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# Compliance to perioperative anticoagulation protocols in elderly patients undergoing elective orthopedic procedures: a retrospective observational cohort study on 548 patients

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## Abstract

**Background** Compliance with perioperative anticoagulation guidelines is essential to minimize bleeding and thromboembolic risks in patients undergoing surgery. Compared to vitamin-K antagonists (VKAs), perioperative management of direct oral anticoagulants (DOACs) contains fewer steps. Therefore, we hypothesized that noncompliance with guidelines in VKA users is higher than in DOAC users. The primary aim of our study was to investigate the difference in noncompliance to perioperative anticoagulant management guidelines between elderly patients using VKAs versus those using DOACs. The secondary aim was to determine the difference in occurrence of conflicting information communicated to the patients and the difference in incidence of coagulation-related adverse events.

**Methods** This retrospective non-controlled observational cohort study examined elderly patients undergoing elective orthopedic surgery in a teaching hospital in the Netherlands. All patients undergoing elective orthopedic surgery between 1 May 2016 and 1 January 2020, aged 70 years and over, using VKAs or DOACs were selected. Nonelective surgeries were excluded. The primary outcome was the noncompliance to perioperative anticoagulant management guidelines. Secondary outcomes were missing or conflicting information on anticoagulation management communicated to the patient and coagulation-related adverse events. For continuous data, the unpaired T-test was used and for categorical data, the chi-square test.

**Results** In patients using VKAs, noncompliance to one of the steps of perioperative anticoagulation management was 81%, compared to 55% in patients using DOACs ( $p < 0.001$ ). In most cases, VKAs or DOACs were interrupted for longer than recommended. In 13% of patients using a VKA with perioperative bridging, bridging was not conducted as recommended in the guidelines. In 13% of patients using a DOAC, a low-molecular-weight heparin (LMWH) was prescribed while a DOAC had already been restarted postoperatively. VKA users received conflicting information about perioperative anticoagulation management more often than DOAC users (33% versus 20%;  $p < 0.001$ ). No difference was seen in postoperative coagulation-related complications.

**Conclusion** Guidelines compliance in DOAC users is higher than in VKA users. Clinical decision support to help in selecting the right interruption interval in DOAC users, simplified standardized perioperative management, good coordination of instructions given to patients, and familiarity with updated guidelines are important in reducing noncompliance.

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**Keywords** Orthopedic surgery, Elective surgical procedures, Anticoagulants, Guideline compliance, Thromboembolism

**Background**

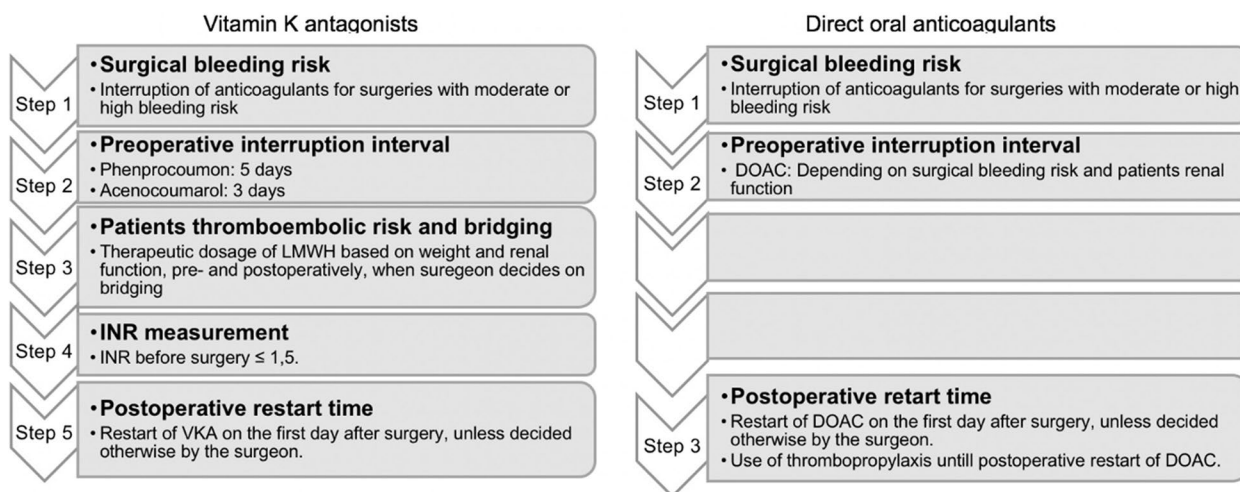
In patients treated with anticoagulants who are in need of elective surgery, the right perioperative anticoagulation management should be executed to minimize the risk of both bleeding and thromboembolic complications [1–5]. This is especially the case for elderly patients who often have multiple comorbidities and are at an increased risk for bleeding complications [6].

Perioperative anticoagulation management is a high-risk and challenging process; multiple healthcare professionals are involved, and the process contains multiple steps (Fig. 1). For a long time, the periprocedural management of direct oral anticoagulants (DOACs) was based on expert reviews instead of clinical data, which led to various guidelines and unwanted variation in local protocols [7–12]. These guidelines suggested periprocedural management for patients using DOACs based on the DOAC used, renal function, and procedural bleeding risk [13, 14]. With the periprocedural management suggested in these guidelines, there was a low risk of thrombotic and bleeding complications, with no significant difference compared to the interruption of vitamin K antagonists (VKAs) [2]. In the PAUSE cohort study, a simple standardized perioperative management approach was studied [5]. DOACs were omitted for 1 day before a low-bleeding-risk procedure and for 2 days before a high-bleeding-risk-procedure, except for patients using dabigatran with an eGFR less than 50 ml/min. This approach

resulted in low rates of perioperative bleeding and thromboembolism.

At the time of this study, neither the American College of Chest Physicians (CHEST) guidelines on perioperative management of antithrombotic therapy nor the American Academy of Orthopaedic Surgeons guidelines on perioperative management of chronic anticoagulation in orthopedic surgery mentioned interruption intervals for DOAC therapy [15, 16]. In the American College of Cardiology 2017 periprocedural management of anticoagulation guidelines, DOAC intervals for dabigatran and the other DOACs were given depending on procedural bleeding risk and renal function [9]. In the Netherlands, two guidelines were published concerning perioperative anticoagulation management in patients undergoing elective surgery that were applicable during the study period [17, 18]. In these guidelines, the interruption interval for DOACs depended on the DOAC used, renal function, and the procedural bleeding risk; these intervals deviated from the ACC 2017 guidelines (Supplementary Table 1). Previous studies have shown that the compliance to the perioperative anticoagulation guidelines is poor [19–22]. However, these studies focused on patients using VKAs, and less is known about the guidelines compliance in patients using DOACs.

In the past decade, the number of DOAC users has increased, and the number of VKA users has decreased [23, 24]. Because perioperative anticoagulation management in DOAC users contains fewer steps (Fig. 1),



**Fig. 1** Perioperative anticoagulation management steps for Vitamin K antagonists and DOACs. DOAC: Direct oral anticoagulants, INR: International Normalized Ratio, LMWH: Low-molecular-weight heparin, VKA: Vitamin K antagonist

we hypothesize that guidelines noncompliance in VKA users is higher than in DOAC users. The primary aim of this study is to investigate the difference in guidelines noncompliance of perioperative anticoagulation management in elderly VKA and DOAC users undergoing elective orthopedic surgery. Regarding anticoagulation management prior to hospital admission, differentiation is made between noncompliance by the physician and noncompliance by the patient. Secondary aims are to investigate whether information regarding anticoagulation management is recorded in the medical file, the difference in occurrence of conflicting information on perioperative anticoagulation management communicated to the patients as described in medical records, incidence of coagulation-related adverse events, and perioperative blood loss and blood transfusions.

## Methods

### Design and setting

This study is a retrospective noncontrolled observational cohort study of elderly patients using anticoagulants and undergoing elective surgery at the department of orthopedic surgery in the Spaarne Gasthuis Hospital, a teaching hospital in Hoofddorp, the Netherlands. The local perioperative anticoagulation management protocol of the Spaarne Gasthuis Hospital is based on the national guidelines of the Knowledge Institute of Medical Specialists (KIMS). At the Spaarne Gasthuis Hospital, patients undergoing elective surgery visit an anesthesiologist for preoperative screening and a pharmacy technician for medication reconciliation before surgery. The orthopedic surgeon is responsible for selecting and executing the appropriate perioperative anticoagulation management.

### Study population

All patients aged 70 years or older, using a VKA or DOAC and undergoing elective orthopedic surgery between 1 May 2016 and 1 January 2020, were included. Whether patients used a VKA or DOAC was based on prescriptions at the time of medication reconciliation. An exclusion criterion was nonelective surgery because the process of perioperative anticoagulation management is different from that for elective surgeries. For patients undergoing multiple surgeries during the study period, each surgery was included separately in the analyses.

### Data





Baseline characteristics such as sex, age, laboratory results, ASA classification, type of orthopedic surgery, and the individual complication registration were extracted from the electronic hospital information system Epic (Madison, WI, USA), using Crystal Reports (Walldorf, Germany). Drug use was extracted, and VKA

or DOAC use as well as perioperative use of platelet aggregation inhibitors and tranexamic acid were verified by reviewing medical records. Comorbidities were assessed by reviewing preoperative screening reports. Bleeding risk of surgeries was based on the local perioperative anticoagulation management protocol of the hospital and classified by one researcher (PN). Blood transfusions, blood loss during surgery, whether a tourniquet was used during surgery to create a bloodless operative field, and whether a Bellovac drain was placed during surgery were assessed by reviewing operative reports.

### Outcome parameters

The primary outcome of this study—noncompliance to perioperative anticoagulation management guidelines—was defined as noncompliance to one or more steps of perioperative anticoagulation management (Fig. 2). Noncompliance was assessed by reviewing medical records and characteristics including laboratory results (International Normalized Ratio [INR], renal function [estimated Glomerular Filtration Rate]) and patient weight. When medical records did not contain the exact timing of interruption of anticoagulants as executed by the patient, the assumption was made that patients followed the last stated advice on the timing of interruption in their medical record. Acenocoumarol should be discontinued 3 days before surgery, phenprocoumon 5 days, and the discontinuation of DOACs as stated in the local protocol (see Supplementary Table 1).

Nonreporting of anticoagulation management was assessed by reviewing the medical records. If none of the healthcare records mentioned the interruption interval—either as decided by the physician or as executed by the patient—this was regarded as nonreporting. Conflicting information from different healthcare professionals communicated to the patient on perioperative anticoagulation management in medical records was assessed by reviewing medical records. All notes made by healthcare professionals from the moment the decision was made to operate to the operation itself were reviewed by LM. All information on the anticoagulation management in these records was compared. If any information mismatched the number of days of interruption or the date on which interruption had to be started, the information was noted as confusing. Coagulation-related adverse events were defined as the need to administer vitamin K, the presence of coagulation factors and/or blood transfusions perioperatively until 6 weeks after surgery, the occurrence of unexpected blood loss of more than 500 ml during surgery, and the presence of coagulation-related complications such as thromboembolic and bleeding complications until 6 weeks after surgery. The administering of vitamin K or coagulation factors was assessed for VKA

Evaluation criteria	
PAM Step	Compliance to guideline
<b>Preoperative</b>	
 <p>Step 1&amp;2</p>	<p>Surgical bleeding risk and preoperative interruption interval</p> <p>Correct interruption interval, depending on:</p> <ul style="list-style-type: none"> <li>- Anticoagulant</li> <li>- Surgical bleeding risk</li> <li>- Renal function (in case of DOAC)</li> </ul>
 <p>Step 3</p>	<p>Patients thromboembolic risk and bridging</p> <p>No bridging in DOAC users. When decided on bridging in VKA users:</p> <ul style="list-style-type: none"> <li>- Correct therapeutic dosage of LMWH based on weight and renal function</li> <li>- Bridging pre- and postoperative</li> </ul>
 <p>Step 4</p>	<p>INR measurement</p> <p>INR measurement in VKA users:</p> <ul style="list-style-type: none"> <li>- Preoperative INR described in laboratory results or medical record</li> <li>- Preoperative INR ≤ 1,5</li> </ul>
<b>Postoperative</b>	
 <p>Step 5</p>	<p>Postoperative restart time and use of thrombosis prophylaxis</p> <p>Restart of anticoagulant on the first day after surgery, unless decided otherwise by the surgeon No thrombosis prophylaxis with LMWH after restart of DOAC</p>

**Fig. 2** Evaluation criteria of compliance to perioperative anticoagulant management protocol. PAM: perioperative anticoagulation management DOAC: Direct oral anticoagulants, INR: International Normalized Ratio, LMWH: Low-molecular-weight heparin, VKA: Vitamin K antagonist

users and based on prescriptions before surgery. During preoperative screening, all surgeons answered a standard question about expected blood loss during surgery. The answer to this question—combined with the amount of blood loss during surgery—was used to determine whether a blood loss of more than 500 ml was expected. Coagulation-related complications were based on complication registration and verified by reviewing medical records.

**Statistics**

Statistical analyses were performed using IBM SPSS software, version 24. For continuous data, such as age and blood loss during surgery, an unpaired T-test was used to determine a difference between VKA and DOAC users. For all other categorical outcomes, a chi-square test was used. For all tests, a *p*-value < 0.05 was considered statistically significant.

**Ethics, funding, and potential conflicts of interest**

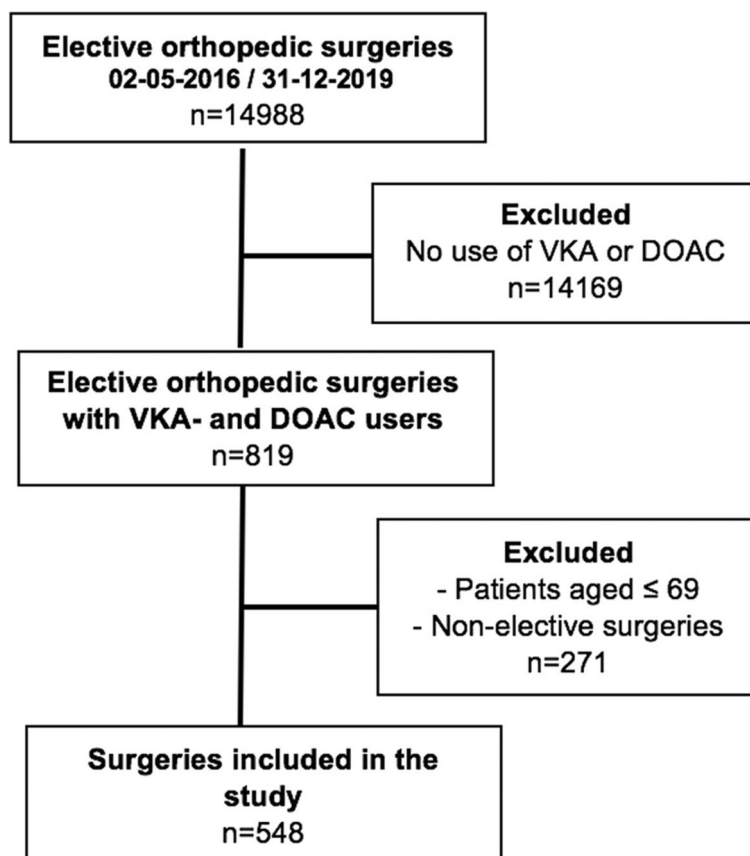
The study was conducted according to the principles of the Declaration of Helsinki (October 2013 version) and in

accordance with the General Data Protection Regulation. The research protocol was reviewed and approved by the local Institutional Review Board of the Spaarne Gasthuis Hospital. No approval from the ethics committee was required because this was a non-interventional study. The study has not received any funding, and none of the authors has any conflicts of interest to declare.

**Results**

**Study population**

We included 548 elective orthopedic surgeries in our analyses. In 319 surgeries (58%), the patient used a VKA and in 229 surgeries a DOAC (42%; Fig. 3). During the study period, there was a decrease in the number of patients using VKAs and an increase in the number of patients using DOACs (Supplemental Figure 1). The mean age of patients was 78.2 years in VKA users and 77.5 years in DOAC users. Of all included surgeries, 30% were total knee arthroplasties (27% in VKA users and 35% in DOAC users), and 36% were total hip arthroplasties (36% in VKA users and 37% in DOAC users) (Table 1).



**Fig. 3** Patient inclusion flowchart. DOAC: Direct oral anticoagulants, VKA: Vitamin K antagonist

### Primary outcome: noncompliance to the perioperative anticoagulation management guidelines

Noncompliance to one of the steps of perioperative anticoagulation management occurred more often in surgeries of VKA users than of DOAC users (81% versus 55%;  $p < 0.001$ ). Noncompliance to the perioperative anticoagulation management guidelines is displayed in Table 2, and details on the steps in which noncompliance occurred are presented in Table 3. Noncompliance was highest in step 2 of the perioperative anticoagulation management, in which the timing of discontinuation of the anticoagulants before the surgery is determined. The timing of interruption varied from 2 to 14 days before surgery for patients using a VKA and from 1 to 11 days before surgery for patients using a DOAC. In 217 of 319 VKA users (68%) and 76 of 229 DOAC users (33%), the interruption interval was longer than recommended in the guidelines ( $p < 0.001$ ). In most of these cases, the interruption interval was executed by the patient as advised by the physician (VKA 78%; DOAC 72%) and the noncompliance was because of the physician. In the other cases (VKA 22%; DOAC 28%), the noncompliance was because the patient did not follow the physician's advice.

In 11 VKA users (3%) and 15 DOAC users (7%), the interruption interval was shorter than recommended. In 18% of these VKA users and 80% of these DOAC users, the interruption interval was executed by the patient as advised by the physician, while in 82% of VKA users and 20% of DOAC users the noncompliance was because the patient did not follow the physician's advice.

Two surgeries in VKA users were cancelled because the INR was above 2 despite the correct timing of interruption and administering of vitamin K. Six surgeries in DOAC users were cancelled because DOAC use was not interrupted before surgery. Two of the six patients received incorrect information, and four of the six patients did not correctly execute the information they received.

Bridging with low-molecular-weight heparin (LMWH) during the interruption of VKA or DOAC use occurred in 51 of 319 surgeries with VKA users (16%) and in 12 of 229 of surgeries with DOAC users (5%). In 42 of 51 (82%) of surgeries with bridging in VKA users, bridging was not performed according to guidelines. In DOAC users, bridging with LMWHs is never indicated according to the guidelines.

**Table 1** Baseline characteristics of included surgeries

	VKA users n = 319	DOAC users n = 229	P-value
Sex, (%)			0.7
Male	46	48	
Female	54	52	
Mean age (SD)	78,2 (5,2)	77,5 (4,9)	0.2
VKA users (%)			
Acenocoumarol	53		
Phenprocoumon	47		
DOAC users (%)			
Dabigatran		33	
Rivaroxaban		31	
Apixaban		28	
Edoxaban		8	
TAI users (%)	1	1	0.7
Administering tranexamic acid (%)	30	39	0.02
Comorbidities (%)			
Coronary heart disease	19	23	0.3
CVA/TIA	20	19	0.7
Decompensatio cordis	20	14	0.1
Diabetes mellitus	3	6	0.7
Valvular heart disease	23	10	<0.001
Hypertension	67	63	0.4
Peripheral arterial disease	4	8	0.1
Heart rhythm disorder	84	91	0.02
Thrombosis	17	12	0.1
Clotting disorder	1	0	0.1
Renal impairment (%)	13	9	0.2
eGFR 30—50	11	8	
eGFR < 30	2	1	
Surgical bleeding risk (%)			0.3
Low	0	0	
Intermediate	17	14	
High	83	86	
ASA score (%)			0.3
II	50	50	
III	48	49	
IV	2	1	
Tourniquet use (%)	22	26	0.3
Bellovac drain (%)	15	13	0.4

DOAC Direct oral anticoagulants, eGFR estimated glomerular filtration rate in ml/min, TAI thrombocyte aggregation inhibitors, VKA Vitamin K antagonist

### Secondary outcomes: conflicting information, blood loss during surgery, and adverse events

Secondary outcomes are displayed in Table 4. Of the 548 patients, 152 (28%) received conflicting information about the timing of interruption. In surgeries of VKA users, blood loss during surgery was higher and

administering of blood transfusions occurred more often compared to surgeries with DOAC users. There were no differences in the occurrence of coagulation-related adverse events between the two groups.

### Discussion

In patients who use VKAs and have elective orthopedic surgery, the risk of perioperative anticoagulation management noncompliance was higher compared to patients who use a DOAC and have elective orthopedic surgery. This is in line with our expectations because perioperative anticoagulation management in DOAC users contains fewer steps than perioperative anticoagulation management in VKA users. Nevertheless, the noncompliance remains high in DOAC users, with 55% of patients having noncompliance with at least one step of perioperative anticoagulation management. Moreover, 28% of patients received conflicting information from various healthcare providers on the timing of interruption.

In VKA users, noncompliance was most prevalent in the preoperative steps of perioperative anticoagulation management. In 68% of these patients, the interruption interval was longer than recommended by the guidelines, and in most patients this was advised by the physician. The longer interruption interval was prompted by the experience that the advised interruption interval for VKAs was too short and resulted in too many cancellations of surgeries. Therefore, an interruption interval of 5 days for acenocoumarol and 7 days for phenprocoumon was used. This interruption interval may increase the risk of thromboembolic events in these patients. However, the risk of these events in patients with atrial fibrillation, which is the most prevalent indication of anticoagulants in our population, is low. In the BRIDGE trial, the risk of thromboembolism was 0.4% in patients with atrial fibrillation who were not bridged with an LMWH, and this risk was not significantly different compared to patients with atrial fibrillation who were bridged with an LMWH [1]. In the BRIDGE trial, patients were using warfarin, and warfarin therapy was stopped 5 days before surgery; the average CHADS2 score in this trial was 2.3. Although not the subject of this trial, it is to be expected that the thromboembolic risk is not substantially increased if VKA therapy is stopped several days earlier. This is especially the case in high-risk patients because anticoagulation therapy is bridged with an LMWH, reducing the thromboembolic risk. In 3% of patients, the interruption interval was shorter than recommended by the guidelines with the potential of a too-high INR before surgery, in most cases because of noncompliance by the patient. Because INR is measured preoperatively, patients with too-high INR levels before surgery are intercepted

**Table 2** Non-compliance to perioperative anticoagulation management guideline

	VKA users N = 319		DOAC users N = 229		P-value
Non-compliance to PAM guideline, total (%)	257	(81%)	125	(55%)	<0.001
Non-compliance to PAM guideline, preoperative (%)	253	(79%)	102	(45%)	<0.001
Non-compliance to PAM guideline, postoperative (%)	11	(3%)	34	(15%)	<0.001

PAM Perioperative anticoagulation management

**Table 3** Non-compliance to perioperative anticoagulation management guideline, specified per step

PAM Step	PAM step, specified	VKA users N = 319		DOAC users N = 229		P-value	
<b>Preoperative</b>							
Step 1&2	Surgical bleeding risk and preoperative interruption interval	Postponement of surgery because of incorrect interruption interval	2	(1%)	6	(3%)	0.1
		Interrupting anticoagulation not according to bleeding risk	3	(1%)	1	(1%)	0.4
		Interruption interval not according to guideline, total	228	(71%)	91	(40%)	<0.001
		Interruption interval > compared to guideline	217	(68%)	76	(33%)	<0.001
		Interruption interval < compared to guideline	11	(3%)	15	(7%)	0.1
Step 3	Patients thromboembolic risk and bridging	Bridging not according to guideline, total	42	(13%)	12	(5%)	0.002
		Bridging in DOAC user	-	-	12	(5%)	
		Bridging with prophylactic dosage of LMWH	18	(6%)	-	-	
		Bridging with incorrect therapeutic dosage of LMWH	17	(5%)	-	-	
		Bridging only pre- or post-operative	16	(5%)	-	-	
Step 4	INR measurement	Last preoperative INR >1,5	27	(8%)	-	-	
		Preoperative INR unknown	7	(2)	-	-	
<b>Postoperative</b>							
Step 5	Postoperative restart time and use of thrombosis prophylaxis	Restart time OAC unknown	11	(3%)	6	(3%)	0.4
		Use of LMWH despite restart of DOAC	-	-	29	(13%)	

PAM perioperative anticoagulation management, DOAC Direct oral anticoagulants, INR International Normalized Ratio, LMWH Low-molecular-weight heparin, VKA Vitamin K antagonist

and treated with vitamin K as needed. Bridging was performed incorrectly in 13% of VKA users, mostly because of incorrect doses prescribed.

In DOAC users, the percentage of patients with a timing of interruption not according to the guidelines was 40% (91 of 229 patients) compared to 71% in VKA users. We noticed that superseded versions of guidelines on the perioperative management of DOACs were still used in the study period, such as the 2012 guidelines 'guided introduction on new oral anticoagulants' [25]. In DOAC users, renal function was incorporated in the judgment

regardless of whether the interruption interval was in line with the guidelines as presented in Supplementary Table 1. The percentage of patients with an interruption interval shorter than recommended in the guidelines was 7% in DOAC users compared to 3% in VKA users. Because anticoagulation levels are not measured before surgery in DOAC users, unlike VKA users in whom INR is measured, too short of an interruption interval in DOAC users exposes them to a potential increased bleeding risk during surgery. In most cases, the patient executed the interruption interval as instructed by the

**Table 4** Secondary outcomes

	VKA users N = 319		DOAC users N = 229		P-value
Preoperative (%)					
Administration of vitamin K	28	(9%)	-	-	
Administration of coagulations factors	1	(0%)	-	-	
Non-reporting of anticoagulation management as decided by physician	15	(5%)	4	(2%)	0.06
Non-reporting of exact timing of interruption as executed by patient	174	(55%)	92	(40%)	< 0.001
Conflicting information about perioperative anticoagulant management in medical records	106	(33%)	46	(20%)	< 0.001
Perioperative (%)					
Mean blood loss during surgery (SD)	252	(227)	210	(145)	0.041
> 500 ml unexpected blood loss during surgery	12	(4%)	2	(1%)	0.106
Postoperative until six weeks after surgery					
Coagulation-related complications, total	37	(12%)	22	(10%)	0.10
Tromboembolic complications	2	(1%)	6	(3%)	0.06
Bleeding complications	37	(12%)	20	(9%)	0.30
Clinical relevant non-major bleeding	29	(9%)	18	(8%)	0.61
Major bleeding	8	(3%)	2	(1%)	0.16
Administration of blood transfusion	24	(8%)	6	(2%)	0.013

DOAC Direct oral anticoagulants, VKA Vitamin K antagonist, SD standard deviation

physician, and the noncompliance was because of the physician. Moreover, we found that in 5% of patients, DOAC therapy was bridged with LMWH therapy—although not recommended in the guidelines—and in 13% of patients, LMWH was used postoperatively together with DOAC therapy erroneously. However, the overall noncompliance is lower in DOAC users than in VKA users; we found that DOAC users are exposed to a higher bleeding risk because of a too-short interruption interval and erroneous use of DOAC and LMWH combined. Contrary to this, we see in the secondary end points that perioperative blood loss during surgery and the administration of blood transfusions were lower in patients using DOACs, suggesting that DOAC use might be safer than VKA use. However, because the numbers were low and differences small, no hard conclusions should be drawn. Implementation of a simplified standardized perioperative management approach, as suggested in the PAUSE study, may result in higher guidelines compliance by the physician [5]. This approach has been implemented in the CHEST 2022 guidelines on perioperative management of antithrombotic therapy [11].

Previous studies on noncompliance with perioperative anticoagulation management guidelines have shown poor compliance, similar to the results found in our study [19–22]. Moesker et al. described guidelines compliance of 40–81%, depending on the step of the perioperative anticoagulation management [21, 22]. Contrary to our study,

they found that the incidence of guidelines noncompliance was highest in the postoperative steps when VKA therapy was reinitiated. An explanation for this could be that we assessed whether the operator made a conscious decision concerning the day of reinitiating VKA therapy after surgery. In the study by Moesker et al., guidelines compliance in 48 DOAC users was analyzed, and the interruption interval was more frequently too long than too short, as compared to the guidelines [20]. For 3 of 34 patients (9%) in whom the interruption interval was analyzable, the interruption interval was too short. This percentage is comparable to the 7% found in our study.

Our study has several shortcomings and limitations. First, we retrospectively analyzed patient dossiers and depended on what was reported in them. The moment of stopping anticoagulation therapy before surgery was not reported for all patients, and assumptions had to be made. If a decision deviated from the guidelines, in most cases no reason was mentioned—and we do not know whether the noncompliance was intentional or erroneous. Moreover, we do not know whether patients complied with the instructions by their physician or reported their use correctly. Second, there were differences in baseline characteristics between the VKA users and DOAC users, which might have influenced the results. Because the percentage of DOAC users increased over time, a change in perioperative anticoagulation management compliance over time might have influenced the difference in guidelines compliance between VKA



and DOAC users. However, we have not seen any trend in compliance over time. Third, in the patients using DOACs, more patients preoperatively received tranexaminic acid. During the study period, the guidelines concerning the administration of tranexaminic acid were changed, and the administration was not recommended in the new guidelines. Nevertheless, preoperative administration of tranexaminic acid was higher in patients using DOACs. It is possible that patients using VKAs had more comorbidities, such as valvular heart disease, and therefore more frequently had a contra-indication for the administration of tranexaminic acid. This might have influenced the risk of bleeding complications. Fourth, we analyzed peri- and postoperative bleeding complications as a secondary outcome. However, complications depend on many factors that were not part of the scope of this study, and we therefore cannot draw conclusions on this.

Our study shows that, although guidelines compliance is higher in the group of patients using DOACs, compliance with these guidelines is still limited. Moreover, we identified that one in four patients was given conflicting information about the timing of interruption. Decision support given by the hospital information system could be used to optimize perioperative anticoagulation management guidelines compliance. During the study period, several changes were made to the hospital information system, including mandatory questions about the anticoagulants used and the advised interruption period in the process of ordering a surgery. The orthopedic surgeon must complete these questions and therefore must be aware of whether a patient uses anticoagulants and make an explicit decision on the interruption interval. Because the guidelines recommendations are based on drug use, renal function, and the bleeding risk of the surgery, an algorithm could be developed that gives advice on the interruption interval. In addition, good coordination among healthcare providers is important because many providers are involved in perioperative anticoagulation management.

## Conclusion

With the increasing use of DOACs in elderly patients undergoing orthopedic surgery, anticoagulation management has become easier. Guidelines compliance in DOAC users is higher compared to VKA users. The noncompliance with the highest risk for bleeding complications is a too-short interruption interval before surgery in patients using DOACs. Decision support in the hospital information system can help in selecting the right interruption interval, based on renal function and the bleeding risk of the surgery. Another strategy

could be to implement a simplified standardized perioperative management system that is independent of the renal function for all DOACs except dabigatran. All healthcare providers involved in perioperative anticoagulation should coordinate and communicate the anticoagulation management for each patient with one another to make sure that the patient is not given conflicting information. The providers should be familiar with the most recent guidelines; we noticed that non-compliance was frequently because superseded guidelines were being followed.

## Abbreviations

DOAC	Direct oral anticoagulants
INR	International Normalized Ratio
KIMS	Knowledge Institute of Medical Specialists
LMWH	Low-molecular-weight heparin
VKA	Vitamin K antagonists

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13037-023-00357-w>.

**Additional file 1: Supplementary table 1.** Interruption time of DOAC as stated in local protocol. **Supplementary Figure 1.** Use of VKA and DOAC over the years in the study population.

## Authors' contributions

All authors were involved in preparing the study. LM and MB collected and analyzed the data. LM wrote the manuscript. All authors reviewed the manuscript. The author(s) read and approved the final manuscript.

## Funding

The study has not received any funding.

## Availability of data and materials

The datasets used and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declarations

### Ethics approval and consent to participate

The research protocol was reviewed and approved by the local Institutional Review Board of the Spaarne Gasthuis Hospital (2020.0023; 04 March 2020). No approval from the ethics committee was required, as this was a non-interventional study.

### Competing interests

The authors declare no competing interests.

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Received: 11 January 2023 Accepted: 14 March 2023  
Published online: 20 April 2023

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