

Is VTE prophylaxis beneficial in upper limb major joint replacement surgery? A Systematic Review.

Abstract:

Background:

Upper limb arthroplasty is an increasingly used treatment modality for end-stage joint disease of the shoulder, elbow and wrist. While complications have been reported, the risk of venous thromboembolism (VTE) has received less attention when compared to the lower limb. Guidance to aid clinical decision-making remains limited. This review aims to ascertain whether VTE prophylaxis is beneficial after upper limb major joint replacement surgery.

Methods:

A systematic review was performed in April 2019, utilising EMBASE, MEDLINE, Cochrane and Google Scholar. All clinical studies reporting VTE incidence and risk reduction (after prophylaxis) in upper limb joint replacement were included.

Results:

Twenty-four observational studies were identified. The reported incidence of VTE ranged from 0.2%-16% (weighted mean 0.68%) and 0.2%-0.8% (weighted mean 0.49%) in shoulder and elbow arthroplasty respectively. No records for wrist arthroplasty were found. In the literature, baseline VTE risk of patients without an operation is reported as 0.5%.

Discussion:

There is a lack of good quality evidence regarding the risks and benefits of VTE prophylaxis in upper limb major joint replacement surgery. We recommend further research, ideally formal randomised controlled trials to guide recommendations. Although VTE is rare in upper limb surgery, surgeons should remain vigilant to this possibility.

Background:

Venous thromboembolism (VTE) refers to two specific clinical diagnoses, deep vein thrombosis (DVT) and pulmonary embolism (PE) ¹. VTE continues to impact significantly on morbidity, mortality and carries an economic burden both in the community and hospital setting ^{1,2}. A recent population-based cohort study revealed that patients diagnosed with VTE are at highest risk of dying within the first year of diagnosis, but also carry an increased mortality risk for up to 30 years when compared to the general population ³. It is estimate that VTE complicates 2-3 cases per 1000 hospital admissions and is responsible for 5-10% of all in-hospital deaths ⁴. However, the associated morbidity and mortality may be preventable, with appropriate application of prophylactic methods.

VTE prophylaxis, through mechanical and pharmacological techniques, has been demonstrated to be successful in reducing the frequency of VTE cases by up to 70% ⁵. Such optimal results may only be achieved via best practice prophylaxis, which involves patient-specific assessment of risk factors and clinical management ⁵. VTE prophylaxis, therefore, aims to reduce the incidence of VTE and complications including, post-thrombotic syndrome, cardiorespiratory complications and ultimately death ⁵. Historically, the use of pharmacological prophylaxis was engrained in routine practice for all inpatients ⁶. Expert opinion, however, remains divided, and recent evidence has demonstrated little clinical benefit for use in medical patients compared to surgical patients, leading to appeals for re-evaluation of guidance surrounding the use of pharmacological prophylaxis ⁶. For high-risk individuals or if pharmacological prophylaxis is contraindicated, mechanical methods may be employed, such as graduated compression stockings (GCS) ⁷.

Major orthopaedic surgery, including joint replacement surgery, remains a strong risk factor for VTE, impacting on all three of the pathophysiological processes described by Virchow's Triad; through the use of tourniquets and immobilisation affecting circulatory stasis, vascular wall injuries due to surgical limb manipulations and the use of pro-coagulant intra-operative agents, such as polymethylmethacrylate bone cement ⁸. Whilst the evidence for the use of VTE prophylaxis in medical patients has been questioned, it remains a mainstay in trauma and orthopaedic surgery ⁶. Recent updates to NICE guidance has provided robust recommendations for VTE prophylaxis in lower limb orthopaedic surgery, yet guidance remains limited for upper limb surgery ⁸.

Various operations are currently offered routinely in the National Health Service (NHS), from total shoulder to partial wrist arthroplasties, with the total number of operations increasing on a yearly basis according to the National Joint Registry ⁹. In the United States, shoulder replacement surgery is projected to increase by over 700% in the next ten years ¹⁰. Current NICE guidance suggests that VTE prophylaxis is unnecessary in upper limb surgery utilising local or regional anaesthetic techniques ¹¹. NICE, however, advise consideration of VTE prophylaxis for upper limb surgery lasting over 90 minutes or where their operation is likely to make it difficult for patients to mobilise ¹¹. Other similar guidance also exists, notably the British Elbow and Shoulder Society guidance for VTE prophylaxis ¹². In an effort to aid further development of guidance on the use of VTE prophylaxis after upper limb joint replacement surgery, a systemic review of the literature was performed. This systematic review aimed to ascertain whether VTE prophylaxis is beneficial in upper limb joint replacement surgery by focussing on

multiple outcome measures, including VTE incidence and complication rates with and without the use of VTE prophylaxis.

Methods:

A systematic review was performed in April 2019, utilising the preferred reporting items for systemic reports and meta-analyses (PRISMA) statement as an overall guideline for this study. The review was registered in PROSPERO (CRD42019133486).

The search strategy targeted level three and higher evidence, according to the Oxford Centre for Evidence-Based Medicine ¹³. Case reports were excluded. The main outcome measures involved assessment of the incidence and overall risk reduction with VTE prophylaxis in patients who have had major upper limb joint replacement surgery, limited to total shoulder arthroplasty, shoulder hemiarthroplasty, reverse shoulder arthroplasty, distal humeral replacement, total elbow arthroplasty, elbow hemiarthroplasty, total wrist arthroplasty and partial wrist arthroplasty. Secondary outcome measures included assessment of complications after using VTE prophylaxis. Patients who had multiple surgical operations during admission in addition to upper limb joint replacement or presented in a polytrauma context were excluded.

The search strategy was executed in Medline, Embase, Google Scholar and the Cochrane Central Register of Controlled Trials in May 2019 (Supplementary Materials). All identified titles and abstracts were analysed using screening inclusion criteria (Table 1) and if eligible, the full paper was scrutinised. Duplicates were removed. The reference lists of included studies were reviewed to identify additional records. Data on VTE

incidence after upper limb joint surgery, VTE prophylaxis and complications were extracted. Two authors (MK and ARE) independently performed the search strategy and extracted the relevant data. Disagreements were resolved by discussion with a third author (DF). Data analysis was performed using R software (2019) and meta-analysis performed only if the results were similar in interventions and outcomes across two or more studies. Weighted mean incidence was calculated by extracting data on the number of VTE cases and total procedures performed. Randomized controlled trials were assessed using the Cochrane Risk of Bias tool ¹⁴. Non-randomized comparative studies were assessed using the Quality Assessment Tool For Quantitative Studies, with each paper given a global rating of “good”, “fair” or “poor” ¹⁵.

Results:

The literature search yielded 450 articles after duplicate records were removed. Of these, 402 articles were excluded after screening the titles and abstracts. After full text review of the remaining 48 records, 24 articles were included in the systematic review (Figure 1); 20 on shoulder arthroplasty, and four on elbow arthroplasty. No articles were found on wrist arthroplasty. The articles were all observational in study design, with no randomised control trials identified. The majority of included studies were retrospective, with only five designed prospectively. All included studies were level II or III ¹³.

Shoulder Arthroplasty

Twenty included studies relating to VTE following shoulder arthroplasty involved a total of 323,005 patients, with no overlapping datasets (Table 2). The total number of

procedures was 152,177 total shoulder arthroplasty, 105,347 shoulder hemiarthroplasty, 407 reverse shoulder arthroplasty and 7674 revision arthroplasty (Table 2). Two articles did not provide baseline characteristics to assess the number of each surgical procedure performed ^{16,17}. These surgical procedures were performed for a range of indications, of which 73% were due to osteoarthritis, with the remaining procedures due to proximal humeral fractures, inflammatory arthropathy, rotator cuff arthropathy, osteonecrosis and failed primary operations (Table 2). The mean age of patients was 66.5 years.

All included articles reported VTE incidence as a percentage (Table 3). The weighted mean VTE incidence in shoulder arthroplasty across all 20 included articles was 0.68% (Table 3). The total number of VTE events was 2198 episodes, with 268 PEs, 144 DVTs and the remaining episodes were unspecified. Mortality secondary to VTE was reported in four articles, each reporting a single case from a total of 634 patients ^{16,18-20}. Other complications including post-thrombotic syndrome and clot extension triggering cardiac involvement were not reported.

VTE risk factors were identified in 10 articles, and included advanced age, obesity, cancer, previous history of VTE and coagulopathy (Table 3). VTE prophylaxis methods were described in only six articles. These included one study that excluded patients with VTE prophylaxis ²¹, to mechanical (graduated compression and intermittent pneumatic compression devices) and pharmacological (aspirin and LMWH) methods ^{20,22-25}. Of note, the effects of VTE prophylaxis on overall (VTE) risk reduction or complication rates were not reported and no direct comparisons were made between patients undergoing joint replacement with or without VTE prophylaxis.

Elbow Arthroplasty

Four included studies reported on cases of VTE following elbow arthroplasty. These involved a total of 6993 patients (Table 4). The total number of procedures was 6733 total elbow arthroplasty and 260 revision total elbow arthroplasty (with no overlapping datasets). No articles describing elbow hemiarthroplasty or distal humeral replacements were identified. Indications for surgery included osteoarthritis, rheumatoid arthritis or trauma, although two articles did not provide data on the indication for surgery in their patient cohort ^{26,27}. Three articles reported the age of patients, with the mean age calculated at 58.3 years.

All four included elbow arthroplasty studies reported incidence as a percentage (Table 5). The weighted mean VTE incidence in elbow arthroplasty across the four included articles was 0.49% (range from 0.2% to 0.8%). The total number of VTE events was 34, comprising of seven PEs, 25 DVTs and the remaining two episodes unspecified. Mortality secondary to VTE was reported in one article, which described one death occurring from three cases of VTE ²⁸. No other complications were reported.

VTE risk factors were not identified in any of the four included studies. VTE prophylaxis techniques were reported by one study, which described GCS or intermittent pneumatic compression, and early post-operative ambulation, without the use of pharmacological prophylaxis ²⁸. Of note, the effects of VTE prophylaxis on overall (VTE) risk reduction or complication rates were not reported and no direct comparisons were made between patients undergoing joint replacement with or without VTE prophylaxis.

Discussion

Upper limb joint replacement has been postulated to influence thrombus formation due to its effect on Virchow's triad. Pre-operatively, many patients undergoing upper limb arthroplasty have systemic risk factors predisposing to the development of VTE. These include advanced age in those receiving arthroplasty as a treatment for osteoarthritis or trauma, or patients with inflammatory arthropathies ^{20,24}. During the intra-operative period, kinking of the axillary vein may occur during humeral positioning, leading to vessel wall injury ²⁰. This, however, does not occur in elbow or wrist arthroplasty ²⁹. Chemicals, including acrylic bone cement may also be utilised intra-operatively, which have been shown to produce a hypercoagulable environment ⁸. In the post-operative period, the arm may routinely be immobilised in a sling, which may contribute to venous stasis ²⁴. Also, patients may lose some mobility after surgery, and prolonged sitting may lead to kinking of the femoral veins and gravitational pooling of blood in the lower limb, increasing venous stasis and lower limb DVT ^{20,24}. This may also provide an explanation for the more frequently reported lower limb DVT seen after upper limb joint replacement surgery, compared to upper limb DVT episodes that were only described in two included articles in this systematic review ^{30,31}. Interestingly, this suggests that the pathogenesis of VTE following upper limb joint replacement may be influenced more significantly by systemic factors, rather than local factors such as limb manoeuvring, chemical cement use or post-operative limb positioning.

In the included articles, VTE prophylaxis was not given to most patients, attributed by authors to the overall low incidence of VTE, lack of guidance and possibility of complications secondary to pharmacological prophylaxis. In the six included articles that specified their respective VTE prophylaxis protocol, mechanical prophylaxis was

most commonly used. However, two authors utilised Aspirin for pharmacological prophylaxis ^{20,25}. Aspirin has recently been shown to be effective, inexpensive and safe form of VTE prophylaxis following lower limb arthroplasty and has been introduced into national guidance ^{11,32,33}. Otherwise, two authors utilised a LMWH-based VTE prophylaxis protocol in selected 'high-risk' patients ^{23,24}, reporting a VTE incidence of 0.3% and 12.3% respectively. Interestingly, after the implementation of the 2007 NICE guidance advising the prescription of LMWH to all orthopaedic inpatients, there was no significant difference in total VTE events before and after universal use of LMWH ²³. Current national guidance published in 2018 advises a patient-specific analysis of risk factors, benefits and risks of pharmacological prophylaxis by the clinician for every orthopaedic inpatient ¹¹.

The results of the included studies have demonstrated that although VTE following upper limb arthroplasty may be considered as rare, there remains a significant variability in the described VTE incidence, which ranged from 0.2% to 16% (with a weighted mean of 0.68%) for shoulder arthroplasty and from 0.2% to 0.8% (with a weighted mean of 0.49%) for elbow arthroplasty. No studies reporting VTE incidence after wrist arthroplasty were identified. In comparison, baseline VTE risk of patients without an operation is reported as 0.5% in the literature ³⁴.

The wide variability documented by these studies may represent differences in diagnostic procedure. Some studies included only symptomatic VTE, whilst the others relied on the use of duplex screening or CT scanning ²⁰. The latter, employed by 6 included studies, will inevitably result in a higher diagnostic rate. The remaining included articles either did not define their use of imaging in the diagnostic process or

relied on a clinical diagnosis. The wide variability in VTE incidence may also be compounded by differing patient populations amid the included studies, with 12 studies not reporting specific risk factors for VTE development in their respective patient cohort.

VTE prophylaxis, utilising both mechanical and pharmacological methods, is widely regarded as a standard of care of hip and knee arthroplasty procedures ¹¹. Although various reports exist, the estimated incidence of VTE in hip and knee arthroplasty exceeds 3% ^{35,36}. Interestingly, studies have been published recommending that an overall VTE risk of over 3% is required to outweigh the bleeding risk from pharmacological prophylaxis using LMWH ^{6,37}. Major bleeding has been postulated to occur in 2.5 per 1000 patients prescribed LMWH, with a even higher risk of minor bleeding ³⁸. Of note, various other risks to the patient occur with use of pharmacological prophylaxis, including heparin-induced thrombocytopenia, skin reactions, thrombocytosis, electrolyte imbalances such as hyperkalaemia and osteoporosis. Taking this into account, the VTE risk associated with shoulder arthroplasty (0.68%) and elbow arthroplasty (0.49%) may be sufficiently low to discourage the use of pharmacological prophylaxis. The risks of mechanical prophylaxis methods, such as GCS, may include discomfort and pressure necrosis if poorly fitted, allergic reactions or worsening of ischaemia in legs with impaired arterial flow ³⁹. Although data on complications remains scarce for mechanical prophylaxis methods, they are generally assumed to be safe if no absolute contraindication is present ³⁹. In addition, GCS have been shown to be significantly effective in reducing overall DVT risk in hospitalised orthopaedic patients in a recent Cochrane review ⁴⁰. Mechanical methods such as GCS, combined with patient

education and early post-operative ambulation, may represent a safe, yet effective VTE prophylaxis protocol in upper limb joint replacement surgery.

There are major limitations of the studies included in this systematic review. Due to the lack of a randomised controlled study design, quantifying the overall benefit and complications of VTE prophylaxis in upper limb joint replacement surgery remains difficult. All the studies included within this systematic review were of an observational nature, with data mainly extracted from databases. All included studies were prone to intrinsic differences in study populations (selection bias) and lack of an explicit reporting protocol (reporting bias). Data on the complications of VTE prophylaxis or its absence was poorly documented, including no records of post-thrombotic syndrome, clot extension or cardiac involvement. This may possibly be due to a lack of a suitable follow-up and retrospective design in the majority of the included studies. Most included studies did not report details of their VTE prophylaxis protocol, posing difficulties when attempting to contextualise the reported VTE incidence rates within that defined population. This review was also limited to work published in English, therefore it was not possible to identify the incidence across the worldwide literature.

For upper limb joint replacement surgery, NICE guidelines recommend consideration of VTE prophylaxis in patients undergoing upper limb surgery and who are under general anaesthesia for over 90 minutes, or in patients who may struggle to mobilise post-operatively ¹¹. NICE also suggest that procedures under local or regional anaesthesia do not require VTE prophylaxis ¹¹. More comprehensive guidance is required to aid surgeons to minimise VTE risk, but this is currently limited by the available evidence base ²⁹.

Conclusion

The risk of VTE in upper limb joint replacement surgery is variable across differing published articles. However, the mean weighted VTE incidence was found to be 0.68% and 0.49% in shoulder and elbow arthroplasty respectively, which compare to a literature reported baseline risk of 0.5% in people not undergoing an operation. No articles describing VTE risk in wrist arthroplasty were found. Although VTE is rare in upper limb surgery, surgeons should remain vigilant to the possibility, especially in procedures under general anaesthetic lasting greater than 90 minutes or patients who have a prolonged post-operative immobility. All patients undergoing upper limb joint replacement surgery should be formally assessed for VTE and bleeding risk, as per national guidance (NICE). Across all major upper limb joint replacement surgery, surgeons should employ mechanical prophylaxis methods, promote early mobilisation post-operatively, and provide patient education in regards to the symptoms, signs and preventative methods for VTE. Pharmacological prophylaxis may be utilised in patients with significant VTE risk factors, but surgeons must be aware of complications, including a major bleeding risk of 0.25%. All of the included articles within this review were observational in nature. Further research, employing a case-control strategy or prospective randomised trial, is required to quantify the risk-benefit ratio of VTE prophylaxis in upper limb joint replacement surgery.

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Figures and Tables

Table 1: Inclusion Criteria

Question	Minimum Criteria
Does it address the study question?	VTE or VTE prophylaxis in upper limb joint replacement surgery
Does it address the topic?	Upper limb joint replacement surgery
Is it a clinical study?	Yes
What is the level of evidence?	Observational study or above
Does it address relevant outcome measures?	Any of: <ul style="list-style-type: none"> • Incidence or prevalence of VTE in upper limb joint replacement • Risk reduction of VTE in upper limb joint replacement after use of VTE prophylaxis • Complications associated with or without the use of VTE prophylaxis

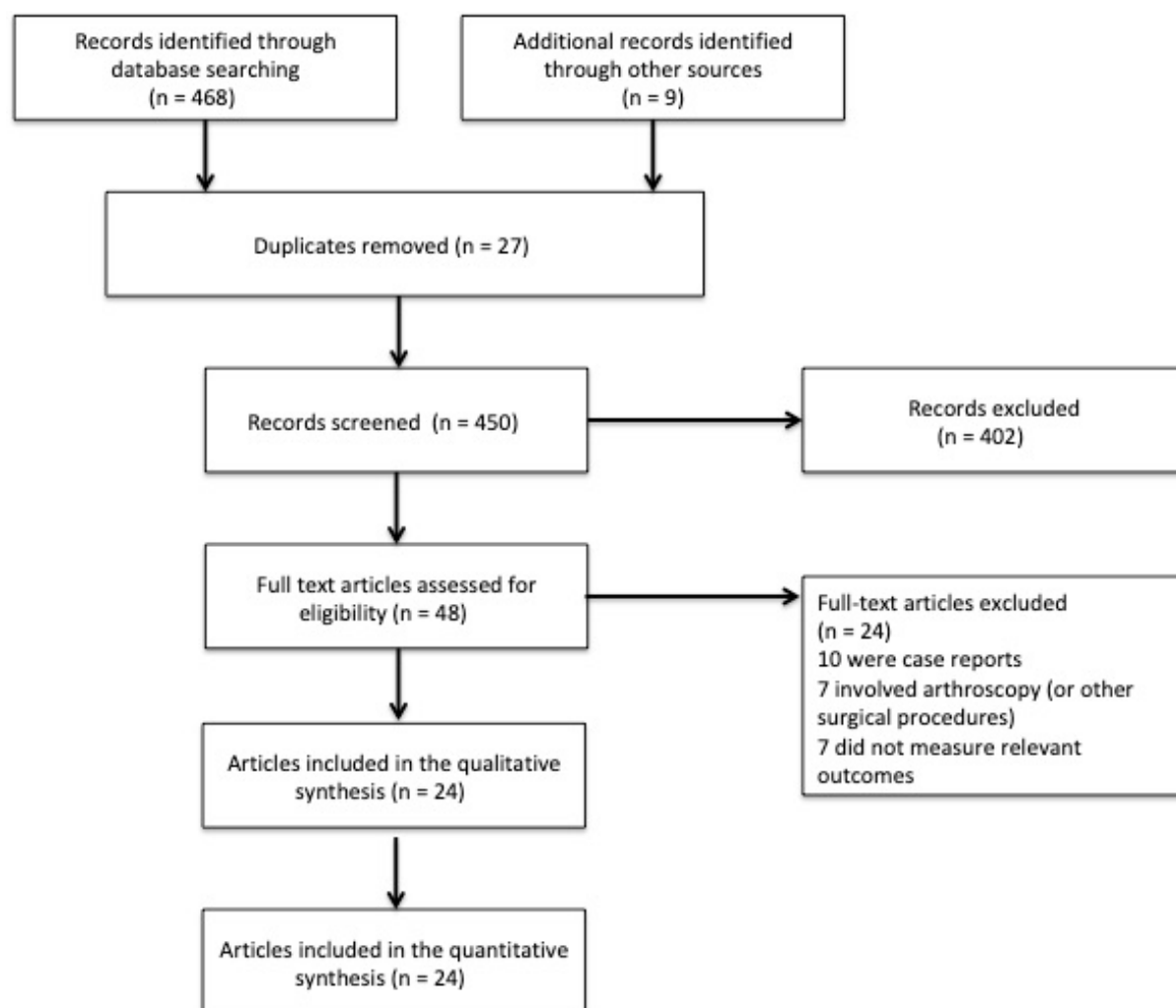


Figure 1: PRISMA diagram showing search and selection method.

Table 2: Baseline characteristics and summary of included shoulder arthroplasty articles.

Article (year)	Study Design	Surgical Procedure (number)	Indication for procedure	Number of patients (n)	Mean Age (years)
Norris and Lannotti (2002) ¹⁸	Prospective	Total shoulder arthroplasty (TSA) (133) and shoulder hemiarthroplasty (SHA) (43)	Osteoarthritis (OA)	160	65.1
Sperling and Cofield (2002) ⁴¹	Retrospective	TSA (2308) and SHA (577)	OA and proximal humerus (PH) fractures	2885	67
Anjum and Butt (2005) ¹⁹	Retrospective	SHA (22)	PH fracture	22	77.6
Lyman et al. (2006) ⁴²	Retrospective	TSA (4931) and SHA (8828)	OA and PH fractures	13759	TSA group 66.4, SHA group 66.3
Hoxie et al. (2007) ²²	Retrospective	SHA (37)	PH fractures	37	63.1
Krishan et al. (2007) ³⁰	Prospective	SHA (36)	OA	34	51
Willis et al. (2009) ²⁰	Prospective	TSA (73) and SHA (27)	OA and PH fractures	100	67
Lenarz et al. (2010) ⁴³	Retrospective	Reverse shoulder arthroplasty (RSA) (30)	PH fractures	30	76.7
Farnig et al. (2010) ⁴⁴	Retrospective	TSA (6005) and SHA (9283)	OA and PH fractures	15288	TSA group 68.3, SHA group 69.5
Jameson et al. (2010) ²³	Retrospective	TSA (4061), SHA (8297)	OA and PH fractures	12358	TSA group 70, SHA group 69
Navarro et al. (2013) ²¹	Retrospective	TSA (1153), SHA (1186) and RSA (235)	OA and PH fractures	2574	69.2
Wronka et al. (2014) ¹⁶	Retrospective	TSA and SHA	OA and PH fractures	352	Not specified
Day et al. (2015) ⁴⁵	Retrospective	TSA (74203) and SHA (55955)	Osteoarthritis	130158	72
Kusnezov et al. (2016) ³¹	Prospective	TSA (26)	OA	24	45.8
Tashjian et al. (2016) ²⁵	Retrospective	TSA (245), SHA (92), RSA (112) and revision shoulder arthroplasty (84)	OA, rotator cuff arthropathy, rheumatoid arthritis, failed primary operation	533	65.2

Sing et al. (2017) ⁴⁷	Retrospective	TSA (49686), SHA (20942) and revision shoulder arthroplasty (7590)	OA, PH fracture, rotator cuff arthropathy, failed primary operations	83391	64
Koch et al. (2017) ²⁴	Retrospective	TSA (5), SHA (22) and RSA (30)	OA	57	62.6
Belmont et al. (2017) ⁴⁸	Retrospective	TSA (3547)	OA	3547	70.1
Lovy et al. (2017) ⁴⁹	Prospective	TSA (5801)	OA	5801	69.5 (no complications) and 73.6 (complications)
Craig et al. (2019) ¹⁷	Retrospective	Primary shoulder replacement (58054)	OA, rotator cuff arthropathy, inflammatory arthritis, osteonecrosis	51895	72.2

Table 3: Summary of results and bias assessment of included shoulder arthroplasty articles.

Article (year)	VTE Risk Factors	Prophylaxis Measures	VTE Incidence (%)	Complications and Mortality (number)	Diagnosis method (modality)	Bias Assessment
Norris and Lannotti (2002) ¹⁸	Not specified	Not specified	0.6%	PE (1) Mortality (1)	Not specified	Poor
Sperling and Cofield (2002) ⁴¹	Hypertension, Systemic Lupus Erythaematosus	Not specified	0.2%	PE (5) Hematoma evacuation (1)	Imaging (ultrasound and CT)	Poor
Anjum and Butt (2005) ¹⁹	Not specified	Not specified	3.3%	PE (1) Mortality (1)	Not specified	Poor
Lyman et al. (2006) ⁴²	Cancer, trauma and elderly age	Not specified	0.7%	Lower limb DVT (69) PE (32) All Cause Mortality (81)	Not specified	Fair
Hoxie et al. (2007) ²²	Hypertension, Systemic Lupus Erythaematosus	Graded Compression Stockings and/or Intermittent pneumatic compression (IPC)	10.8%	PE (4) Hematoma evacuation (1)	Imaging (CT)	Poor
Krishan et al. (2007) ³⁰	Not specified	Not specified	2.9%	Upper limb DVT (1)	Not specified	Fair
Willis et al. (2009) ²⁰	Obesity, elderly age, past history of VTE	Post-operative aspirin and IPC	16%	Lower limb DVT (13) PE (3) Mortality (1)	Imaging (ultrasound)	Fair
Lenarz et al. (2010) ⁴³	Not specified	Not specified	3.3%	Lower limb DVT (1)	Not specified	Poor
Farnig et al. (2010) ⁴⁴	High Charlson Comorbidity Index	Not specified	0.6%	VTE (91) All Cause Mortality (199)	Not specified	Fair
Jameson et al. (2010) ²³	Elderly age, obesity, high Charlson Index	Pharmacological prophylaxis (4178 patients)	0.3%	Lower limb DVT (11) PE (23) All Cause Mortality (118)	Not specified	Fair
Navarro et al. (2013) ²¹	Not specified	Patients taking chemoprophylaxis were excluded	1.01%	Lower limb DVT (13) PE (14) All cause mortality (13)	Clinical	Fair
Wronka et al. (2014) ¹⁶	No risk factors identified between cases of VTE versus those	Not specified	0.43%	Lower limb DVT (6) PE (4) Mortality (1)	Imaging (ultrasound and CT)	Poor

	without.					
Day et al. (2015) ⁴⁶	Cancer, coagulopathy, congestive heart failure, obesity and alcohol abuse	Not specified	0.53%	VTE (695)	Not specified	Fair
Kusnezov et al. (2016) ³¹	Not specified	Not specified	7.7%	Lower limb DVT (2)	Not specified	Fair
Tashjian et al. (2016) ²⁵	Raised Charlson Index, previous VTE, diabetes, anaemia and obesity	Aspirin (125 patients)	2.6%	Upper limb DVT (5) PE (12)	Clinical	Fair
Sing et al. (2017) ⁴⁷	Elderly age, male, coagulopathy, long operating time and obesity	Authors note no data available	0.26%	VTE (204)	Not specified	Fair
Koch et al. (2017) ²⁴	Not specified	LMWH (18 patients) Aspirin (81mg, 4 patients) No mechanical prophylaxis used	12.3%	Lower limb DVT (7) LMWH (2 patients developed DVT) Aspirin (2 patients developed DVT)	Imaging (ultrasound)	Poor
Belmont et al. (2017) ⁴⁸	Not specified	Not specified	0.9%	Lower limb DVT (16) PE (13) All cause mortality (61)	Not specified	Fair
Lovy et al. (2017) ⁴⁹	Elderly age, inflammatory arthritis, male and multiple co-morbidities	Not specified	14%	VTE (812) Dislocation (12) Post-operative infection (8) Hematoma (5) All cause mortality (12)	Not specified	Fair
Craig et al. (2019) ¹⁷	Elderly age, sex and Charlson score	Not specified	0.27%	VTE (156) Myocardial infarction (161) Respiratory tract infection (1110) All cause mortality (118)	Not specified	Fair

Table 4: Baseline characteristics and summary of included elbow arthroplasty articles.

Article (year)	Study Design	Surgical Procedure (number)	Indication for procedure	Number of patients (n)	Mean Age (years)
Duncan et al. (2007) ²⁸	Retrospective	Total elbow arthroplasty (TEA) (816) and revision total elbow arthroplasty (REA) (260)	Not specified	1076	Not specified
Krenek et al. (2011) ²⁷	Retrospective	TEA (1625)	Rheumatoid arthritis and osteoarthritis	1625	56
Jenkins et al. (2012) ²⁶	Retrospective	TEA (1146)	Inflammatory arthropathy, osteoarthritis and trauma.	1146	61
Zhou et al. (2016) ⁵⁰	Retrospective	TEA (3146)	Not specified	3146	58

Table 5: Summary of results and bias assessment of included elbow arthroplasty articles.

Article (year)	VTE Risk Factors	Prophylaxis Measures	VTE Incidence (%)	Complications and Mortality (number)	Diagnosis method (modality)	Bias Assessment
Duncan et al. (2007) ²⁸	Not specified	Graded compression stockings and IPC. Post-operative ambulation	0.28%	PE (3) Mortality (1)	Imaging (CTPA)	Poor
Krenek et al. (2011) ²⁷	Not specified	Not specified	0.25%	PE (4) All cause Mortality (10)	Not specified	Fair
Jenkins et al. (2012) ²⁶	Not specified	Not specified	0.2% at 90 days (0.4% at one year)	VTE (2) (4 at one year) Implant infection (22), dislocation (8) and fracture (35)	Not specified	Poor
Zhou et al. (2016) ⁵⁰	Not specified	Not specified	0.8%	Lower limb DVT(25)	Not specified	Poor

Supplementary Material:

Table 1- Search strategy utilised in this systematic review.

Search Strategy
1. Shoulder replacement
2. Shoulder arthroplasty
3. Distal humeral replacement
4. Elbow arthroplasty
5. Elbow replacement
6. Wrist replacement
7. Wrist arthroplasty
8. VTE
9. Venous thromboembolism
10. DVT
11. Deep vein thrombosis
12. PE
13. Pulmonary embolism
14. VTE prophylaxis
15. Venous thromboembolism prophylaxis
16. Incidence
17. Prevalence
18. Complications
19. Risk
20. 1 AND 8/9/10/11/12/13/14/15/16/17/18/19
21. 2 AND 8/9/10/11/12/13/14/15/16/17/18/19
22. 3 AND 8/9/10/11/12/13/14/15/16/17/18/19
23. 4 AND 8/9/10/11/12/13/14/15/16/17/18/19
24. 5 AND 8/9/10/11/12/13/14/15/16/17/18/19
25. 6 AND 8/9/10/11/12/13/14/15/16/17/18/19
26. 7 AND 8/9/10/11/12/13/14/15/16/17/18/19
27. 1 AND 8/9 AND 16/17/18/19
28. 2 AND 8/9 AND 16/17/18/19
29. 3 AND 8/9 AND 16/17/18/19
30. 4 AND 8/9 AND 16/17/18/19
31. 5 AND 8/9 AND 16/17/18/19
32. 6 AND 8/9 AND 16/17/18/19
33. 7 AND 8/9 AND 16/17/18/19

Supplementary Material - Quality assessment of included studies

	Selection Bias	Study Design	Confounders	Blinding*	Data collection	Global Rating
Norris and Iannotti (2002)	●	●	▲	▲	●	▲
Sperling and Cofield (2002)	●	●	▲	▲	▲	▲
Anjum and Butt (2005)	●	●	▲	▲	▲	▲
Lyman et al (2006)	●	●	●	▲	●	●
Hoxie et al (2007)	●	●	▲	▲	●	▲
Krihan et al (2007)	●	●	▲	▲	●	●
Willis et al (2009)	●	●	●	▲	●	●
Lenarz et al (2010)	●	●	▲	▲	●	▲
Farng et al (2010)	●	●	●	▲	●	●
Jameson et al	●	●	●	▲	●	●
Navarro et al	●	●	●	▲	●	●
Wronka et al	●	●	▲	▲	●	▲
Day et al	●	●	●	▲	●	●
Kusnezov et al	●	●	●	▲	●	●
Tashjian et al	●	●	●	▲	●	●
Sing et al	●	●	●	▲	●	●
Koch et al	▲	●	▲	▲	●	▲
Belmont et al	●	●	●	▲	●	●
Lovy et al	●	●	●	▲	●	●
Craig et al	●	●	●	▲	●	●

Figure 1- Quality of assessment of shoulder arthroplasty articles. Green circle indicates good articles, yellow circle fair and red triangle poor articles in the specified domains.

	Selection Bias	Study Design	Confounders	Blinding*	Data collection	Global Rating
Duncan et al (2007)	●	●	▲	▲	●	▲
Krennek et al (2011)	●	●	●	▲	●	●
Jenkins et al (2012)	●	●	▲	▲	●	▲
Zhou et al (2016)	●	●	▲	▲	●	▲

Figure 2- Quality assessment of elbow arthroplasty articles. Green circle indicates strong articles, yellow circle fair and red triangle poor articles in the specified domains.

●	Good assessment of quality indicating low risk of bias
●	Fair assessment of quality indicating adequate risk of bias
▲	Poor assessment of quality indicating high risk of bias

* All the included studies score poorly on blinding as per the EPHP quality assessment tool given the nature of the study design thus limiting the possible global rating.