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ORIGINAL ARTICLE

Risk of venous thromboembolism after endoprosthetic surgeries: lower versus upper extremity endoprosthetic surgeries

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Abstract

Venous thromboembolism (VTE) is a potentially fatal disease. Important risk factors of a provoked VTE are trauma, surgery or immobilization. Especially, patients who undergo hip and knee replacements are at high risk for postoperative VTE. We aimed to compare in-hospital VTE burden and other outcomes after upper and lower extremity endoprosthetic surgeries in Germany. The nationwide German inpatient sample of the years 2005–2015 was used for data analysis. Patients who underwent endoprosthetic joint/bone replacements of the extremities (OPS codes 5-820, 5-822, 5-824 and 5-826) were further stratified in those operated on lower (OPS codes 5-820, 5-822 and 5-826) or upper extremity (OPS code 5-824) joints. Patients operated at upper and lower extremity were compared and lower extremity endoprosthetic surgery was investigated as a predictor for adverse outcomes. Overall, 4,134,088 hospitalized patients with extremity joint endoprosthetic surgeries (64.3% females, 54.0% aged > 70 years) were included in our analysis. Of these, 3,950,668 patients (95.6%) undergo lower and 183,420 (4.4%) upper extremity endoprosthetic joint surgery. VTE [RR 2.60 (95% CI 2.41–2.79), $P < 0.001$] and all-cause death [RR 1.68 (95% CI 1.58–1.77), $P < 0.001$] were more common in patients with lower extremity joint surgery. Risk for VTE events [OR 2.69 (2.50–2.90), $P < 0.001$] and in-hospital death [OR 1.65 (1.56–1.75), $P < 0.001$] were both higher in lower than in upper extremity joint surgeries independently of age, sex and comorbidities. Patients who undergo lower extremity endoprosthetic joint surgeries, bear a higher risk for VTE and in-hospital death compared to those with upper extremity endoprosthetic joint surgeries.

Keywords Venous thromboembolism · Pulmonary embolism · Deep venous thrombosis · Hip replacement · Knee replacement

Abbreviations

CI	Confidence interval
DVT	Deep venous thrombosis or thrombophlebitis
IQR	Interquartile range
LJS	Lower extremity endoprosthetic joint surgery
OR	Odds ratio
PE	Pulmonary embolism
RR	Relative risk
UJS	Upper extremity endoprosthetic joint surgery
VTE	Venous thromboembolism

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Introduction

Venous thromboembolism (VTE) with its two clinical entities of deep venous thrombosis and pulmonary embolism (PE) is the third most frequent cardiovascular disease in Europe [1]. VTE is a potentially life-threatening complication in the acute phase after surgeries, but can also lead to significant morbidity and disability [1–3]. It is a major health problem, especially among the old patients [4–6]. Provoked VTE events are caused by temporary or reversible risk factors such as trauma, surgery or immobilization [1, 7, 8]. Major trauma, surgery, lower extremity fractures and joint replacements are strong provoking factors for VTE [1, 2, 8–14]. Especially, patients undergoing total hip and knee replacements are at high risk of postoperative VTE events [2, 11, 13–15], although pharmacological prophylaxis is established [10, 11, 14–18]. The incidence of VTE in patients who underwent upper extremity endoprosthetic joint surgery (UJS) and the relative risk between UJS and lower extremity endoprosthetic joint surgery (LJS) are widely unknown.

Thus, we aimed to investigate the incidence of VTE events in patients who underwent UJS and LJS, and to compare the risk to develop a VTE event in patients with UJS and LJS.

Materials and methods

Data source

The study analyses were performed on our behalf by the Research Data Center of the Federal Statistical Office and the Statistical Offices of the federal states in Wiesbaden, Germany (source: RDC of the Federal Statistical Office and the Statistical Offices of the federal states, DRG Statistics 2005–2015, own calculations). The aggregated statistics were given on basis of SPSS codes (SPSS® software, version 20.0, SPSS Inc., Chicago, IL), which all were supplied from us to the Research Data Center. For this analysis, we selected all surgical hospitalized patients with primary extremity endoprosthetic joint surgeries of the years 2005–2015 in Germany.

Diagnoses, procedural codes, and definitions

In Germany, a diagnosis- and procedure-related remuneration system was introduced in the year 2004 [German Diagnosis Related Groups (G-DRG) system] and the data are gathered by the Research Data Center of the Federal Statistical Office and the Statistical Offices of the federal states in Wiesbaden (Germany). Patients' diagnoses are coded according to the International Classification of Diseases and Related Health Problems with German Modification (10th Revision with German Modification—ICD-10-GM) and surgical or interventional procedures according to the German Procedure Classification [OPS, surgery and procedures codes (Operationen- und Prozedurenschlüssel)].

Thus, we were able to identify all hospitalized surgical patients with primary endoprosthetic joint/bone surgeries of the extremities, who were relevant for the present data analysis, based on the diagnostic code for surgical and interventional procedure codes (OPS codes 5-820, 5-822, 5-824 and 5-826). The patients were further stratified in those operated on lower extremity (OPS codes 5-820, 5-822 and 5-826) or upper extremity (OPS code 5-824) joints.

Study endpoints

The outcomes of this study were death of all-causes during in-hospital stay (in-hospital death), pneumonia (ICD codes J12, J15, J17 and J18), deep venous thrombosis or thrombophlebitis (DVT, ICD code I80), pulmonary embolism (PE, ICD code I26), venous thromboembolism (VTE, including DVT and/or PE), high-risk PE [PE with additional cardiopulmonary resuscitation (OPS code 8-77) and/or shock (ICD code R57)], shock, myocardial infarction (MI, ICD code I21), and ischemic or heamorraghic stroke (ICD codes I61-I64), intracerebral bleeding (ICD code I61), subarachnoid bleeding (ICD code I60) and gastrointestinal bleeding (ICD codes K92.0, K92.1 or K92.2).

Ethical aspects

Since this study did not involve a direct access by the investigators to data of individual patients, approval by an ethics committee and informed consent were not required, in accordance with the German law.

Statistical methods

Descriptive statistics for relevant patient characteristics comparisons of patients with UJS and LJS are provided as median and interquartile range (IQR) or absolute numbers and corresponding percentages. The Mann–Whitney *U* test was used to test the continuous variables of the groups for differences and categorical variables were compared with Fisher's exact or χ^2 test, as appropriate. Risk ratios (RR) were computed to compare patients of the different groups. RR were presented with the corresponding 95% confidence intervals (CIs).

Univariate and multivariate logistic regression models were analyzed to investigate the impact of LJS as a predictor on the mentioned outcomes. The multivariate

regression models were adjusted either for age and sex, or for age, sex, obesity, cancer, heart failure, essential arterial hypertension, renal insufficiency, diabetes mellitus, peripheral artery disease (PAD), coronary artery disease (CAD) and chronic obstructive pulmonary disease (COPD). Odds ratios (OR) are given with the corresponding 95% CIs. Since particularly cardiovascular and renal diseases, but also COPD as well as cancer, are well-known potential fatal conditions during the in-hospital stay of patients hospitalized for other reasons, an epidemiological approach with adjustment of the multivariate regressions including age, sex and all mentioned comorbidities was selected to test the widespread independence of the variables and important triggers of in-hospital mortality beside VTE events.

To test the time trends regarding temporal changes in the aforementioned study endpoints, we calculated linear regressions for the 11-year timeframe. Additionally, we showed temporal changes of these study endpoints descriptively.

The software SPSS® (version 20.0; SPSS Inc., Chicago, Illinois) was used for computerized analysis. *P* values of < 0.05 (two sided) were considered to be statistically significant.

Results

In total, 4,134,088 hospitalized patients with primary extremity endoprosthetic surgeries (64.3% females, 54.0% aged > 70 years) were included in our analysis. Among these, 3,950,668 patients (95.6%) undergo lower and 183,420 (4.4%) upper extremity endoprosthetic surgery.

Patients undergoing UJS were in median 2 years older, more often of female sex, but less often obese, although they showed a higher prevalence of diabetes (Table 1). Patients with LJS revealed more often coronary artery disease and essential arterial hypertension (Table 1).

The incidence of VTE events per 100,000 endoprosthetic joint surgeries was in LJS distinctly higher than in UJS (1035.50 vs. 402.88 VTE events per 100,000 surgeries).

VTE events [RR 2.60 (95% CI 2.41–2.79), $P < 0.001$] encompassing DVT [RR 3.12 (95% CI 2.83–3.43), $P < 0.001$], PE [RR 1.92 (95% CI 1.73–2.13), $P < 0.001$], high-risk PE [RR 2.41 (95% CI 1.91–3.03), $P < 0.001$] and fatal PE [RR 3.03 (95% CI 2.26–4.05), $P < 0.001$] were consistently more often observed in hospitalized patients with LJS (Table 2). Also all-cause death [RR 1.68 (95% CI 1.58–1.77), $P < 0.001$], shock [RR 1.49 (95% CI 1.34–1.64), $P < 0.001$], cardiopulmonary resuscitation [RR 1.20 (95% CI 1.14–1.27), $P < 0.001$], MI [RR 1.17 (95% CI 1.08–1.26), $P < 0.001$] and stroke [RR 1.13 (95% CI

Table 1 Baseline characteristics of the 4,134,088 joint replacement patients stratified for upper or lower extremity joint replacements

Parameters	Upper extremity joint replacement ($n = 183,420$; 4.4%)	Lower extremity joint replacement ($n = 3,950,668$; 95.6%)	*P* value
Age	73.0 (65.0–79.0)	71.0 (63.0–78.0)	**< 0.001**
Age > 70 years	108,826 (59.3%)	2,123,996 (53.8%)	**< 0.001**
Female sex[a]	135,910 (74.1%)	2,520,481 (63.8%)	**< 0.001**
In-hospital stay (days)	11 (8–15)	13 (10–15)	**< 0.001**
Obesity	21,404 (11.7%)	649,360 (16.4%)	**< 0.001**
Comorbidities			
Cancer	3232 (1.8%)	65,412 (1.7%)	**< 0.001**
Coronary artery disease	17,339 (9.5%)	402,447 (10.2%)	**< 0.001**
Chronic heart failure	13,820 (7.5%)	304,180 (7.7%)	**0.010**
Peripheral artery disease	1898 (1.0%)	49,025 (1.2%)	**< 0.001**
Atrial fibrillation/flutter	13,106 (7.1%)	291,695 (7.4%)	**< 0.001**
Chronic obstructive pulmonary disease	8367 (4.6%)	157,767 (4.0%)	**< 0.001**
Essential arterial hypertension	96,781 (52.8%)	2,182,106 (55.2%)	**< 0.001**
Renal insufficiency	14,900 (8.1%)	307,435 (7.8%)	**< 0.001**
Diabetes mellitus	32,872 (17.9%)	625,409 (15.8%)	**< 0.001**
Coagulation abnormalities	5234 (2.9%)	106,711 (2.7%)	**< 0.001**
Thrombophilia	138 (0.08%)	3404 (0.09%)	0.118

P values < 0.05 were considered to be statistically significant

[a]Data available for $n = 4,133,939$ patients

Table 2 In-hospital conditions/outcomes of the 4,134,088 joint replacement patients stratified for upper or lower extremity joint replacements

Parameters	Upper extremity joint replacement ($n=183,420$; 4.4%)	Lower extremity joint replacement ($n=3,950,668$; 95.6%)	*P* value
In-hospital death	1254 (0.7%)	45,021 (1.1%)	**< 0.001**
Pneumonia	2092 (1.1%)	46,129 (1.2%)	0.291
Venous thromboembolism	736 (0.4%)	40,909 (1.0%)	**< 0.001**
Deep venous thrombosis or thrombophlebitis	420 (0.2%)	28,040 (0.7%)	**< 0.001**
Pulmonary embolism	369 (0.2%)	15,243 (0.4%)	**< 0.001**
Pulmonary embolism—High-risk status	73 (0.04%)	3782 (0.10%)	**< 0.001**
Fatal pulmonary embolism	46 (0.03%)	2996 (0.08%)	**< 0.001**
Shock	427 (0.2%)	13,643 (0.3%)	**< 0.001**
Adverse in-hospital event	6035 (3.3%)	119,111 (3.0%)	**< 0.001**
Mechanical ventilation	4418 (2.4%)	69,649 (1.8%)	**< 0.001**
Cardio-pulmonary resuscitation	1212 (0.7%)	31,359 (0.8%)	**< 0.001**
Myocardial infarction	668 (0.4%)	16,767 (0.4%)	**< 0.001**
Stroke	625 (0.3%)	15,265 (0.4%)	**0.002**
Intracerebral bleeding	60 (0.03%)	742 (0.02%)	**< 0.001**
Subarachnoid bleeding	26 (0.01%)	143 (0.004%)	**< 0.001**
Gastro-intestinal bleeding	392 (0.2%)	8518 (0.2%)	0.864
Transfusion of blood constituents	26,764 (14.6%)	812,283 (20.6%)	**< 0.001**

P values < 0.05 were considered to be statistically significant

1.05–1.23), $P=0.002$] were more often detected in the in-hospital course of patients with LJS (Table 2).

In contrast, bleeding events such as intracerebral bleeding [RR 0.57 (95% CI 0.44–0.75), $P<0.001$] and subarachnoid bleeding [RR 0.26 (95% CI 0.17–0.39), $P<0.001$] were more often found in patients with UJS (Table 2).

Risk for VTE events [OR 2.69 (95% CI 2.50–2.90), $P<0.001$] and in-hospital death [OR 1.65 (95% CI 1.56–1.75), $P<0.001$] were both higher in LJS than in UJS independently of age, sex and comorbidities (Table 3).

While the annual in-hospital mortality rate decreased in patients with UJS [β −0.19 (95% CI −0.35 to −0.02), $P=0.025$] as well as in those with LJS [β −0.06 (95%

Table 3 Impact of joint replacements of the lower extremity on in-hospital outcomes (univariate and multivariate logistic regression models) in comparison to inpatients with joint replacements of the upper extremity

	Univariate regression model		Multivariate regression model[a]		Multivariate regression model[b]	
	OR (95% CI)	*P* value	OR (95% CI)	*P* value	OR (95% CI)	*P* value
Pneumonia	1.02 (0.98–1.07)	0.291	0.99 (0.95–1.03)	0.590	0.96 (0.92–1.01)	0.110
Venous thromboembolism	2.60 (2.41–2.79)	**< 0.001**	2.74 (2.55–2.95)	**< 0.001**	2.69 (2.50–2.90)	**< 0.001**
Deep venous thrombosis or thrombophlebitis	3.12 (2.83–3.43)	**< 0.001**	3.24 (2.94–3.56)	**< 0.001**	3.17 (2.87–3.49)	**< 0.001**
Pulmonary embolism	1.92 (1.73–2.13)	**< 0.001**	2.08 (1.87–2.30)	**< 0.001**	2.03 (1.83–2.25)	**< 0.001**
All-cause in-hospital death	1.68 (1.58–1.77)	**< 0.001**	1.71 (1.61–1.80)	**< 0.001**	1.65 (1.56–1.75)	**< 0.001**
Myocardial infarction	1.17 (1.08–1.26)	**< 0.001**	1.18 (1.09–1.27)	**< 0.001**	1.13 (1.05–1.23)	**0.002**
Stroke	1.13 (1.05–1.23)	**0.002**	1.18 (1.09–1.28)	**< 0.001**	1.18 (1.09–1.28)	**< 0.001**
Intracerebral bleeding	0.57 (0.44–0.75)	**< 0.001**	0.57(0.44–0.75)	**< 0.001**	0.59(0.45–0.76)	**< 0.001**
Subarachnoid bleeding	0.26 (0.17–0.39)	**< 0.001**	0.26 (0.17–0.40)	**< 0.001**	0.27 (0.18–0.41)	**< 0.001**
Gastro-intestinal bleeding	1.01 (80.91–1.12)	0.864	1.01 (0.91–1.12)	0.828	1.00 (0.91-1.11)	0.965

P values < 0.05 were considered to be statistically significant

[a]Adjusted for age and sex

[b]Adjusted for age, sex, obesity, cancer, heart failure, essential arterial hypertension, renal insufficiency, diabetes mellitus, peripheral artery disease, coronary artery disease and chronic obstructive pulmonary disease

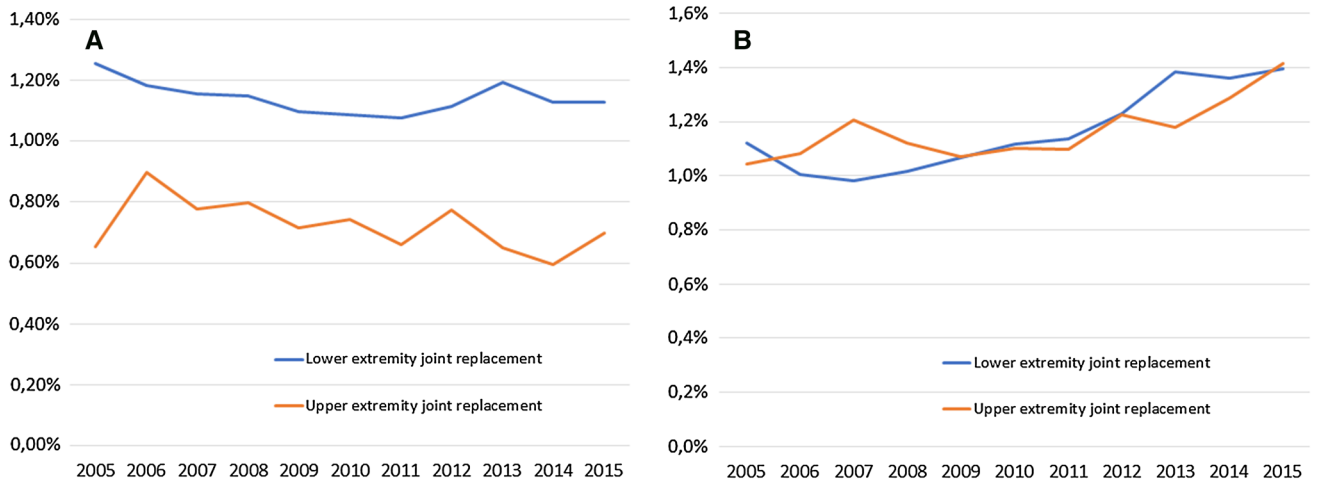

Fig. 1 Annual rates of in-hospital death (**a**) and pneumonia during hospitalization (**b**) in Germany 2005–2015. The orange line represents patients with upper extremity endoprosthetic joint surgery and the blue line patients with lower extremity endoprosthetic joint surgery

CI −0.09 to −0.03], $P<0.001$) over time (Fig. 1a), the annual rate of pneumonia during in-hospital stay increased in both patients groups: UJS [β 0.22 (95% CI 0.10–0.35), $P=0.001$] and in LJS [β 0.35 (95% CI 0.33 to 0.38), $P<0.001$] (Fig. 1b). VTE events during in-hospital stay decreased over time in patients with LJS [β −0.49 (95% CI −0.52 to −0.46], $P<0.001$), but not in those with UJS [β −0.21 (95% CI −0.43–0.00), $P=0.051$] (Fig. 2a). This result was consistent for both VTE entities: DVT events during in-hospital stay declined in patients with LJS over time [β −0.56 (95% CI −0.60 to −0.53), $P<0.001$], but not in those with UJS [β −0.13 (95% CI −0.42–0.16), $P=0.374$] (Fig. 2b). Similarly, annual PE event rate during in-hospital stay decreased in patients with LJS [β −0.35 (95% CI −0.40 to −0.30), $P<0.001$], but not in those with UJS [β −0.28 (95% CI −0.59 to 0.02), $P=0.066$] (Fig. 2c). Intracerebral bleeding events were, during the whole observational period (2005–2015), higher in patients with UJS than in those with LJS (Fig. 3a). The rate of intracerebral bleeding declined in patients with LJS over time [β −0.24 (95% CI −0.47 to −0.01), $P=0.037$], whereas patients with UJS had no temporal change [β −0.42 (95% CI −1.17 to 0.33), $P=0.270$] regarding intracerebral haemorrhage (Fig. 3a). Annual rate of gastrointestinal bleeding was recognized to decrease in patients with LJS [β 0.15 (95% CI 0.08 to 0.22), $P<0.001$], but not in these with UJS [β 0.03 (95% CI −0.27 to 0.32), $P=0.861$] from 2005 to 2015 (Fig. 3b).

Discussion

Patients who undergo total hip or knee arthroplasty surgeries are at high risk to develop a postoperative VTE event; therefore, a thromboprophylactic treatment is strongly recommended [2, 10, 11, 16, 19–22]. Without thromboprophylaxis, the incidence of symptomatic combined with

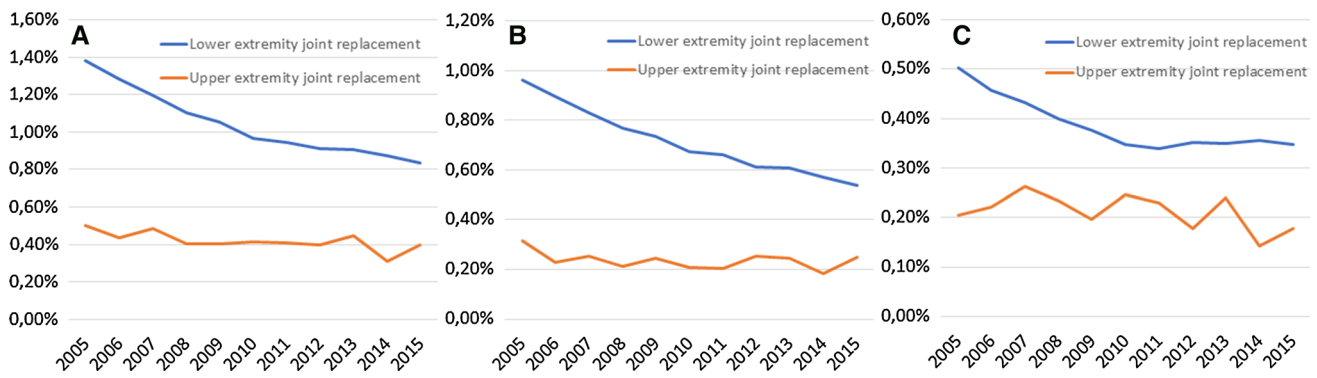

Fig. 2 Annual changes regarding VTE (**a**), DVT (**b**) and PE (**c**) in Germany 2005–2015. The orange line represents patients with upper extremity endoprosthetic joint surgery and the blue line patients with lower extremity endoprosthetic joint surgery

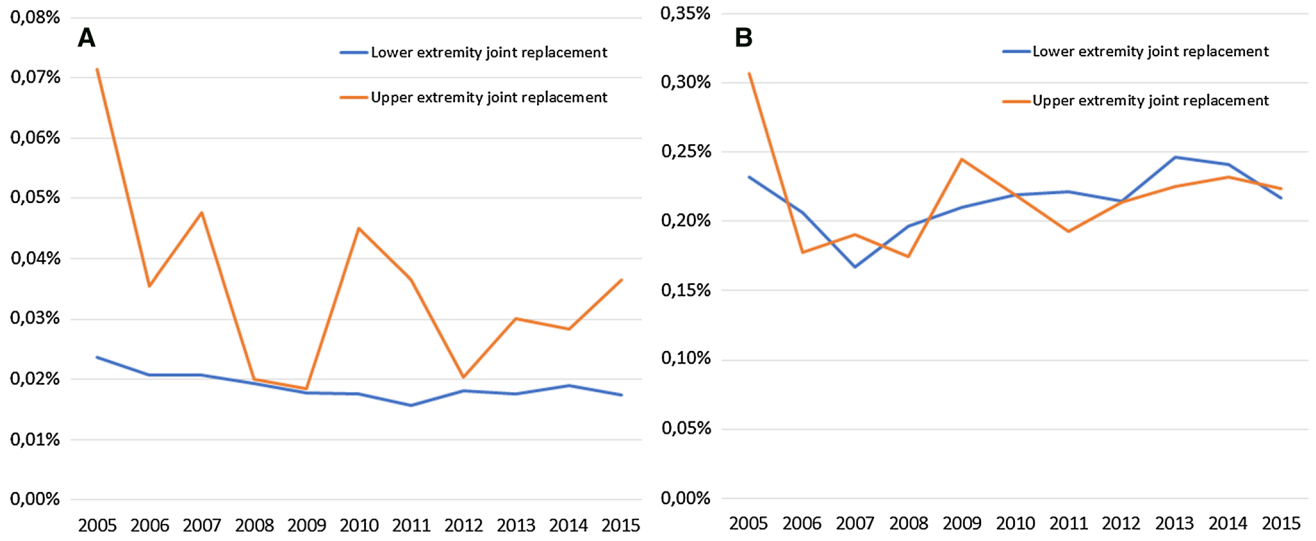

Fig. 3 Annual rates of intracerebral bleeding (**a**) and gastrointestinal bleeding during hospitalization (**b**) in Germany 2005–2015. The orange line represents patients with upper extremity endoprosthetic joint surgery and the blue line patients with lower extremity endoprosthetic joint surgery

asymptomatic VTE complications is high (18–60%) after hip [18, 19, 21–27] and (5–84%) after knee arthrosplasty surgeries [18–22, 27–33] in screening examinations.

Despite the medical progress and the benefits of the well-established thromboprophylactic treatment, nevertheless, approximately 8.9–25.6% of the patients develop still a symptomatic or asymptomatic VTE event and 0.5–4.0% suffer from symptomatic VTE complications after hip and knee replacement surgeries nowadays [2, 10, 22, 27, 34, 35]. The more hazardous VTE complication of acute PE occurs in 0.2–1.9% of the patients [35–37].

In contrast, data about the incidence of VTE after upper extremity joint replacements are limited. Dattani et al. [38]. reported a VTE incidence of 0.5% after shoulder replacement surgeries and of 0.3% after elbow joint replacements [38]. Particularly, information about the relative risk between upper and lower extremity joint replacement surgeries is missing.

Our results of the nationwide inpatient sample of Germany, analyzing more than 4 Million hospitalized patients undergoing endoprosthetic joint/bone surgeries between the years 2005 and 2015, revealed a significantly higher incidence of VTE events per 100,000 endoprosthetic surgeries in LJS than in UJS (1035.50 vs. 402.88 VTE events per 100,000 surgeries). The incidence rate of VTE in this present study of 1.0% during the in-hospital stay in patients with LJS was in the range of other studies about total hip and knee arthroplasty surgeries, but the reported range of VTE events in these studies was wide (between 0.3% and 61.0%) [36, 39] and not per se comparable to our data, because we focused on the in-hospital period only and depending on cited studies more than one-third [40] or even the majority [27] of the VTE events after hip and knee replacements were identified after discharge. Studies reported that although venous thrombi often begin to grow during the intraoperative period, some thrombi did not develop until days or weeks after surgery [27, 40–42]. VTE events occurred in median between 3 and 21 days after hip and knee replacement surgeries [37, 41]. Moreover, while DVT after surgery is usually located in the deep veins of the calf, approximately half of such calf DVT resolve spontaneously within the first 3 days post-surgery [41]. Remarkably, an extension of the DVT thrombus burden to the proximal leg veins is associated with increased risk for PE [41]. In clinical practice, there is no systematic screening for VTE events in clinical routine. Silent asymptomatic VTE events will in most cases not identified, before they get symptomatic. These limitations could lead to a BIAS in the frequency of the detected VTE complications after the mentioned joint replacement surgeries.

The VTE incidence in Germany in our study was 0.4% in patients with UJS, which is in line with the results of Dattani et al. [38] of 0.5% investigating in their review about 14 studies with more than 44,000 patients [38].

In our study, VTE events occurred with a RR of 2.60-fold more frequently in patients with LJS compared to UJS. In parallel, the RR for VTE entities DVT with 3.12-fold and PE with 1.92-fold, but also for all-cause mortality with RR of 1.68-fold, showed significant higher rates in LJS than in UJS.

Remarkably, while MI and stroke, as important major cardiovascular events, were only slightly elevated in patients with endoprosthetic surgeries of LJS compared to UJS, rate of VTE and especially fatal PE was significantly higher in

patients with LJS. These findings suggest that VTE plays a key role regarding postoperative complications especially after LJS and is a major cause of in-hospital mortality in these patients. Additionally, our results suggest firstly that VTE in patients with endoprosthetic surgeries occurred more often in LJS than in UJS and secondly had a higher impact on in-hospital death in patients with LJS compared to UJS (Table 2; the rate of fatal PE was higher in patients, who had a LJS compared to patients with UJS 0.08% vs. 0.03%, $P < 0.001$). Importantly, the risk for VTE events and in-hospital death were both higher in LJS than in UJS independent of age, sex and comorbidities.

While both the replacements of weight-bearing joints of the lower extremities as well as those of non-weight bearing joints of the upper extremity are accompanied by VTE risk factors such as trauma, surgery, inflammation and immobilization, especially the immobilization period after replacements of weight-bearing joints might influence the risk of VTE significantly [1, 11]. Immobilization period is commonly longer for LJS compared to UJS and immobilization affects a larger part of the human body. This may explain the higher VTE rates after surgeries and especially replacements of weight-bearing joints.

The results of our study highlight the outstanding importance of thromboprophylaxis particularly in patients undergoing LJS [10, 14, 43], especially in consideration of an increased demand for total hip and total knee replacement surgeries and an aging population in the western countries [15, 44].

Although lower rates regarding the administration of prophylactic pharmacological anticoagulation have to be expected after UJS, the risk for intracerebral bleeding and subarachnoid bleeding during hospitalizations for UJS was significantly higher compared to those patients with LJS. This might be partly explained by higher age and higher rate of renal insufficiency in patients with UJS compared to those with LJS [45, 46].

During the observational period, the annual VTE rates and the rates of intracerebral as well as gastrointestinal bleeding events decreased significantly in LJS patients from 2005 to 2015, resulting in a lower short-term mortality rate in these patients. This might be driven by better patient management with changes in thromboprophylactic treatment over time.

Limitations

Our study results are based on ICD discharge codes and OPS procedural/surgical coding, which might lead to incomplete data due to under-reporting/under-coding. One important limitation of our study is the focus on in-hospital observation period without assessment of outpatient events after discharge, potentially underestimating the real numbers of postoperative VTE events. It is well known that although venous thrombi often begin during the intraoperative period, some are not identified until days or weeks after surgery [27, 40–42], but nevertheless we were able to compare the risk of VTE events and other outcomes in patients with LJS and UJS. Due to coding reasons, we were not able to investigate deep venous thrombosis singularly without combination with thrombophlebitis. Of note, silent (asymptomatic) VTE events might be partly overlook in daily routine, but it seems unlikely that symptomatic VTE events were not identified. Nevertheless, the key strength of this analysis is the large number of analysed patients.

To avoid a bias by revision surgeries, we decided to exclude the revision surgeries and focus on the primary joint replacements. Revisions of knee, hip and upper extremity joint replacements are more commonly due to stiffness or infections than primary joint replacements and those surgeries are more often accompanied with longer surgery durations, longer immobility and more difficult procedures [47]. Therefore, revision procedures have a higher risk for VTE events than primary joint replacements [48, 49].

Conclusions

Patients, who undergo LJS, bear a 2.6-fold higher risk for VTE and 1.7-fold higher risk for in-hospital all-cause death compared to those with UJS.

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Author contributions KK, LH and ME contributed in conception and design of the study, and analysis as well as interpretation of data. All authors contributed in writing, revising and drafting the manuscript. They have read and approved the final submitted manuscript version. K.K. takes responsibility for the integrity of the work as a whole, from inception to finished article.

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Compliance with ethical standards

Conflicts of interest The author(s) declare that they have no competing interests.

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