Meta-Analysis

While the Incidence of Venous Thromboembolism After Shoulder Arthroscopy Is Low, the Risk Factors Are a Body Mass Index Greater than 30 and Hypertension

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Purpose: This study aims to determine the overall incidence of venous thromboembolism (VTE) following shoulder arthroscopy and to define potential risk factors associated with its development that may help define guidelines for the use of thromboprophylaxis**. Methods:** A systematic review was performed using PubMed, Embase, Web of Science, CINAHL, and Cochrane databases per PRISMA guidelines. The search terms consisted of variations of "Venous Thromboembolism" and "Shoulder Arthroscopy." Information regarding arthroscopy indication, risk factors, outcomes, and patient demographics was recorded and analyzed, and pooled odds ratios were reported for each variable. **Results:** Six hundred eighty-five articles were identified in the initial search, and 35 articles reported DVT, PE, or VTE incidence following shoulder arthroscopy. Seventeen nonoverlapping articles with a unique patient population incidence rates. Four articles were then used for subgroup meta-analysis. The incidence rate of VTE was 0.24%, ranging from 0.01% to 5.7%. BMI >30 (OR = 1.46; 95% CI = [1.22, 1.74]; I^2 = 0%) and hypertension (OR = 1.64; 95% CI = [1.03, 2.6]; I^2 = 75%) were significant risk factors ($P < .05$) for developing VTE following shoulder arthroscopy. Diabetes (OR = 1.2; 95% CI = [0.97, 1.48]; I^2 = 0%), insulin-dependent diabetes (OR = 5.58; 95% CI = [0.12, 260.19]; I^2 = 85%), smoking (OR = 1.04; 95% CI = [0.79, 1.37]; I^2 = 12%), male sex (OR = 0.95; 95% CI = [0.49, 1.85]; I^2 = 86%) and age over 65 (OR = 4.3; 95% CI = [0.25, 72.83]; I^2 = 85%) were not associated with higher VTE risk. **Conclusion:** The VTE incidence following shoulder arthroscopy is low at 0.24%. Patients with BMI >30 and hypertension are at a higher risk for VTE after shoulder arthroscopy. **Level of Evidence:** Level IV, systematic review and meta-analysis of Level I-IV studies.

Introduction

Shoulder arthroscopy is one of the most common surgical procedures in orthopaedic surgery. According to the data on ambulatory surgeries performed in 2006, an estimated 530,000 shoulder arthroscopic procedures were done in the United States that year.[1] With an aging active population and advancements in surgical procedures, expected to rise. The complication rate following shoulder arthroscopy procedure has been estimated to be 7.9%, with

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surgical complications being the most common.[2] These complications include joint stiffness, persistent pain, infection, nerve palsy, and vascular injury.[2-4] Other less common complications can be related to anesthesia and medical causes. However, since the number of procedures is increasing annually, those complications are expected to be encountered more often and, thus, require specific guidelines.

Venous thromboembolism (VTE) is an established complication following major lower extremity surgeries. The mortality rate related to VTE in such cases is around 1%, with deep vein thrombosis (DVT) rates as high as 20% without DVT prophylaxis.[5,6]. Thus, specific guidelines were established for the use of thromboprophylaxis to prevent VTE-related complications and were able to decrease the incidence rate to less than 1%.[7] Knee arthroscopy is also the most common lower limb surgeries worldwide. Although the incidence rate of VTE is low, and thromboprophylaxis is not warranted, certain risk factors may necessitate thromboprophylaxis. According to the 2012 American College of Chest Physicians (ACCP) and 2018 European Society of Anesthesiology (ESA) guidelines, thromboprophylaxis following knee arthroscopy surgery is only recommended in patients with a previous history of VTE or patients are at a high risk of developing VTE.[8,9] Risk factors for developing VTE following knee arthroscopy surgery include a history of VTE, cancer, prior surgery within 30 days, operating room time >1.5 hours, black race, BMI, and oral contraceptive use.[10-13] In a more recent guideline, set by The International Consensus Meeting (ICM) on VTE, recommendations are made for VTE prevention after various orthopaedic surgeries.[14-16] The guidelines demonstrated that although specific risk factors are associated with VTE occurrence in lower extremity and trauma surgeries, there is still no clear understanding and risk stratification method for VTE occurrence in shoulder arthroscopy.[16]

Thromboprophylaxis following shoulder arthroscopy has rarely been warranted since the risk of VTE is low. However, as the number of shoulder arthroscopy procedures has increased, so has the expected rate of reporting VTE. Therefore, there is a need to establish guidelines for thromboprophylaxis to prevent VTE and its complications in patients at risk. It is also essential to identify specific risk factors that may predispose to VTE after shoulder arthroscopy. The purposes of this study were to determine the overall incidence of VTE following shoulder arthroscopy and to define potential risk factors associated with its development that may help define guidelines for the use of thromboprophylaxis. We hypothesized that the incidence of VTE would be low after shoulder arthroscopy and that risk factors would be identified.

Methods

Search Strategy and Selection Criteria

A search was carried out using PubMed, Embase, Web of Science, CINAHL, and Cochrane databases per the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement in December 2022.[17] The search terms consisted of variations of "Venous Thromboembolism" and "Shoulder Arthroscopy" (see Appendix 1: Search strategy). We included studies reporting the incidence of VTE following shoulder arthroscopy and its associated risk factors. Studies were eligible for inclusion if they met the following criteria: 1) reported incidence of VTE following shoulder arthroscopy; 2) case-control, cohort studies, or randomized controlled trial; 3) full-text articles available in English; and 4) at least 30 days of follow-up postsurgery. Meeting presentations, abstracts, reviews, case reports, and studies containing patients with a primary or secondary hypercoagulable state, current antithrombotic therapy, and history of VTE or cancer, were excluded from this analysis.

Screening and Data Extraction

Two investigators (K.M. and S.J.M.) screened the studies independently for eligibility. Disagreements were solved by an attempt to reach a consensus. Six hundred seventy-six articles were identified in the initial search. After screening of the abstract and full text, 33 articles from the systematic search and 2 articles from the manual search met eligibility criteria and were considered for data extraction. After excluding overlapping data, 18 articles with unique patient populations were used for assessing the incidence rate of DVT, PE, and VTE. Four articles were then used for meta-analysis (Fig 1). Two independent reviewers (K.M. and D.Y.) extracted data, according to a standardized template that included the journal name first author, publication year, span of participant enrollment, study design, the country in which the study was performed, number of included patients, sex ratio, the mean age of participants, duration of follow-up, DVT, PE, and total VTE occurrences and risk factors. The level of evidence for each article was noted on the basis of the Oxford Centre for Evidence-based Medicine Levels of Evidence.[18]

Statistical Analysis

Risk factors of interest that were consistently reported by at least 2 studies were included in the meta-analysis. Data analysis was performed using STATA 17 software. We compiled odds ratios (OR) and exposed participants to generate pooled effect sizes with 95% confidence intervals (CI). Risk ratios and crude data were converted to odds ratios to generate pooled ORs. A

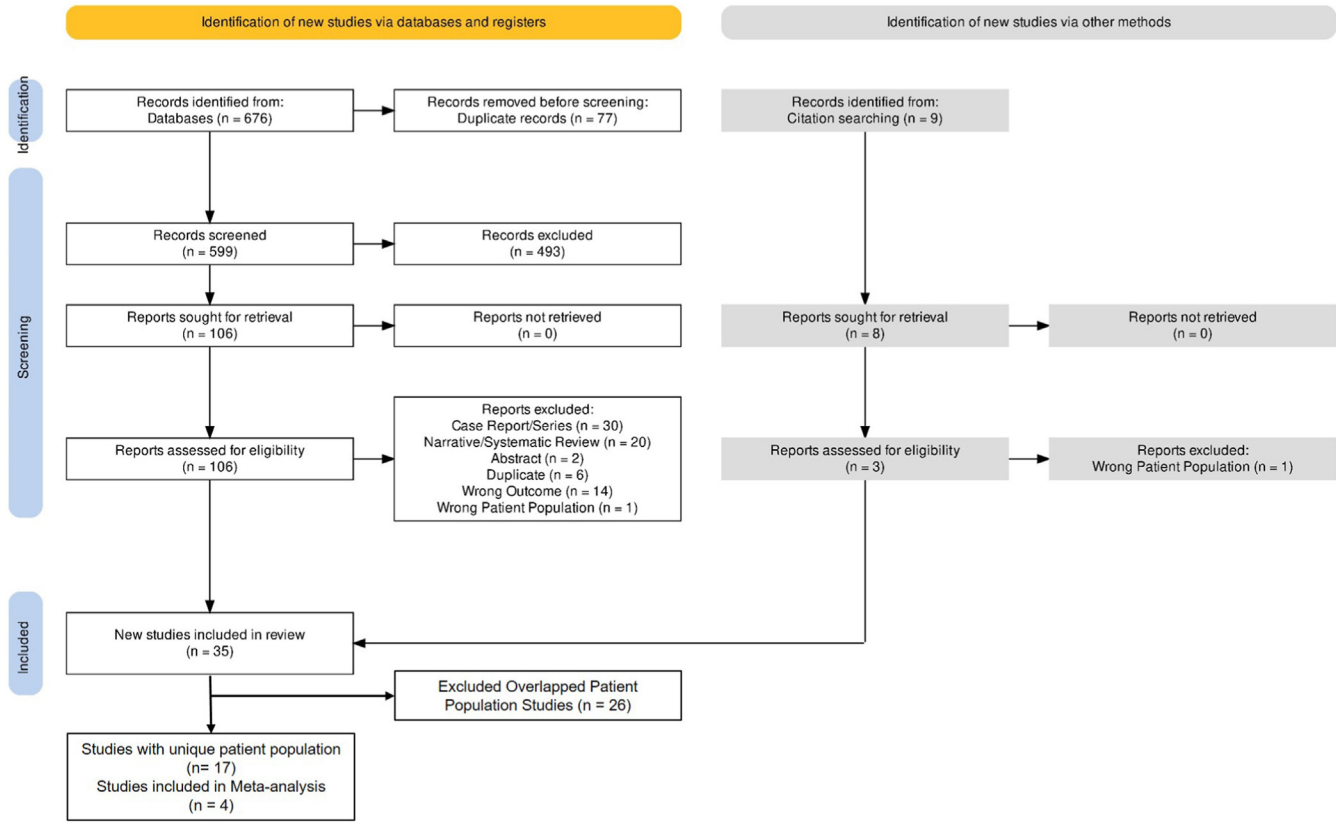

Fig 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow chart for inclusion in this systematic review and meta-analysis.

random-effects model was selected to account for between-study variation.

The methodologic quality of the reported studies was assessed using the Newcastle-Ottawa Scale (NOS) by one author (D.Y.) and verified by a second author (K.M.). Heterogeneity between studies was assessed using the I^2 statistic. Further analysis was implemented in cases of statistically significant heterogeneity ($P < .05$). A random-effects model was employed in cases where sensitivity analyses could not explain the heterogeneity. Publication bias was evaluated using a funnel plot and further assessed by the Begg and Mazumdar test.[19] The protocol for this study has been registered in the PROSPERO register (ID=CRD42021205992).

To calculate the number of patients needed to treat (NNT) to avoid one VTE, we used absolute risk reduction (ARR), the difference between the incidence of VTE in the treated and untreated groups. Assuming that VTE prophylaxis is given to all patients, the ARR for VTE in obese patients would be 0.26% × 46% = 0.12%, and in hypertensive patients, it would be 0.26% × 64% = 0.17%. Using the formula NNT = 1/ARR, we can estimate the number of patients to avoid one VTE.

Results

Thirty-five articles were identified to report the risk of DVT, PE, or VTE (Table 1). Among these 35 articles, 9 directly used hospital databases (i.e., small-data), and the other 26 articles used data derived from national registries (i.e., Big-Data); 18 from NSQIP, two from NHS, two from PearlDiver, one from SIGASCOT, one from ABOS, one from Medicaid, one from ACESS, and one from RECOS. Overlap (i.e., duplication) in primary studies was assessed to ensure that unique patient populations are included in data analysis, and the single article that encompasses the largest patient population was included from the overlapping registries. Overall, 17 articles with a unique patient population (526,145 patients) were selected, and the incidence of DVT, PE, and VTE was calculated in populations that reported these outcomes (Table 2).

The overall incidence rate of VTE was 0.24% (16 articles, 237,895 arthroscopy patients), ranging from 0.01% to 5.71%. Looking at the small-data group (8 articles, 6,484 arthroscopy patients), the overall VTE incidence was calculated to be 0.53%, twice as high as the overall incidence rate when national registries are included. DVT incidence ranged from 0.005% to 5.7% in 14 articles involving 179,859 arthroscopy patients,

Table 1. Characteristics of Studies Included in the Systematic Review

Study	Year	Country	Database / Registry	Level of Evidence[18]	Mean Age	Sex, % of Male	# of Arthroscopy Patients	# DVT (%)	# PE (%)	# VTE (%)
Agarwalla et al.[61]	2019	USA	NSQIP 2005 – 20016	3 Cohort study	58.4	58	27,524	NR	52 (0.189)	77 (0.28)
Kuremsky et al.[62]	2011	USA	**Single Center 2002 – 2006**	3 Non-randomized follow-up study	47	NR	1,908	5 (0.262)	4 (0.21)	6 (0.314)
Randelli et al.[63]	2010	Italy	**SIGASCOT 2005 – 2006**	4 Case-Control Study	NR	NR	9,385	5 (0.053)	1 (0.011)	6 (0.064)
Wronka et al.[64]	2014	UK	**Single Center**	4 Case series	NR	NR	1,281	3 (0.234)	1 (0.078)	4 (0.312)
Hill et al.[53]	2017	USA	NSQIP 2011 – 2013	3 Non-randomized controlled cohort study	NR	83	15,015	21 (0.14)	20 (0.133)	41 (0.273)
Day et al.[65]	2018	USA	NSQIP 2005 – 2013	3 Cohort study	59.04	57.99	8,632	12 (0.139)	21 (0.243)	33 (0.382)
Alyea et al.[66]	2019	USA	**Multicenter 2010 – 2015**	4 Case-control study	58.4	65	914	6 (0.656)	1 (0.109)	6 (0.656)
Basques et al.[67]	2018	USA	NSQIP 2005 – 2012	3 Non-randomized controlled cohort study	NR	59.4	15,774	NR	NR	35 (0.222)
Boddapati et al.[68]	2018	USA	NSQIP 2012 – 2015	3 Cohort study	NR	60.3	33,095	NR	NR	31 (0.094)
Bokshan et al.[69]	2017	USA	NSQIP 2005 – 2014	3 Non-randomized controlled cohort study	31.8	74	2,291	2 (0.087)	1 (0.044)	3 (0.131)
Brislin et al.[70]	2007	USA	**Single Center 2003**	4 Case-series	61	NR	263	1 (0.38)	NR	1 (0.38)
Cancienne et al.[71]	2017	USA	**Medicare database 2005 – 2012**	4 Case-control Study	NR	51.8	24,430	39 (0.16)	24 (0.098)	49 (0.201)
Hastie et al.[72]	2014	UK	**Single Center 2009 – 2012**	3 Non-randomized controlled cohort study	54	NR	472	2 (0.424)	1 (0.212)	3 (0.636)
Heyer et al.[73]	2018	USA	NSQIP 2006 – 2015	3 Non-randomized controlled cohort study	NR	58	21,143	NR	NR	54 (0.255)
Hoxie et al.[74]	2008	USA	**Single Center 2001 – 2005**	3 Non-randomized controlled cohort study	60.3	60.7	309	NR	2 (0.647)	2 (0.647)
Khazi et al.[75]	2020	USA	NSQIP 2006 – 2016	4 Case-control study	NR	65.31	147	1 (0.68)	NR	1 (0.68)
Martin et al.[76]	2013	USA	NSQIP 2005 – 2011	4 Case-control study	NR	NR	9,410	8 (0.085)	6 (0.064)	14 (0.149)
McCrum et al.[77]	2019	USA	**Single Center 2006 – 2014**	4 Case-control study	53.7	70.8	1,526	2 (0.131)	2 (0.131)	4 (0.262)
Goodloe et al.[78]	2020	USA	NSQIP 2005 – 2017	4 Case-control study	30.5	76.7	5,964	NR	NR	6 (0.101)

(continued)

Table 1. Continued

Study	Year	Country	Database / Registry	Level of Evidence[18]	Mean Age	Sex, % of Male	# of Arthroscopy Patients	# DVT (%)	# PE (%)	# VTE (%)
Imberti et al.[20]	2015	Italy	**RECOS 2009 – 2011**	2 Inception cohort studies	55.4	54.8	982	2 (0.204)	1 (0.102)	3 (0.305)
Jameson et al.[33]	2011	UK	**NHS 2005 – 2008**	3 Non-randomized controlled cohort study	52	NR	65,302	3 (0.005)	5 (0.008)	7 (0.011)
Nicolay et al.[40]	2019	USA	**NSQIP 2006 – 2016**	4 Case-control study	NR	NR	56,463	60 (0.106)	67 (0.119)	112 (0.198)
Rubenstein et al.[79]	2019	USA	NSQIP 2015 – 2016	3 Non-randomized controlled cohort study	NR	NR	26,509	31 (0.117)	35 (0.132)	66 (0.249)
Rubenstein et al.[4]	2017	USA	NSQIP 2006 – 2013	3 Non-randomized controlled cohort study	67.7	NR	7,867	17 (0.216)	14 (0.178)	31 (0.394)
Sager et al.[52]	2019	USA	NSQIP 2005 – 2017	4 Case-control study	58.3	58.4	31,615	39 (0.123)	66 (0.209)	94 (0.297)
Schick et al.[38]	2014	USA	**ACESS 2002 – 2011**	4 Case-control study	NR	NR	15,033	15 (0.1)	8 (0.053)	22 (0.146)
Shields et al.[80]	2014	USA	NSQIP 2005 – 2010	3 Non-randomized controlled cohort study	NR	NR	6,697	NR	NR	31 (0.463)
Shields et al.[3]	2015	USA	NSQIP 2005 – 2011	4 Case-series	59.7	NR	10,255	8 (0.078)	7 (0.068)	15 (0.146)
Sing et al.[81]	2016	USA	NSQIP 2011 – 2013	4 Case-control study	54.3	59.3	9,290	15 (0.161)	10 (0.108)	25 (0.269)
Stone et al.[82]	2019	USA	**PearlDiver 2007 - 2016**	4 Case-control study	NR	54.3	57,727	NR	196 (0.34)	328 (0.568)
Takahashi et al.[23]	2014	Japan	**Single Center 2011 – 2013**	4 Case-control study	61	71.4	175	10 (5.714)	1 (0.571)	10 (5.714)
Xiao et al.[83]	2019	USA	PearlDiver 2007 – 2017	3 Non-randomized controlled cohort study	NR	53.59	58,907	NR	NR	45 (0.076)
Yeung et al.[84]	2020	USA	**ABOS 2012 – 2016**	4 Case-series	56.27	62.6	1725	2 (0.116)	3 (0.174)	5 (0.29)
Rees et al.[85]	2022	UK	**NHS 2009 – 2017**	2 Randomized trial study	55	52.19	288,250	NR	202 (0.07)	NR
Plantz et al.[54]	2022	USA	NSQIP 2016 – 2017	4 Case-control study	NR	57.77	17,880	23 (0.12)	40 (0.22)	63 (0.35)

ABOS, American Board of Orthopaedic Surgery; ACESS, Association of Clinical Elbow and Shoulder Surgeons; NHS, National Health Service; NR, Not reported; NSQIP, National Surgical Quality Improvement Program; SIGASCOT, Society for Knee Surgery, Arthroscopy, Sport Traumatology, Cartilage and Orthopaedic Technologies.

Studies with **Bold databases** were used for incidence calculations. LoE, Level of evidence.[18]

Table 2. Incidence rate of DVT, PE, and VTE in Small-Data (Defined as Data Derived Directly From Hospital Databases), Big-Data (Defined as Data From Registries), and Overall Patient Populations

	DVT			PE			VTE		
	Small Data	Big Data	Overall	Small Data	Big Data	Overall	Small Data	Big Data	Overall
Total arthroscopy cases	6539	173320	179859	6585	519297	525882	6848	231047	237895
Number of outcomes	29	126	155	12	507	519	36	532	568
Average (%)	0.44	0.07	0.09	0.18	0.10	0.10	0.53	0.23	0.24
Min (%)	0.13	0.005	0.005	0.08	0.01	0.01	0.26	0.01	0.01
Max (%)	5.71	0.20	5.71	0.65	0.34	0.65	5.71	0.57	5.71

with an overall rate of 0.09%. Similarly, upon looking into the small-data group, the incidence of DVT was almost 5 times higher, at 0.44%. Finally, 16 articles (525,882 arthroscopy patients) reported pulmonary embolism (PE) rates ranging from 0.01% to 0.65%, with an overall rate of 0.1%. Similarly, the risk of PE was also substantially greater in the small-data population at 0.18%.

Four articles, including 211,107 shoulder arthroscopy patients, were included in the meta-analysis (Table 3). All studies included in the meta-analysis received a score of 6 or greater on the Newcastle-Ottawa Scale (NOS). The risk factors that were significantly associated with developing VTE following shoulder arthroscopy were BMI >30 (OR = 1.46; 95% CI = [1.22, 1.74]; I^2 = 0%) and hypertension (OR = 1.64; 95% CI = [1.03, 2.6]; I^2 = 75%) (Table 4 and Fig 2). Diabetes (OR = 1.2; 95% CI = [0.97, 1.48]; I^2 = 0%), insulin-dependent diabetes (OR = 5.58; 95% CI = [0.12, 260.19]; I^2 = 85%), smoking (OR = 1.04; 95% CI = [0.79, 1.37]; I^2 = 12%), male sex (OR = 0.95; 95% CI = [0.49, 1.85]; I2 = 86%) and age over 65 (OR = 4.3; 95% CI = [0.25, 72.83]; I^2 = 85%) were not associated with higher VTE risk.

The NNT for obese patients would be ~833 (1/0.0012), and for hypertensive patients, it would be ~588 (1/0.0017).

Discussion

The findings from this meta-analysis indicate that the incidence of VTE following shoulder arthroscopy is low, with an overall rate of 0.24%. However, the individual rates varied widely across the studies included in the analysis, with some reporting rates as low as 0.01% and others as high as 5.7%. This variability underscores the importance of identifying and understanding risk factors that may contribute to VTE development in this patient population. Our analysis also found that BMI >30 and hypertension were significant risk factors for developing VTE following shoulder arthroscopy. Identifying these modifiable risk factors may help guide clinical decision-making and preventive measures to reduce the incidence of VTE in patients undergoing shoulder arthroscopy.

Although the incidence of VTE following shoulder arthroscopy was relatively low (0.24%), the risk is still present and is devastating, especially when there are no clear guidelines for antithrombotic prophylaxis.[16,20,21] This risk is doubled when looking at data directly extracted from hospital patient records (small-data group), at 0.53% (1 per 200 patients). The rationale for this discovery is that the overall incidence is closer to national registries or the big-data group, as they have a more significant patient population and include large and diverse patient pools. However, they are associated with substantial constraints, especially when the outcome of interest is a rare disease, the quality of data produced from registries could not be assessed.[22] This key fact is highlighted even when the incidence of DVT and PE in the small-data group is calculated at 0.44% and 0.18%, respectively, compared to data derived from registries, in which the incidence of DVT and PE is 0.07% and 0.01%, respectively. The overall incidence of DVT was calculated to be 6 times higher in hospital database-based articles compared to those that used Big-Data (i.e., registries).

In a study by Takahashi et al., the incidence of asymptomatic DVT detected by ultrasonography in 175 patients undergoing shoulder arthroscopy surgery was reported to be as high as 5.7%.[23] However, the incidence of symptomatic VTE is reported to be relatively lower in other studies. This contrast illustrates that although the incidence of symptomatic VTE is low, there are asymptomatic cases of VTE following shoulder arthroscopy that remain undiagnosed. Moreover, the number of shoulder arthroscopic surgeries has increased in the last decades due to its excellent success rate, especially with a significant up trend for arthroscopic rotator cuff repairs.[24,25] It is interesting to note that, from 35 original articles included in the current systematic review, 30 were published in the last decade, emphasizing the increased attention among surgeons to this topic. Despite diverse publications, there is no universal risk stratification method for VTE prevention after shoulder arthroscopy.[16]

Venous thromboembolism is one of the most challenging orthopedic surgery complications, leading to significant patient morbidity and mortality.[14]

Table 3. Characteristics of Studies Included in the Meta-analysis

Study	Year	Country	Age (yrs.)	Male (%)	Database/ Recruitment	No. of VTE	No. of patients	Type of Study	NOS	LoE
Jameson et al.[33]	2011	UK	52	NR	NHS 2005 – 2008	7	65302	Retrospective Prognosis Study	6	3b
Nicolay et al.[40]	2019	USA	NR	NR	NSQIP 2006 – 2016	112	56463	Retrospective comparative study	7	3b
Sager et al.[52]	2019	USA	58.3	58.4	NSQIP 2005 – 2017	94	31615	Retrospective comparative study	6	3b
Stone et al.[82]	2019	USA	NR	54.3	PearlDiver 2007 – 2016	328	57727	Cohort Study	9	3b

Development and prophylaxis of VTE in lower limb surgery have been extensively studied. Earlier studies demonstrated that the risk of VTE after total joint arthroplasty without prophylaxis was between 35% and 85%; however, the majority were asymptomatic.[26-29] Therefore, pharmacologic prophylaxis, such as aspirin, nowadays is considered a common and effective practice after lower extremity procedures. As such, the ICM-VTE practice guideline strongly recommends low-dose ASA as the primary method of VTE prophylaxis in all patients undergoing TJA.[15,26] Even with either or both pharmacologic and mechanical prophylaxis, the risk of asymptomatic DVT after total hip arthroplasty is considered high and, in particular cases, it has been reported to be up to 33% of patients.[30]

Currently, limited information is available on the rate, risk factors, and prophylaxis of VTE after upper limb surgery.[16,20,31,32] The incidence rate of VTE after shoulder for nonfracture indications ranges from 0.16% for symptomatic cases to as high as 13% for asymptomatic cases.[16,33,34] The incidence rate is higher in fracture-related arthroplasty and traumatic indications; therefore, proximal humerus fracture surgeries are considered a major factor concerning the risk of VTE.[16,33] On the contrary, the risk is substantially lower following elbow procedures and arthroscopic shoulder surgeries; thus, these surgeries are considered non-major factors in the recent ICM-VTE guidelines.[16]

The current study found that BMI >30 and hypertension are major risk factors for developing VTE following shoulder arthroscopy. These findings align with previous meta-analysis studies that demonstrated the same risk factors for VTE after upper and lower extremity procedures.[35-37] The fact that these risk factors are comparable to those recognized for other medical and surgical situations supports the importance of developing risk-based thromboprophylaxis guidelines individually. Contrary to our findings, Schick et al. reported that no statistically significant risk factors were identified in the 22 cases of VTE among more than 15,000 shoulder arthroscopic procedures performed in the United States from 2002 to 2011.[38] Their study's major limitation was relying only on the surgeons' recall of symptomatic VTE cases. Specifically, because of the small number of VTE events, Schick et al. could not statistically identify any risk factors.[38] Our current study demonstrated an exponential increase in the risk of VTE in patients with the presence of metabolic syndrome risk factors, including obesity and hypertension. A possible mechanism could be the cumulative effects of risk factors resulting in decreased mobility, venous stasis, and increasing systemic activation of the blood coagulation cascade. Moreover, from a biological point of view, metabolic syndrome is frequently accompanied by a prothrombotic state.[39] The inference of our study on the association of obesity class 1 (BMI >30) with increased risk of VTE is in line with studies that reported a similarly higher risk of VTE in obesity class 1 or 2 (BMI >40) patients who underwent shoulder arthroplasty and also those who underwent lower limb arthroscopic or arthroplasty procedures.[35,40-43] Comparably, hypertension is also a known risk factor

Table 4. Pooled Odds Ratios of Factors for Sustaining a VTE and Homogeneity Tests

Factors	No. of Studies	All Patients	Pooled OR [95% CI]	*P* value	Heterogeneity: I^2 (%)
Age > 65	2 (Jameson, Sager)[33,52]	96,917	4.3 [0.25, 72.83]	.31	85
Male Sex	2 (Sager, Stone)[52,82]	89,342	0.95 [0.49, 1.85]	.89	86
Smoking	2 (Sager, Stone)[52,82]	89,342	1.04 [0.79, 1.37]	.80	12
Hypertension	2 (Sager, Stone)[52,82]	89,342	1.64 [1.03, 2.6]	.04	75
BMI > 30	2 (Nicolay, Stone)[40,82]	114,190	1.46 [1.22, 1.74]	<.01	0
Diabetes	2 (Sager, Stone)[52,82]	89,342	1.2 [0.97, 1.48]	.10	0
Insulin-dependent diabetes	2 (Jameson, Sager)[33,52]	96,917	5.58 [0.12, 260.19]	.38	85

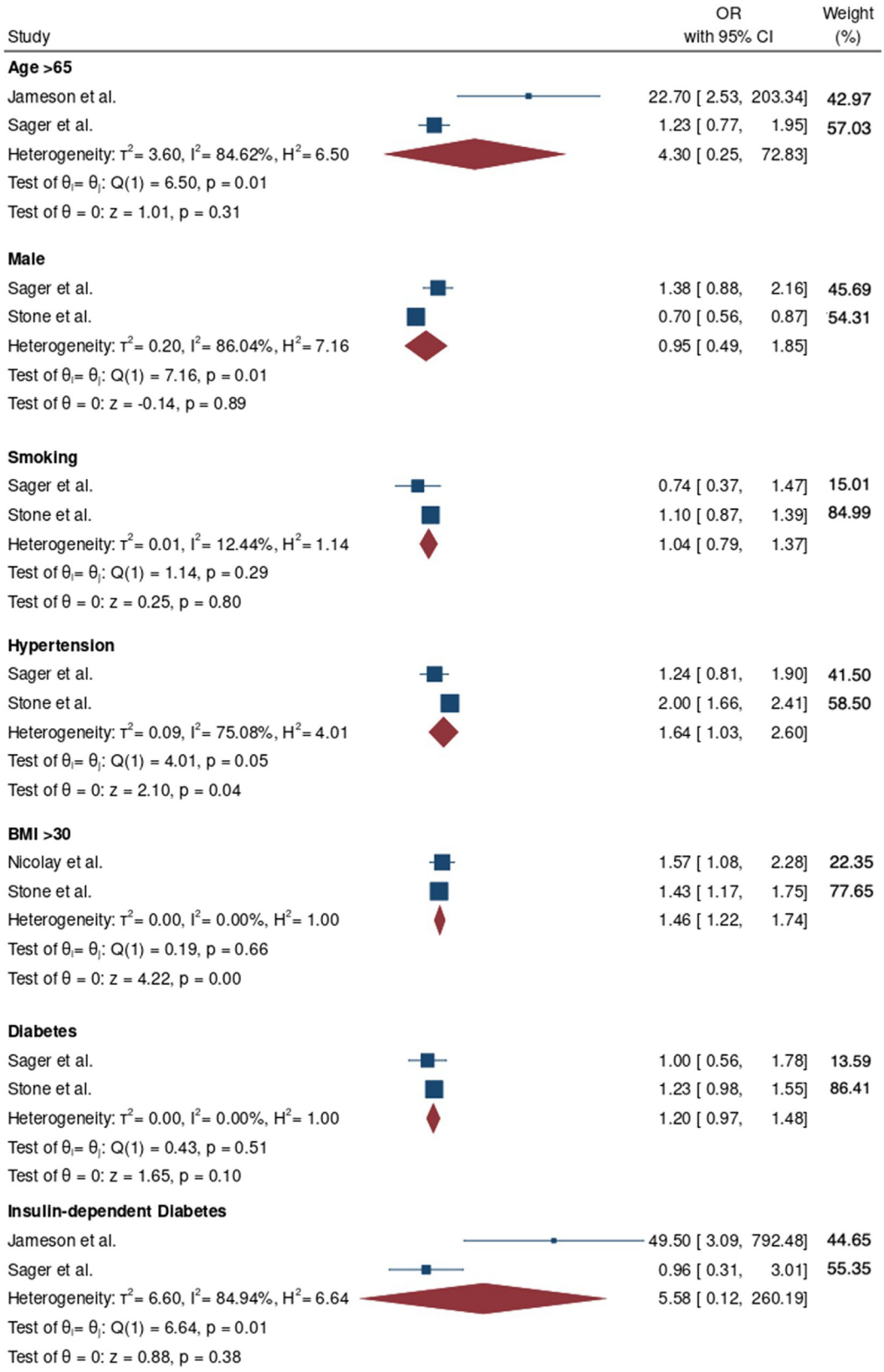

Fig 2. Individual and pooled odds ratios of risk factors for sustaining a venous thromboembolism.

for thrombus formation that can induce endothelial damage, leading to clot formation.[44,45]

Our findings on the association of increased age with the risk of VTE contradict the recent ICM-VTE recommendations on the overall risk of VTE after orthopaedic surgeries; however, they reported that this risk might not apply to all types of procedures.[16] Moreover, several studies have shown increased risk of VTE and unfavorable outcomes in older patients following surgical procedures.[34,46-51] In the pooled data from Sager et al. and Jameson et al., however, age over 65 was not identified as a significant risk factor for the development of VTE in shoulder arthroscopy patients.[33,52] Remarkably, although Hill et al. (NSQIP 2011-2013) and Sager et al. (NSQIP 2005-2011) used the same registries to analyze age over 65 as a risk factor for VTE incidence following shoulder arthroscopy, their results were conflicting.[52,53] Similar to the current meta-analysis, Plantz et al. did not find age over 65 as a risk factor for DVT or PE following shoulder arthroscopy.[54] Although increased age has been associated with a higher incidence of VTE following shoulder arthroplasty and shoulder and elbow replacements,[34,55,56] this risk is yet to be fully established in shoulder arthroscopy patients.

An extensive systematic review of the general population evaluated the association of classic cardiovascular risk factors with the incidence of VTE, including 244,865 participants and 4,910 VTE events, and classified diabetes mellitus as a risk factor for developing VTE.[45] In the studies included in the current meta-analysis, Jameson et al. found a similar risk associated with diabetes.[33] Although reported with higher VTE outcomes, our study did not find an association between diabetes mellitus and VTE. This finding with studies by Bell et al. and Mahmoodi et al., which reported no association or a modest positive association between diabetes mellitus and VTE in the general population.[57,58] Similar to the result of this meta-analysis, Lung et al. did not find diabetes a significant risk factor for VTE following shoulder arthroplasty.[21] By contrast, several studies assessing this association in other orthopaedic patients have considered diabetes as a risk factor for VTE complications.[36,42,59]

The NNT for obese patients was calculated to be ~833, and for hypertensive patients, ~588. The cost of VTE prophylaxis for this amount of patients could be substantial. For instance, the cost of pharmacological prophylaxis with LMWH for 833 obese patients for 7-10 days could be around $50,000 to $60,000, assuming the at LMWH costs ~$70-$90 per dose. Similarly, for 588 hypertensive patients, the prophylaxis cost could range from $33,000 to $40,000. However, it is worth considering that the cost of VTE events could be much higher than the cost of prophylaxis. Hospitalization for VTE treatment and associated complications can be very expensive, with the average cost for VTE treatment ranging from $15,000 to $20,000 per patient.[8,60] Additionally, VTE-related complications can result in significant morbidity, impacting patients' quality of life and work productivity. Therefore, although the cost of VTE prophylaxis may be high, it may be more cost-effective compared to the cost of VTE events in the long run. It is worth noting that alternatives to pharmacological prophylaxis exist, such as mechanical prophylaxis, which may be less expensive. Additionally, targeted prophylaxis for patients with high-risk factors, as identified by a risk stratification tool, may be more cost-effective than prophylaxis for all patients. A thorough cost-benefit analysis and consideration of alternative strategies are warranted before deciding the use of VTE prophylaxis, and VTE prophylaxis should be based on a comprehensive assessment of individual patient risk factors and should not solely rely on the calculation of NNT.

Our study analyzed a large dataset of 526,145 nonoverlapping shoulder arthroscopy patients to calculate and identified significant risk factors, such as BMI >30 and hypertension. The scarcity of data on VTE occurrence after upper limb surgeries highlights the importance of our study in providing valuable information for clinicians to identify high-risk patients and implement preventative measures. As more studies are published on this topic, we anticipate a better understanding of the demographic and risk factors associated with VTE after shoulder arthroscopy. Most current knowledge is based on data acquired from national databases, which cannot adequately represent the actual patient population; thus, there is a great need for single or multicenter studies concentrating on VTE occurrence after shoulder arthroscopy.

Targeted prophylaxis for patients with high-risk factors and consideration of alternative strategies are warranted before deciding on VTE prophylaxis following shoulder arthroscopy.

Limitations

This study is not without limitations. Similar to any systematic review and meta-analysis, this study on the data reported in the primary studies. In order to overcome this limitation, all studies were evaluated for publication bias and methodological quality. Second, some studies included in this systematic review did not include the patients' demographic characteristics. Additionally, because of limited nonoverlapping publications on the risk of VTE following shoulder arthroscopic procedures, there was high heterogeneity among articles included for each risk factor. Specifically, only 2 studies were included for each risk factor assessed in this meta-analysis. Finally, most of the studies used data derived from the big-data group or national registries, are associated with bigger problems. Despite the fact that registries can be used to derive important findings for patient groups, they lack active follow-up,

underestimate the rate of adverse events, and have varying data quality.

Conclusions

The VTE incidence following shoulder arthroscopy is considerably low at 0.24%. Patients with BMI >30 and hypertension are at a higher risk for VTE after shoulder arthroscopy.

Disclosure

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Appendix 1

Search Strategy

CINAHL Plus with Full Text:

S4=(MH Venous Thromboembolism OR AB Venous Thromboembolism OR AB VTE OR AB deep vein thrombosis OR AB DVT OR MH pulmonary embolism OR AB pulmonary embolism OR MH Venous Thrombosis OR AB Venous Thrombosis) AND (S1 AND S2 AND S3)=59

S3= MH Venous Thromboembolism OR AB Venous Thromboembolism OR AB VTE OR AB deep vein thrombosis OR AB DVT OR MH pulmonary embolism OR AB pulmonary embolism OR MH Venous Thrombosis OR AB Venous Thrombosis=29,002

S2= MH Shoulder Joint OR MH Shoulder OR AB Shoulder Joint OR AB Shoulder OR AB glenohumeral=27,561

S1= MH Arthroplasty OR MH Arthroscopy OR MH shoulder joint surgery OR AB Arthroplasty OR AB Arthroscopy OR AB Arthroscopic OR AB hemiarthroplasty =39,505

[59 results on 11/18/20]

Cochrane:

#1 MeSH descriptor: [Arthroplasty] explode all trees 4979

#2 MeSH descriptor: [Arthroscopy] explode all trees 1474

#3 MeSH descriptor: [Shoulder Joint] explode all trees and with qualifier(s): [surgery - SU] 248

#4 ("arthroplasty"):ti,ab,kw (Word variations have been searched) 11,924

#5 ("Arthroscopy"):ti,ab,kw (Word variations have been searched) 3042

#6 ("arthroscopic"):ti,ab,kw (Word variations have been searched) 3200

#7 ("hemiarthroplasty"):ti,ab,kw (Word variations have been searched) 440

#8 #1 OR #2 OR #3 OR #4 OR #5 OR #6 OR #7 16,797

#9 MeSH descriptor: [Shoulder Joint] explode all trees 745

#10 MeSH descriptor: [Shoulder] explode all trees 537

#11 ("shoulder joint"):ti,ab,kw (Word variations have been searched) 1308

#12 ("shoulder"):ti,ab,kw (Word variations have been searched) 11,723

#13 (glenohumeral):ti,ab,kw (Word variations have been searched) 483

#14 #9 OR #10 OR #11 OR #12 OR #13 11757

#15 MeSH descriptor: [Venous Thromboembolism] explode all trees 664

#16 MeSH descriptor: [Pulmonary Embolism] explode all trees 1030

#17 MeSH descriptor: [Venous Thrombosis] explode all trees 2720

#18 ("Venous Thromboembolism"):ti,ab,kw (Word variations have been searched) 4089

#19 (VTE):ti,ab,kw (Word variations have been searched) 2024

#20 ("deep-vein thrombosis"):ti,ab,kw (Word variations have been searched) 4937

#21 ("DVT"):ti,ab,kw (Word variations have been searched) 2315

#22 (pulmonary embolism):ti,ab,kw (Word variations have been searched) 3937

#23 ("venous thrombosis"):ti,ab,kw (Word variations have been searched) 3452

#24 #15 OR #16 OR #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 12,560

#25 #8 AND #14 AND #24 11

[11 results on 11/18/20]

Embase:

('arthroplasty'/exp AND [embase]/lim OR ('arthroscopy'/exp AND [embase]/lim) OR ('shoulder surgery'/exp AND [embase]/lim) OR ('shoulder surgery':ti,ab AND [embase]/lim) OR ('arthroscopy':ti,ab AND [embase]/lim) OR (arthroscopic:ti,ab AND [embase]/lim) OR ('hemiarthroplasty':ti,ab AND [embase]/lim)) AND ('hemiarthroplasty'/exp AND [embase]/lim OR ('shoulder'/exp AND [embase]/lim) OR ('shoulder joint':ti,ta AND [embase]/lim) OR (shoulder:ti,ab AND [embase]/lim) OR (glenohumeral:ti,ab AND [embase]/lim)) AND ('venous thromboembolism'/exp AND [embase]/lim OR ('lung embolism'/exp AND [embase]/lim) OR ('vein thrombosis'/exp AND [embase]/lim) OR ('venous thromboembolism':ti,ab AND [embase]/lim) OR (vte:ti,ab AND [embase]/lim) OR ('deep vein thrombosis':ti,ab AND [embase]/lim) OR (dvt:ti,ab AND [embase]/lim) OR ('lung embolism':ti,ab AND [embase]/lim) OR ('vein thrombosis':ti,ab AND [embase]/lim))

[473results on 11/17/20]

PubMed:

("Arthroplasty"[MeSH Terms] OR "Arthroscopy"[MeSH Terms] OR "Arthroplasty"[Title/Abstract] OR "Arthroscopy"[Title/Abstract] OR "Arthroscopic"[Title/Abstract] OR "hemiarthroplasty"[Title/Abstract] OR "shoulder joint/surgery*"[MeSH Terms])AND ("Shoulder Joint"[MeSH Terms] OR "Shoulder"[MeSH Terms] OR "Shoulder Joint"[Title/Abstract] OR "Shoulder"[Title/Abstract] OR "glenohumeral"[Title/Abstract]) AND ("Venous Thromboembolism"[MeSH Terms] OR "Venous Thromboembolism"[Title/Ab-

stract] OR "VTE"[Title/Abstract] OR "deep vein thrombosis"[Title/Abstract] OR "DVT"[Title/Abstract] OR "pulmonary embolism"[Title/Abstract] OR "pulmonary embolism"[MeSH Terms] OR "Venous Thrombosis"[MeSH Terms] OR "Venous Thrombosis"[Title/Abstract])

[134 results on 1/05/2021]

Web of Science:

18 209 #17 AND #10 AND #6

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

17 196,961 #16 OR #15 OR #14 OR #13 OR #12 OR #11

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

16 102, 681 TS=(Venous Thrombosis)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

15 88,389 TS=(Pulmonary Embolism)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

14 16,501 TS=(DVT)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

13 44,560 TS=(Deep Vein Thrombosis)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

12 16,584 TS=(VTE)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

11 53,064 TS=(Venous Thromboembolism)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

10 337,903 #9 OR #8 OR #7

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

9 9,903 TS=(glenohumeral)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

8 337,218 TS=(Shoulder)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

7 77,219 TS=(Shoulder Joint)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

6 184,900 #5 OR #4 OR #3 OR #2 OR #1

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

5 23,809 TS=(shoulder joint surgery)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

4 5,275 TS=(hemiarthroplasty)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

3 34,457 TS=(Arthroscopic)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

2 38,826 TS=(Arthroscopy)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

1 122,280 TS=(Arthroplasty)

Databases= WOS, BCI, BIOSIS, CABI, CCC, DRCI, DIIDW, KJD, MEDLINE, RSCI, SCIELO, ZOOREC Timespan=All years

Search language=Auto

[209 results on 11/19/20]