A retrospective analysis of the efficacy of oral venous thromboembolism prophylaxis for patients undergoing minimally invasive direct anterior approach total hip arthroplasty

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Abstract

Background

Venous thromboembolism (VTE), comprising deep vein thrombosis (DVT) and pulmonary embolism (PE), is a pertinent and preventable complication following total hip arthroplasty (THA). Direct anterior approach (DAA) THA has gained global popularity for its potential benefits; however, the optimal duration of postoperative venous VTE prophylaxis remains controversial. This study aimed to compare the efficacy of two weeks versus four weeks of rivaroxaban as postoperative VTE prophylaxis in patients undergoing minimally invasive DAA THA.

Methods

We conducted a retrospective analysis of the medical records of 526 consecutive patients who underwent elective primary THA via the DAA between 1 January 2017 and 31 December 2022. We compared the incidence of symptomatic and asymptomatic VTE, and the rate of complications associated with VTE prophylaxis within six months postoperatively in patients who received either a two- or four-week course of rivaroxaban as VTE prophylaxis following DAA THA. Duplex venous ultrasound was routinely performed at three weeks for all patients to evaluate for the presence of lower limb DVT.

Results

The study included 356 patients who received four weeks of treatment and 170 patients who received two weeks of rivaroxaban for postoperative VTE prophylaxis. The two groups were equally matched for age, sex, comorbidities, and preoperative VTE risk, according to the Caprini score. The overall incidence of VTE was 1% (n = 6) and included three DVTs and three pulmonary emboli (PEs). Of the DVTs detected via duplex venous ultrasound, two were diagnosed as symptomatic DVTs, and one was diagnosed as an asymptomatic DVT. The incidence of VTE was significantly greater in the two-week group than in the four-week group (p = 0.043), and all patients in whom a VTE occurred had a body mass index (BMI) of ≥ 30 kg/m2 and a preoperative Caprini score indicating moderate or high risk. No statistically significant difference was noted in the rate of wound complications (p = 0.40) or the incidence of periprosthetic joint infections between the two cohorts (p = 0.56).

Conclusion

A four-week course of rivaroxaban demonstrated superior efficacy in reducing the incidence of VTE compared to a two-week regimen in patients undergoing DAA THA. Importantly, the extended duration of rivaroxaban prophylaxis did not result in a significant increase in the rate of complications associated with VTE prophylaxis. These findings underscore the potential benefits of a prolonged rivaroxaban regimen for optimising postoperative VTE prevention, particularly in obese patients and high-risk patients undergoing minimally invasive DAA THA.

Level of evidence: 3

Keywords: total hip arthroplasty, direct anterior approach, venous thromboembolism, rivaroxaban, anterior minimally invasive surgery, AMIS

Introduction

Total hip arthroplasty (THA) is a highly regarded and cost-effective surgical intervention,[1] with reported survivorship of up to 95% at ten years and 80% at 25 years.[2-4] Worldwide, the demand for THA is expected to increase significantly in response to the increasing demand for enhanced mobility and quality of life among the ageing population.[5] Current trends demonstrate that the demand for THA is projected to continue to rise over the next 35 years.[6] In the United States of America (USA), the number of THAs performed annually is projected to surpass 4 million by 2030, while in the United Kingdom (UK), Europe and Asia, the number of THAs is estimated to rise from 1.8 to 2.8 million year between 2015 and 2050.[6,7]

Despite the significant utilisation of THA, questions abound regarding surgical technique, including the optimal surgical approach.[8,9] Despite the success of conventional approaches, arthroplasty surgeons are constantly exploring new ways to enhance and refine their technique.[10,11] The direct anterior approach (DAA) to THA is gaining global popularity due to its minimally invasive nature by utilising internervous and intermuscular planes with the aim of enhancing short-term outcomes while minimising certain risks, such as a reduction in the rate of postoperative dislocations, a lower incidence of deep-seated wound infections, and lower revision rates within the first 12 months postoperatively.[12-14] The growing popularity of the DAA is highlighted in a 2021 survey of the American Association of Hip and Knee Surgeons (AAHKS), where Abdel et al. reported that the use of the DAA increased from 12% in 2009 to 45% in 2020.[15,16]

Worldwide, the overall complication rate associated with THA is 5.5%.[17] The complication rate comprises general medical and surgical complications. Reported surgical complications consist of surgical site infections (SSI), sciatic nerve pathology, and significant perioperative blood loss requiring transfusion.[18-22] Medical complications include, and are not limited to, urinary tract infections (UTIs) and respiratory complications.[23-26]

One of the most devastating sequelae of THA is venous thromboembolic (VTE) phenomena.[27] Ten million episodes of VTE are diagnosed annually, with the incidence in THA estimated to be 0.6–1.5%.[28] VTE events and the complications of VTE prophylaxis are associated with a significantly increased morbidity, mortality and economic burden, with an estimated annual cost of $7–10 billion in the USA alone.[28-32]

VTE comprises a spectrum of conditions, from asymptomatic deep vein thrombosis (DVT) to life-threatening pulmonary emboli (PEs).[33] Virchow's triad consists of venous stasis, endothelial injury and hypercoagulable states, which are three variables that promote thrombus formation. VTE requires a combination of at least two of the factors above for its development.[34]

The surgical approach utilised for THA may indirectly promote venous stasis and endothelial injury.[35-37] During preparation of the femoral canal in both the posterior approach (PA) and lateral approach (LA), the combination of flexion, adduction and external rotation of the femur cause the femoral vein to be compressed, ultimately leading to occlusion of blood flow.[35] In contrast, extension, abduction and internal rotation of the femur during canal preparation in the DAA have no impact on the flow through the femoral vein.[38] Additional reported risk factors include age above 70 years, female sex, body mass index (BMI) ≥ 30 kg/m^2, bilateral THA, a history of previous VTE, surgical duration exceeding two hours, the use of polymethyl-methacrylate (PMMA) for cementation of the prosthesis, and bed rest for a period of more than three days postoperatively.[39,40]

Since the implementation of thromboprophylaxis strategies, the incidence of VTE in surgical patients has reduced substantially, from 70% to 44%.[41] Despite an abundance of literature and guidelines recommended by authorities in the USA, Europe and the UK, controversy exists around which pharmacologic agent has the greatest efficiency, the optimal timing of dose administration, and the ideal duration of prophylaxis following THA.[42-46] An area of considerable contention revolves around determining the optimal pharmacological agent/s for VTE prophylaxis in patients undergoing THA, with discrepancies arising among major authorities, while considering factors such as cost, clinical effectiveness, susceptibility to bleeding, and wound-related complications.[43] In a 2023 systematic review evaluating the safety and effectiveness of 11 anticoagulants, Haung et al. concluded that direct oral anticoagulants (DOACs) have the greatest efficacy at reducing the risk of VTE after THA.[47]

A paucity of literature exists evaluating the incidence of VTE and the diagnosis of asymptomatic DVTs in patients undergoing DAA THA. Therefore, considering the globally increasing demand for DAA THA, the increased risk of VTE after THA, and the controversies surrounding the optimal choice and duration of VTE prophylaxis, the rationale of this study is to compare the efficacy of a two- versus four-week rivaroxaban VTE protocol in patients undergoing minimally invasive DAA THA.

Methods

Study design

This study was a retrospective analysis of 526 consecutive patients over 18 years of age who underwent elective, unilateral primary anterior minimally invasive DAA THA between 1 January 2017 and 31 December 2022, by a single high-volume hip surgeon, in Johannesburg, South Africa. All patients who underwent a THA between 1 January 2017 and 31 December 2019 received a four-week course of oral rivaroxaban as postoperative VTE prophylaxis, while those operated on between 1 January 2020 and 31 December 2022 received two weeks of rivaroxaban. The following patients were excluded from this study: those patients who did not receive postoperative rivaroxaban due to contraindications; patients with a history of VTE or currently undergoing VTE treatment; individuals who underwent THA as a result of trauma, and those who underwent revision THA.

Surgical protocol

A structured protocol was followed for all patients, which included a standardised baseline preoperative medical assessment and optimisation by a fellowship-trained physician. All patients underwent surgery in a single laminar-flow operating theatre under general anaesthesia supplemented by a neuraxial regional block, administered by a single trained anaesthesiologist. A single dose of intravenous antibiotic prophylaxis, adjusted based on the patient's weight, was administered preoperatively, and continued for a duration of 24 hours postoperatively. Cefazolin was the antibiotic utilised, except in cases of penicillin allergy, where clindamycin was the preferred alternative. All patients were placed in a supine position on the operating table, and a cushioned peroneal support was positioned between the legs. The affected leg was securely positioned using a mobile leg positioner under the control of an experienced, trained table operator.

A longitudinal skin incision of 6–10 cm in length was made, located 2–3 cm laterally and parallel to a line connecting the anterior superior iliac spine and Gerdy's tubercle. The underlying perimysium was incised to facilitate access to the interval between the tensor fascia lata and sartorius. The lateral aspect of the rectus femoris was retracted medially to expose the joint capsule. Utilising an anterior capsulotomy, entry into the joint was established. The femoral neck was osteotomised under traction, with due care taken to protect the posterior capsule. Wherever possible, the acetabular

labrum was left intact, and the acetabulum was prepared using traditional THA techniques. Preparation of the femur was performed in a position of extension and external rotation to maximise proximal access. Soft tissues were released as needed to ensure sufficient access to the femoral canal while safeguarding ligaments. Femoral broaching was performed utilising AMIS® broaches employing conventional broaching techniques. Uncemented implants with ceramic femoral heads and highly cross-linked polyethylene liners were preferentially used.

Intraoperatively, an intra-articular negative-pressure suction drain was routinely placed and subsequently removed within a 24-hour timeframe. Intermittent pneumatic compression calf pumps were applied immediately postoperatively and utilised until discharge, complemented by twice-daily inpatient physiotherapy sessions that were started as soon as the spinal anaesthetic wore off. On the first day postoperatively, all patients were made to stand and walk a few steps with assistance. Patients were expected to achieve full ambulation with two crutches before being discharged. Upon discharge, which is usually two days postoperatively, patients were prescribed oral thromboprophylaxis in the form of rivaroxaban at a daily dose of 10 mg for either a two- or four-week duration.

Three weeks postoperatively, the surgical incision was evaluated by a clinical associate, and any questionable wounds were reviewed by the primary surgeon. At the same follow-up, a routine lower limb duplex Doppler was performed by a qualified radiologist and sonographer to ascertain the presence of a symptomatic or asymptomatic DVT. If a DVT was clinically suspected, patients were reviewed by a physician, and further investigation followed. Follow-up assessments were conducted by the surgeon at three weeks, six weeks, six months postoperatively, and every five years thereafter.

Variables and outcome measures

Preoperatively, the following baseline demographic patient information was captured for all patients: age (years), sex, comorbidities, and BMI (kg/m^2). Patients' VTE risk was calculated as high, intermediate and low risk using the Caprini score,[48] a validated risk assessment model (RAM) developed to stratify the risk of VTE and determine appropriate methods of prophylaxis in surgical patients based on several medical and surgical risk factors.[49] Patients' preoperative functional status was evaluated using the Harris Hip Score (HHS)[50] – a validated tool that factors in pain, gait and activities of daily living. Pain was quantified using the visual analogue scale (VAS) score,[51] a validated, unidimensional, subjective pain rating scale for assessing acute and chronic pain. It consists of a handwritten mark placed along a 10 cm line, where 0 cm indicates no pain and 10 cm indicates the worst pain.

Intraoperatively, the following data was collected: the type of anaesthesia and regional neuraxial block administered; surgical duration in minutes from initial incision to completion of the last suture; estimated blood loss in millilitres; and the type of fixation used for both femoral and acetabular components. Perioperative data included: the use of blood products; length of stay (LOS) in days measured from date of admission to date of discharge; and discharge destination, namely home or specialist nursing facility.

Postoperatively, follow-ups were conducted at three weeks, six weeks and six months. At subsequent follow-ups, patients were assessed clinically for the presence or absence of a lower limb DVT indicated by pain and swelling of the calf, overlying erythema, and an increased temperature of the affected limb compared to the contralateral side. DVT was also evaluated for at three weeks, as the risk for VTE is highest during the first 10–14 days after THA.[52] All patients underwent a routine three-week duplex Doppler scan to evaluate for the presence of blood clots in the veins of the lower limbs, from the level of the inguinal ligament down to the bifurcation of the popliteal veins. Duplex Doppler scans of the lower limb exhibit a sensitivity of 97% for detecting proximal DVTs and 73% for distal DVTs, coupled with a specificity of 96%.[53] All patients who had a positive result for either symptomatic or asymptomatic DVT were referred to a physician for further management.

Complications were further classified as intraoperative or postoperative. Medical complications were considered as those related to the patient's baseline and physiological effects of the surgery, including VTE (DVT or PE). Surgical complications were those complications assumed to be directly related to the surgery, including wound complications, infection, peri-prosthetic fractures, and joint dislocation. Complications were also classified temporally as early, occurring ≤ 4 weeks, and late, occurring ≥ 4 weeks after THA.

Data analysis

The study compared the incidence of VTE between two cohorts (rivaroxaban for two weeks versus rivaroxaban for four weeks) based on a series of variables. The two means of these variables were compared using t-tests with statistical significance at $p < 0.05$. Confidence intervals were calculated at 95% and used in conjunction with the p-values to determine clinical significance. Groups were tested to verify if they met the assumptions of a linear model, including a normal distribution and equal variability. If these assumptions were not met, the Mann-Whitney U test was used to test hypotheses between the two cohorts. The statistical package used was Stata version 17 (2017), Texas, USA.

Results

Demographics

There were 786 suitable patients identified with 526 included in the study (*Figure 1*). In total, there were 526 patients, of whom 356 (68%) received four weeks and 170 (32%) received two weeks of rivaroxaban postoperatively for VTE prophylaxis. The mean patient age across the entire group was 59.5 ± 13.09 years. The two cohorts were well matched, with no statistically significant differences noted in terms of age ($p = 0.21$), sex ($p = 0.98$), or BMI ($p = 0.78$). Considering all participants, 258 (49%) had no comorbidities, 216 (41%) had at least one comorbidity, and 52 (10%) patients had two or more comorbidities. There were 36 patients (7%), with diabetes mellitus, 37 patients (7%) with asthma, 20 patients (4%) with inflammatory arthritis, 22 patients (4%) with thyroid disease, and 33 patients (6%) with other comorbidities. Overall, 193 (37%) patients were low risk, 307 (58%) patients were moderate risk, and 26 (5%) were high risk for VTE according to the Caprini RAM. Refer to *Table I* for further demographic details.

Figure 1. Flowchart of study cohort

AIMS: anterior minimally invasive surgery; THA: total hip arthroplasty

Table I: Patient demographics

	Total n = 526 (%)	Rivaroxaban 4 weeks n = 356 (%)	Rivaroxaban 2 weeks n = 170 (%)	p-value
Sex (n; %)				0.98
Male	223 (42%)	151 (42%)	72 (42%)	
Female	303 (58%)	205 (58%)	98 (58%)	
BMI (kg/m²) (± SD)	28.02 ± 5.58	27.95 ± 5.37	28.09 ± 5.79	0.78
Age, years (± SD)	59.5 ± 13.09	60.33 ± 12.75	58.82 ± 13.43	0.21
Comorbidities (n; %)				0.29
0	258 (49%)	182 (51%)	76 (54%)	
1	216 (41%)	143 (40%)	73 (43%)	
2	47 (9%)	29 (8%)	18 (11%)	
≥ 3	5 (1%)	2 (1%)	3 (2%)	
Diabetes	36 (7%)	33 (9%)	3 (2%)	0.02
Epilepsy	21 (4%)	19 (5%)	2 (1%)	0.09
Asthma/COPD	37 (7%)	34 (10%)	3 (2%)	0.01
Inflammatory arthritis	20 (4%)	16 (5%)	4 (2%)	0.24
Coronary artery disease	29 (6%)	26 (7%)	3 (2%)	0.08
Previous CVA	2 (0.4%)	2 (1%)	0	0.3
Previous TB	0	0	0	
HIV	0	0	0	
Thyroid disease	22 (4%)	19 (5%)	3 (2%)	0.28
Other	33 (6%)	25 (7%)	8 (5%)	0.55
VTE risk stratification (n; %)				0.52
Low risk	193 (37%)	132 (37%)	61 (36%)	
Moderate risk	307 (58%)	204 (57%)	103 (61%)	
High risk	26 (5%)	20 (6%)	6 (4%)	
Preoperative functional scores (± SD)				
HHS	50.12 ± 10.79	51.74 ± 12.02	48.51 ± 9.56	0.0023
VAS				
At rest	6.22 ± 2.13	5.81 ± 1.98	6.63 ± 2.28	< 0.001
On activity	7.49 ± 2.47	7.16 ± 2.21	7.82 ± 2.73	0.0032

BMI: body mass index; SD: standard deviation; COPD: chronic obstructive pulmonary disease; CVA: cerebral vascular accident; TB: tuberculosis; HIV: human immunodeficiency virus; VTE: venous thromboembolism; HHS: Harris Hip Score; VAS: visual analogue scale

Intraoperative findings

Overall, there were 266 (51%) patients who received pericapsular nerve group block (PENG) and 182 (35%) patients who received a sciatic nerve block. The mean surgical duration was 86.84 ± 24.25 minutes for the four-week rivaroxaban group and 82.81 ± 17.94 for the two-week rivaroxaban group, with no statistically significant difference between the groups (p = 0.054). The average intraoperative blood loss was 191.53 ± 102.83 ml and 174.05 ± 101.87 ml for the four- and two-week groups, respectively (p = 0.06). One patient in the four-week group and two patients in the two-week group required a blood transfusion postoperatively. The mean LOS of the four-week group was 2.46 ± 0.66 days, and the two-week group was 2.12 ± 0.63 days (p < 0.001). Six patients in the four-week group (2%) and four patients in the two-week group (2%) required discharge to a step-down specialist nursing facility (p = 0.60). For further intraoperative details, refer to *Table II*.

Table II: Intraoperative findings

	Total n = 526 (%)	Rivaroxaban 4 weeks n = 356 (%)	Rivaroxaban 2 weeks n = 170 (%)	p-value
Local block				0.63
PENG	266 (51%)	186 (52%)	80 (47%)	
Sciatic	182 (35%)	121 (34%)	61 (36%)	
Other	78 (15%)	49 (14%)	29 (17%)	
Surgical time (min)	84.82 ± 21.09	86.84 ± 24.25	82.81 ± 17.94	0.05
Blood loss (mm)	182.79 ± 102.35	191.53 ± 102.83	174.05 ± 101.87	0.06
Blood transfusion	3	1	2	
Fixation type (n; %)				0.29
Uncemented	289 (559%)	190 (53%)	99 (58%)	
Cemented	0	0	0	
Hybrid	237 (45%)	166 (47%)	71 (42%)	
Length of hospital stay (days)	2.29 ± 0.65	2.46 ± 0.66	2.12 ± 0.63	0.02
Discharge destination (n; %)				
Home	516 (98%)	350 (98%)	166 (98%)	0.60
Specialist nursing facility	10 (2%)	6 (2%)	4 (2%)	

PENG: pericapsular nerve group; SD: standard deviation

Perioperative complications

Overall, the perioperative complication rate was 5% (n = 27). The total complication rate was 2% and 11% in the four- and two-week groups, respectively (p = 0.53). In total, there were six VTEs reported (1%). These included three DVTs and three non-fatal PEs. Overall, of the DVTs identified, two were symptomatic and one was asymptomatic. All reported VTE occurred in the two-week group, with no VTEs reported in the four-week group (p = 0.04). Overall, 20 of the complications (4%) were surgical in nature and resulted in 14 readmissions (six in the four-week group [2%] and eight [5%] in the two-week group) and four revisions (three in the four-week group and one in the two-week group).

Overall, 13 patients presented with wound complications (2%), six (2%) in the four-week group, and seven (4%) in the two-week group (p = 0.40). In total, of the patients who presented with wound complications, there were three patients (2%) who complicated with a prosthetic joint infection (PJI). All noted PJIs occurred in the two-week rivaroxaban group, with no PJIs diagnosed in the four-week rivaroxaban group (p = 0.56). For further perioperative complications and VTE cases, see *Tables III* and *IV*.

Table III: Perioperative complications

	Total n = 526 (%)	Rivaroxaban 4 weeks n = 326 (%)	Rivaroxaban 2 weeks n = 170 (%)	p-value
Total	27 (5%)	8 (2%)	19 (11%)	0.536
Intraoperative	1 (0.2%)	0	1 (1%)	
Postoperative	26 (5%)	8 (2%)	18 (11%)	
Intraoperative				
Periprosthetic femur fracture	1 (0.2%)	0	1 (1%)	0.361
Calcar	1 (0.2%)	0	1 (1%)	
Diaphyseal	0	0	0	
Postoperative	26 (5%)	8 (2%)	18 (11%)	
Early (≤ 4 weeks)	18 (3%)	3 (1%)	15 (9%)	0.098
Late (> 4 weeks)	8 (2%)	5 (2%)	3 (2%)	0.058
Medical complications	6 (1%)	0	6 (4%)	
VTE total	6 (1%)	0	6 (4%)	0.043
DVT	3 (1%)	0	3 (2%)	0.561
Symptomatic	2 (0.4%)	0	2 (2%)	
Asymptomatic	1 (0.2%)	0	1 (1%)	
PE	3 (1%)	0	3 (2%)	0.561
Surgical complications	20 (4%)	8 (2%)	12 (6%)	
Periprosthetic joint infections	3 (1%)	0	3 (2%)	0.561
SSI	0	0	0	
Deep infections	3 (1%)	0	3 (2%)	
Wound complications	13 (2%)	6 (2%)	7 (4%)	0.407
Wound ooze	1 (0.2%)	0	1 (1%)	
Wound dehiscence	12 (2%)	6 (2%)	6 (4%)	0.538
Periprosthetic fractures	2 (0.3%)	2 (1%)	0	0.316
Acetabular component	0	0	0	
Femoral component	2 (0.3%)	2 (1%)	0	
Joint dislocation	2 (0.3%)	0	2 (1%)	0.316
Aseptic loosening	0	0	0	
Acetabular component	0	0	0	
Femoral component	0	0	0	
Readmissions	14 (3%)	6 (2%)	8 (5%)	0.248
≤ 30 days	7 (1%)	2 (1%)	5 (3%)	0.135
31–60 days	7 (1%)	4 (1%)	3 (2%)	
61–90 days	0	0	0	
Re-operations	4 (1%)	3 (1%)	1 (1%)	1.00
≤ 4 weeks	3 (1%)	2 (1%)	1 (1%)	0.501
> 4 weeks	1 (0.2%)	1 (0.3%)	0	

VTE: venous thromboembolism; DVT: deep vein thrombosis; PE: pulmonary embolus; SSI: surgical site infection

Table IV: VTE cases

Cases (n = 6)	Sex	Age	BMI	Caprini score	Prosthesis (cemented/uncemented)	VTE prophylaxis	Complication
1	Female	82	30.71	High risk	Cemented	Rivaroxaban 2 weeks	Symptomatic DVT
2	Male	66	28.31	High risk	Uncemented	Rivaroxaban 2 weeks	Asymptomatic DVT
3	Female	75	32.16	Moderate risk	Cemented	Rivaroxaban 2 weeks	Symptomatic DVT
4	Male	74	42.05	High risk	Cemented	Rivaroxaban 2 weeks	PE
5	Male	54	31.42	High risk	Uncemented	Rivaroxaban 2 weeks	PE
6	Female	60	30.35	High risk	Cemented	Rivaroxaban 2 weeks	PE

BMI: body mass index; VTE: venous thromboembolism; DVT: deep vein thrombosis; PE: pulmonary embolus

Discussion

VTE, encompassing DVT and PE, is a well-recognised and preventable complication following THA, and is associated with significant morbidity and mortality.[54] In the absence of routine thromboprophylaxis, the incidence of VTE in patients undergoing THA is reported to exceed 50%.[55] Since the implementation of thromboprophylaxis strategies, the risk of symptomatic VTE following THA has been reduced to 1%, emphasising the importance of correct prophylaxis to reduce the patient's risk of VTE.[54,56] To the authors' knowledge, this is the first South African study evaluating the incidence of VTE and the rate of complications associated with oral VTE prophylaxis in patients undergoing minimally invasive DAA THA. The overall incidence of VTE in this study following minimally invasive DAA THA was 1%. The incidence of DVT and PE was 0.6% and 0.6%, respectively *(Table III.)* The surgical approach utilised for THA directly influences the risk of developing VTE as a result of venous stasis and endothelial injury.[35-37] Coveney et al. reviewed 8 885 patients who received combined mechanical and chemical prophylaxis with aspirin for six weeks following elective THA via the PA and reported a VTE incidence of 1.1% and a symptomatic DVT rate of 0.6%.[57] Kawano et al. compared the incidence of VTE in 109 patients who underwent THA utilising either the DAA or LA and reported a significantly higher incidence of VTE in the DAA group (19.4% versus 5%) (p = 0.014); however, a vast majority of VTE occurred during the early period after introducing the DAA, which may be attributed to the fact that during a surgeon's early experience utilising the DAA, significantly longer operative times were noted compared to other traditional THA approaches.[35,58] In contrast, a meta-analysis by Chen et al. reported that the rates of VTE after DAA THA were significantly lower than the rates after PA THA (p = 0.02).[59] Worldwide, the incidence of VTE following THA is quoted to be 0.6–1.5%,[28] which is in keeping with our findings.

When analysing international guidelines for VTE prophylaxis in patients undergoing THA, disparities emerge regarding the optimal choice and dosage of pharmacological agents, as well as the ideal recommended duration of thromboprophylaxis.[42,44,57] Current guidelines from the American Academy of Orthopaedic Surgeons (AAOS) and American Academy of Chest Physicians (ACCP) recommend either an oral or injectable VTE prophylactic agent for a period of two to four weeks postoperatively in high-risk patients,[43,57] while guidelines from the National Institute for Health and Clinical Excellence (NICE) recommend low-molecular-weight heparin (LMWH) for two weeks, followed by aspirin for an additional four weeks, or rivaroxaban for a period of more than two weeks.[50,51,59]

In this study, we found a statistically significant difference in the incidence of VTE based on the duration of oral thromboprophylaxis (two weeks as opposed to four weeks) (p = 0.043). However, there was no statistically significant difference noted in the rate of complications associated with oral VTE prophylaxis, whether rivaroxaban was given for two weeks or four weeks following DAA THA (p = 0.40). Anderson et al. reviewed 1 804 THA patients who received either rivaroxaban or aspirin as VTE prophylaxis for four weeks post-THA, and reported a VTE incidence of 0.7% in the rivaroxaban group and 0.64% in the aspirin group. This is lower than the incidence of VTE noted in our study; however, higher rates of overt bleeding from the surgical site were noted in the aspirin group compared to those who received rivaroxaban (1.29 versus 0.99%).[60] In a meta-analysis comparing nine studies and 3 999 patients, Eikelboom et al. evaluated the efficacy of extended duration VTE prophylaxis with LMWH for at least four weeks in patients undergoing THA, and noted a statistically significant reduction in the frequency of VTE (p = 0.02); however, no difference was noted in the risk of major bleeding events.[61]

Frequently cited sequelae associated with VTE prophylaxis include life-threatening bleeding and wound complications, including wound ooze, haematoma formation, and superficial and deep SSIs.[62] Todd et al. noted that the risk of wound ooze was significantly greater in patients receiving aspirin and LMWH compared to those who received rivaroxaban (13% versus 4.2%) (p < 0.001), with no significant difference noted in the risk for haematoma formation or SSI between the above agents.[62] Fallaha et al. evaluated 265 patients who received combined prophylaxis with rivaroxaban and pneumatic compression stockings and reported wound complications in 20% of patients, of which superficial bleeding from the surgical site was the most common wound complication in 12% of patients and resulted in 6% of patients requiring a blood transfusion.[63]

In this study, the overall rate of wound complications was 2%; wound ooze was reported in 0.2% of patients, while 2% of patients experienced dehiscence of their surgical wound. However, we showed that no statistically significant difference was noted in the rate of wound complications whether the duration of rivaroxaban was two or four weeks postoperatively (p = 0.40) (*Table III*).

In the present investigation, only two patients in the four-week group and one patient in the two-week group required a postoperative blood transfusion, implying a limited clinical impact *(Table III)*. A meta-analysis by Le et al. found that patients who received rivaroxaban postoperatively required a significantly greater number of blood transfusions than those patients who received aspirin (p < 0.001). However, no difference was noted in the rate of wound complications between the two groups.[64] Bala et al. compared the bleeding risk in patients receiving aspirin, warfarin, LMWH and rivaroxaban and noted that aspirin was associated with the lowest incidence of blood transfusion in 7% of patients, followed by rivaroxaban in 9% of patients.[65]

One of the greatest limitations surrounding the use of rivaroxaban is the cost difference when compared to other oral agents such as aspirin. Wells et al. noted that the monthly cost of rivaroxaban was $24 more per patient per month than that of aspirin. However, the overall cost of clinical events associated with aspirin was noted to be threefold greater than the cost of rivaroxaban ($381 versus $123).[66] When evaluating cost-effectiveness in terms of quality-adjusted life years (QALYs), Abutorabi et al. analysed the cost-effectiveness of rivaroxaban and LMWH during the prophylaxis period in arthroplasty patients and noted that oral rivaroxaban was 1.5 times more cost effective than injectable LMWH ($161 versus $276) and overall increased the quality of life for patients (0.85 versus 0.69 QALY); it also reduced the LOS by approximately two days compared to LMWH.[67] Heisen et al. reported that the overall cost-effectiveness of rivaroxaban was superior to LMWH and warfarin, resulting in health improvements of 0.047 QALYs and cost reductions of €304, with the major cost driver being the fact that rivaroxaban does not require routine monitoring, is associated with a lower incidence of VTE, and has a better safety profile concerning bleeding events compared to LMWH and warfarin, therefore resulting in an overall reduction in medical costs, travel costs, and less time spent away from work.[68]

All patients in this study underwent a routine lower limb duplex Doppler at three weeks postoperatively; a total of three DVTs were diagnosed, with the overall incidence of DVT being 0.6%. Of the DVTs detected, two were symptomatic in nature, while one was asymptomatic, with no statistically significant difference noted in DVT detection rates between both cohorts (p = 0.560) *(Table III.)* Globally, the incidence of asymptomatic DVT after THA performed using the PA in THA is reported to range from 11–28%.[69,70] In contrast, Itou et al. retrospectively reviewed 162 patients who underwent THA via the anterolateral approach (AL). All patients received LMWH as thromboprophylaxis for a minimum duration of

six days and underwent a routine duplex ultrasound on day seven postoperatively. Their findings revealed a DVT incidence of 9.9%, with all identified DVT cases being asymptomatic except for one.[71] Quinlan et al. reviewed the venographic results of 5 796 patients who received LMWH for a minimum of ten days after THA and noted that the incidence of asymptomatic DVT was 13.2%, with one asymptomatic DVT detected in every five postoperative duplex ultrasounds performed.[72] While a negative duplex ultrasound does not exclude the diagnosis of an asymptomatic DVT with a sensitivity and specificity of 76% and 84%, respectively, asymptomatic DVTs generally have a favourable prognosis regardless of whether anticoagulation therapy is administered and are unlikely to lead to adverse outcomes such as PE.[43,73,74] In contrast, 40–50% of untreated symptomatic DVTs may progress to PE.[43] Both the ACCP and AAOS recommend against routine lower limb duplex Doppler screening postoperatively in asymptomatic patients undergoing elective THA before discharge; however, no recommendation is given regarding ongoing surveillance for detecting a DVT in asymptomatic patients.[43,57] The low incidence of asymptomatic DVTs in this study may be attributed to the minimally invasive surgical approach, the use of in-hospital mechanical prophylaxis, and early rehabilitation and discharge practice.

In this study of the six patients diagnosed with a VTE, 83% were obese (BMI ≥ 30 kg/m^2). (*Table IV*). Obesity results in a constant low-grade inflammatory state, an imbalance of fibrinolysis and fibrinogen activity, as well as elevated levels of Von Willebrand factor and factor VII, resulting in an overall prothrombotic state and increased VTE risk.[75] Aggarwal et al. highlighted that patients with a BMI ≥ 30 kg/m^2 undergoing THA are at a significantly greater risk of wound complications, VTE, and SSI compared to non-obese patients ($p < 0.001$).[76] Previous research by White et al. and Mantilla et al. demonstrated that patients with a BMI ≥ 30 kg/m^2 have a three-fold greater risk of developing VTE, and patients with a BMI ≥ 25 kg/m^2 have a 1.8 times greater risk compared to controls.[77,78] Humphrey et al. reviewed the incidence of VTE in morbidly obese patients taking either DOACs or aspirin as VTE prophylaxis and noted that patients taking DOACs were at a significantly greater risk for developing VTE than those taking aspirin.[79] Therefore, in our study, this may have accounted for the predominance of obese patients in the group of patients diagnosed with a VTE.

There are limitations to this research. As the dataset was limited to a single, high-volume hip surgeon at a single institution, results may not be replicable in settings without equivalent expertise or resources. In this study, the primary method used for diagnosing DVTs was lower limb duplex Doppler, which may reveal suboptimal results for vessels with a deep anatomical location or small vessels, resulting in a missed diagnosis.

Conclusion

This study shows a four-week course of rivaroxaban postoperatively has superior efficacy in reducing the incidence of VTE compared to a two-week regimen in patients undergoing DAA THA. Importantly, the extended duration of rivaroxaban prophylaxis did not result in a significant increase in the rate of wound complications or bleeding risk associated with VTE prophylaxis. These findings underscore the potential benefits of a prolonged rivaroxaban regimen for optimising postoperative VTE prevention, especially in obese and high-risk patients undergoing minimally invasive DAA THA.

Ethics statement

The authors declare that this submission is in accordance with the principles laid down by the Responsible Research Publication Position Statements as developed at the 2nd World Conference on Research Integrity in Singapore, 2010.

Prior to commencement of the study, ethical approval was obtained from the following ethical review board: Human Research Ethics Committee, University of the Witwatersrand (ethics clearance no.: M230838). All procedures were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008. Patients included gave informed consent for their data to be collected for research purposes.

Declaration

The authors declare authorship of this article and that they have followed sound scientific research practice. This research is original and does not transgress plagiarism policies.

Author contributions

DBG: first draft preparation, data capture, data analysis, manuscript revision, manuscript preparation
JRTP: study conceptualisation, data capture, first draft preparation, manuscript revision, manuscript preparation
NG: first draft preparation, manuscript revision, manuscript preparation
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