in postoperative VTE and a 37% reduction in postoperative bleeding rates. Further studies, however, are needed to externally validate our risk assessment model by assessing the impact of this protocol at other institutions and in non-cancer surgical patients.

Acknowledgments and competing interests

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Table 1. The surgical-thrombo-embolism-prevention (STEP) risk assessment model. Medical risk was simplified to 13 validated risk factors, each given a weighted risk-score between 0.5 and 2. The sum of scores calculated the venous thromboembolism (VTE) risk score. BMI, body mass index; MI, myocardial infarction.

	VTE risk/score	Procedures/risk factors
Surgical risk	Low	Endoscopic procedures, excisions of cutaneous lesions
	Intermediate	Procedures on connective tissue, non-complex orthopaedic, head and neck (e.g. thyroidectomy, parotidectomy), breast, non-complex abdominal (e.g. appendectomy), laparoscopic/robotic partial nephrectomy or simple prostatectomy (without pelvic lymph node dissection)
	High	Major intracavity surgery (thoracic/abdominal/pelvic), sarcoma, pelvic lymph node dissection, microvascular free flap reconstruction, vascular, complex orthopaedic, cardiothoracic, oesophagectomy, cranial/spinal procedures
	Major abdominopelvic	Colectomies, anterior or abdominoperineal resections, pelvic exenteration, major debulking surgery including hyperthermic intraperitoneal chemotherapy, liver resections
Medical risk	0.5	Age > 60 years
	0.5	BMI 35-40 kg.m ⁻²
	0.5	Heart failure or acute MI within 6 weeks

0.5	Oestrogen hormone therapy
0.5	Platelet count > 350 x 10 ⁹ .l ⁻¹
0.5	Fibrinogen > 4 g.l ⁻¹
1	Active cancer (excludes localised non-melanomatous skin lesions)
1	Severe obesity (BMI > 40 kg.m ⁻²)
1	Prolonged (> 4 days) or severe immobility prior to surgery
1	Oral contraceptive pill use
2	Prior VTE
2	Known inherited thrombophilia
2	Pregnancy or puerperium

Table 2: Characteristics of patients undergoing surgery before (baseline) and after implementation of the surgical-thrombo-embolism-prevention (STEP) quality improvement program. Values are number (proportion). A venous thromboembolism (VTE) risk score of ≥ 2 escalates low and intermediate surgical risk profile to intermediate and high overall risk profiles respectively.

	Baseline n = 6491	Initial implementation n = 2491	Gap analysis n = 9776	Final implementation n = 6195
Age > 60 yr	3310 (51%)	1295 (52%)	5279 (54%)	3159 (51%)
Gender; male	3505 (54%)	1270 (51%)	5181 (53%)	3407 (55%)
Surgical risk profile				
- Low	3765 (58%)	1370 (55%)	4790 (49%)	2849 (46%)
- Intermediate	1688 (26%)	872 (35%)	3617 (37%)	2726 (44%)
- High	714 (11%)	100 (4%)	880 (9%)	310 (5%)
- Major abdominopelvic	324 (5%)	149 (6%)	489 (5%)	310 (5%)
VTE risk score ≥ 2	844 (13%)	473 (19%)	1662 (17%)	929 (15%)
Overall risk profile				
- Low	3311 (51%)	1171 (47%)	4301 (44%)	2664 (43%)
- Intermediate	1882 (29%)	897 (36%)	4008 (41%)	2602 (42%)
- High	974 (15%)	274 (11%)	978 (10%)	619 (10%)
- Major abdominopelvic	324 (5%)	149 (6%)	489 (5%)	310 (5%)

Table 3. Postoperative venous thromboembolism (VTE) and bleeding rates at baseline (pre-intervention) and final implementation (post-intervention). Values are rate per 1000 surgical admissions (95%CI) and relative risk reduction (95% CI) where stated.

	Baseline	Final Implementation	Relative risk reduction	P value
Primary endpoint				
Postoperative VTE	3.1 (1.9 to 4.8)	0.6 (0.2 to 1.6)	0.8 (0.4 to 0.9)	< 0.005
Secondary endpoints				
Postoperative bleeding	10.0 (0.7 to 2.8)	6.3 (4.5 to 8.6)	0.4 (0.1 to 0.6)	0.020
Major bleeding	6.8 (4.9 to 9.1)	4.7 (3.1 to 6.7)	0.3 (- 0.1 to 0.6)	0.100
Non-major bleeding	3.2 (2.0 to 4.9)	1.6 (0.8 to 3.0)	0.5 (0.1 to 0.8)	0.070

Figure Legends

Figure 1. The surgical-thrombo-embolism-prevention (STEP) quality improvement program implementation stages. VTE, venous thromboembolism.

Figure 2. The surgical-thrombo-embolism-prevention (STEP) protocol risk assessment model and thromboprophylaxis algorithm. VTE, venous thrombo-embolism; LMWH, low molecular weight heparin; TEDS, thrombo-embolic deterrent stockings. *If pharmacological thromboprophylaxis initiation is delayed more than 6 h after completion of surgery, then sequential compression device is continued postoperatively until LMWH is administered.

Figure 3. Process control chart (p-chart) displaying postoperative venous thrombo-embolism (VTE) rates during the four stages of the program averaged over each quarter for the relevant years (March, June, September, December), with upper and lower confidence limits. Rates displayed as events per 1000 surgical admissions. Targeted interventions presented over the study timeline. CL, control limit; UCL, upper control limit; LCL, lower control limit (LCL = zero); app = application; e-Learning module = electronic learning module.

Legend for supplementary tables:

Supplementary Table 1. Diagnostic criteria used for confirmation of postoperative venous thrombo-embolism and/or postoperative bleeding after administrative databases screening.

Supplementary Table 2. Contraindications to thromboprophylaxis interventions.

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Title:

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