



# The prevalence of venous thromboembolism in rectal surgery: a systematic review and meta-analysis

Joshua W. Hayes<sup>1</sup> · Éanna J. Ryan<sup>1</sup> · Patrick A. Boland<sup>1</sup> · Ben Creavin<sup>1</sup> · Michael E. Kelly<sup>1</sup> · David Beddy<sup>1</sup>

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## Abstract

**Purpose** Venous thromboembolism (VTE) following rectal surgery is a significant and preventable cause of morbidity and mortality, yet the true prevalence is not well established. This systematic review and meta-analysis assessed the available literature and determined its prevalence following rectal surgery.

**Methods** A systematic review assessed the prevalence of VTE following rectal surgery. In addition, we evaluated whether subgroups (open vs. minimally invasive or benign vs. malignant resections) impacted on its prevalence or rate of deep venous thrombosis (DVT) or pulmonary embolism (PE).

**Result** Thirty-eight studies met the predefined inclusion criteria. The aggregate prevalence of VTE following rectal surgery was 1.25% (95% CI 0.86–1.63), with DVT and PE occurring in 0.68% (95% CI 0.48–0.89) and 0.57% (95% CI 0.47–0.68) of patients. VTE following cancer and benign resection was 1.59% (95% CI 0.60–1.23 and 1.5% (95% CI 0.89–2.12) respectively. The prevalence of VTE in patients having minimally invasive resection was lower than those having open surgery [0.58% (16/2770) vs. 2.22% (250/11278); RR 0.54, 95% CI 0.33–0.86].

**Conclusion** This review observed that there is sparse evidence on prevalence of VTE following rectal surgery. It provides aggregated data and analysis of available literature, showing overall prevalence is low, especially in those having minimally invasive procedures.

**Keywords** Venous thromboembolism · Deep venous thrombosis · Pulmonary embolism · Rectal surgery · Surgical outcomes

## Introduction

Venous thromboembolism (VTE) following surgery is a significant and preventable cause of morbidity and mortality. VTE has an estimated incidence of 15–40% in patients undergoing general surgical procedures when they are not given thromboprophylaxis [1, 2]. Alarming, 0.8% to 2.0% of all deaths following general surgical procedures are attributable to pulmonary embolism (PE) [3]. This represents a key modifiable risk. More specifically, major abdomino-pelvic procedures are known to confer a higher risk of VTE [4]. Within rectal surgery, the majority of major pelvic surgeries are performed for

neoplastic or inflammatory conditions, both of which are substantial independent risk factors for VTE [5–8]. Other risk factors attributable to rectal surgery include placing the patient in lithotomy position and prolonged procedure duration [9].

Despite concerns over the incidence of VTE in pelvic surgery, there remains limited evidence of the true prevalence of VTE following rectal surgery. The majority of rectal surgery studies, to date, report VTE as secondary outcomes, without specifically looking at subgroups or risk profiles.

At present, there is no international consensus regarding the optimal thromboprophylaxis in patients having rectal surgery [10]. The National Institute for Health and Clinical Excellence (NICE) recommends that for patients having major abdomino-pelvic cancer surgery, clinicians should consider extended pharmacological prophylaxis [11]. However, there is considerable debate as to the agent, method and length of thromboprophylaxis [12]. The aim of this systematic review and meta-analysis was to review the available literature to date and determine the prevalence of VTE in rectal surgery.

✉ Joshua W. Hayes  
joshuawphayes@hotmail.com

<sup>1</sup> Department of Surgery, James Connolly Memorial Hospital, Blanchardstown, Dublin, Ireland

In addition, we sought to ascertain the difference in prevalence between minimally invasive and open surgery and between benign and neoplastic disease and in so doing focus attention on those that may benefit from extended prophylaxis.

## Methods

A systematic review of the literature was performed according to the guidelines and recommendations of the preferred reporting items for systematic reviews and meta-analyses (PRISMA) checklist [13]. Institutional approval was not required for this review.

### Search strategy

An electronic search for relevant publications was performed in June 2018 using a number of online resources including the following: Pubmed, Embase, Scopus and the Cochrane collaboration databases. The following search terms were used in the search algorithms:

- i. (Venous thromboembolism) AND (colorectal) AND (surgery)
- ii. (Venous thromboembolism) AND (rectum) AND (surgery)
- iii. (Venous thromboembolism) AND (colon) AND (surgery)
- iv. (Thrombosis) AND (colorectal) AND (surgery)
- v. (Thrombosis) AND (rectum) AND (surgery)
- vi. (Thrombosis) AND (colon) AND (surgery)

### Inclusion criteria

To be included in the study, the following criteria had to be reported:

1. VTE, DVT or PE must have been documented as a complication and be extractable from the reported data.
2. Indication for surgery was reported.
3. Surgical procedure involved a major operation on the rectum.
4. Studies must have a clear research methodology.
5. Full-text versions of the article must be available.

### Exclusion criteria

Studies were excluded if they were:

- 1 Case reports or editorial letters

2. If the studies were unclear whether surgery had been performed on the rectum. (i.e. Hartmann's procedures grouped with anterior resections)
3. Trans-anal surgery
4. If patients did not have surgery for rectal pathology
5. If the studies combined colon and rectal surgery and subgroup results could not be distinguished from each other
6. If publication was not in English

### Data extraction

Two reviewers (JH and PB) reviewed the literature databases according to the search strategy that was outlined above. Each of the reviewers extracted the following data from every appropriate publication: title and publication details (first author, journal of publication, year of publication, country of publication), study population characteristics (number in study, number undergoing rectal surgery), type of study (Randomised Control Trial, Case Series or Comparative Study), type of surgery performed (open, laparoscopic, robotic, comparisons), database used (single centre, multicentre, national database), study anatomy specificity (colorectal, rectal) disease pathology (benign, malignant), and whether the study was specifically aimed at examining VTE rates or just reported VTE as a secondary outcome of an alternative research question. The outcomes of each study as outlined in the outcomes of interest (i.e. prevalence of VTE, DVT and PE) were also recorded.

In cases where the study reported DVT and PE and it was unclear whether the event occurred in the same patient, the study was excluded from the VTE analysis, but each individual DVT and PE were included in their respective analyses.

Each reviewer independently recorded the data in separate databases. Databases were only compared once each reviewer had completed their reviewing process to limit the risk of selection bias. Any dispute was reviewed and arbitrated by a third independent person (MK). The database was examined for duplicates, which were removed, and any disparities in the collection of data were clarified.

### Outcomes of interest

The following outcomes were used to assess thromboembolic disease in the setting of post-operative recovery from rectal surgery:

#### Primary outcome

The primary outcome of this study was the prevalence of VTE (DVT/PE) in patients who had undergone rectal surgery.

## Secondary outcomes

To assess if subgroups had an impact on prevalence of VTE

1. Pathology of disease (benign vs. neoplastic)
2. Method of resection (open vs. minimally invasive)

## Statistical analysis

Microsoft Office Excel 2011 (Excel for Mac) [Computer programme] Version 14.0. Redmond, Washington, USA. © Microsoft Corporation, 2010 was used to calculate weighted sum of squared differences between individual study effects and the pooled effect across studies for descriptive data analyses, with the weights being those used in the pooling method [14]. A continuity correction of 0.5 was added to outcomes where 0 events were reported [15]. Statistical analyses comparing surgical techniques and operations for malignant vs. benign disease were performed using Review Manager (RevMan) [Computer program] Version 5.3. Copenhagen: the Nordic Cochrane Centre, the Cochrane Collaboration, 2014. Binary outcome data were reported as risk ratios (RR) and 95% confidence interval (95% CI) were estimated using the Mantel–Haenszel method. Pooled estimates of differences were calculated, using random

effects models where necessary to account for potential inter study heterogeneity. Heterogeneity was assessed by  $I^2$ -squared statistics ( $I^2$ ), with  $>50\%$  being considered as considerable heterogeneity. Sensitivity analyses were carried out where appropriate.  $P$  values  $<0.05$  were considered significant.

## Quality assessment

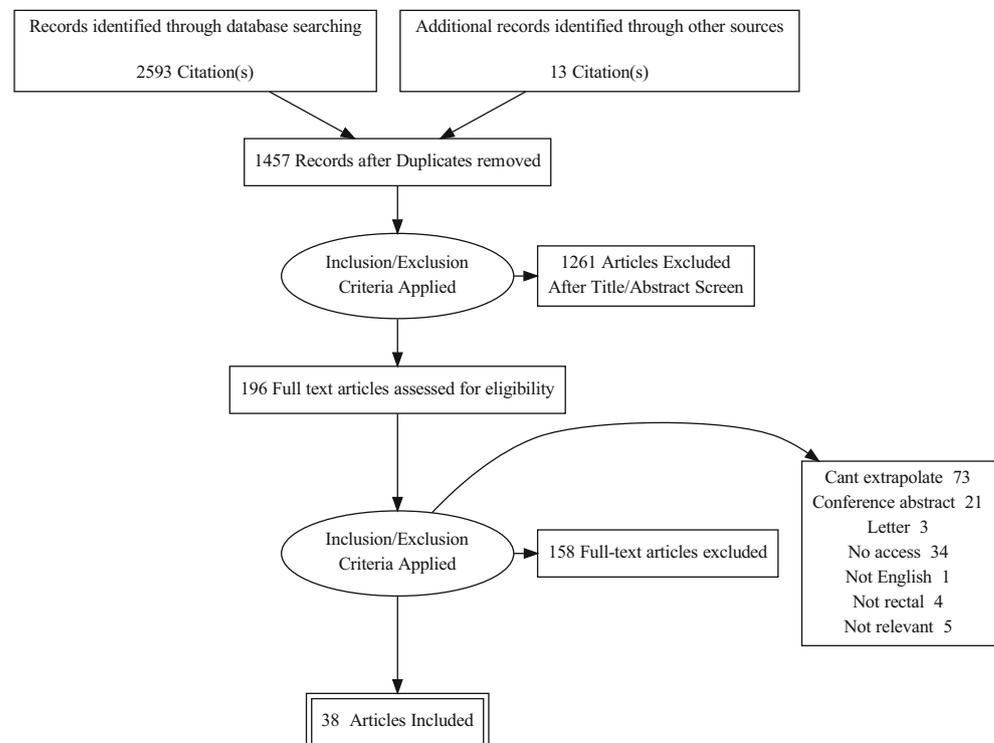
The quality of the studies included in this systematic review was assessed using the Jadad score for Randomised Control Trials [16] and the Newcastle–Ottawa score for non-randomised studies [17]. The quality score rating was determined for each publication.

## Results

### Literature search and study characteristics

The literature search was carried out according to the strategy outlined above. The initial search yielded 2593 studies. A grey literature review was also performed, and a further 13 studies were added. After duplicates were removed, 1457 studies were selected for abstract review. Following abstract review, 196 papers were deemed appropriate for full-paper review. Thirty-eight studies satisfied the inclusion and exclusion

Fig. 1 PRISMA diagram



**Table 1** Characteristics of the included studies

Authors	Year	Colorectal/rectal	VTE study	Study type	Source	Dates of inclusion	Location	Jadad/ Newcastle– Ottawa score
Martin AN [18]	2018	Rectal	N	Comparison	Single centre	Jan 2010–Jul 2015	Charlottesville, USA	7
Chapman [19]	2017	Rectal	N	Comparison	National database	2005–2012	ACS-NSQIP, CO, USA	7
Dosokey [20]	2017	Rectal	N	Comparison	Single centre	2006–2015	Cleveland, USA	7
Goto [21]	2017	Rectal	N	Comparison	Multicentre	Apr 2009–Mar 2014	Kyoto, Japan	6
Law [22]	2017	Rectal	N	Comparison	Single centre	Jan 2008–Jun 2015	Pokfulam, Hong Kong	7
Gorgun [23]	2016	Rectal	N	Comparison	Single centre	Jan 2011–Jun 2014	Cleveland, USA	8
Holubar [24]	2016	Rectal	N	Comparison	National database	2005–2010	ACS-NSQIP, NH, USA	6
Lee [25]	2016	Colorectal	Y	Case series	Single centre	Sep 2011–Mar 2014	Seongnam, Korea	8
Bökkerink [26]	2015	Rectal	N	Case series	5 centres	Dec 1996–Dec 2010	Postbus, the Netherlands	7
Buchs NS [27]	2015	Rectal	N	Case series	Single centre	May 2000–Nov 2013	Geneva, Switzerland	6
Huang [27]	2015	Rectal	N	Comparison	Single centre	Jan 2006–Dec 2013	Shanghai, China	6
Liu P [28]	2015	Rectal	N	Comparison	Single centre	Jan 2002–Dec 2011	Dalian, China	7
Nelson [29]	2015	Colorectal	Y	Case series	Single centre	Jan 2006–Dec 2011	Washington, USA	6
Rao [30]	2015	Rectal	N	Comparison	Single centre	Nov 2008–Sep 2012	Qassim, Saudi Arabia	7
ZENG [31]	2015	Rectal	N	Comparison	Single centre	Jun 2007–Jun 2012	Beijing, China	7
Dobbins [32]	2014	Colorectal	N	Comparison	State data set	July 2000–Dec 2008	Sydney, Australia	8
Georgiou [33]	2014	Rectal	N	Case series	Single centre	Mar 2006–Dec 2011	London, UK	6
Liang [34]	2013	Rectal	N	Comparison	Single centre	May 2005–Apr 2012	Taipei, Taiwan	7
Nurkin [35]	2013	Rectal	N	Comparison	National database	Jan 2005–Dec 2008	New York, USA	7
Kang [36]	2012	Rectal	N	Comparison	National database	Jan 2006–Dec 2009	NIS, CA, USA	7
Wallaert [7]	2012	Colorectal	Y	Case series	National database	2005–2010	ACS-NSQIP, NH, USA	6
Buchberg [3]	2011	Colorectal	Y	Comparison	National database	Jan 1, 2002–Dec 31, 2006	NIS, USA	7
Desouza [37]	2011	Rectal	N	Comparison	Single centre	Aug 2005–Nov 2009	Chicago, USA	8
Greenblatt [38]	2011	Rectal	N	Comparison	national database	2005–2009	ACS-NSQIP, NH, USA	7
Liang [38]	2011	Rectal	N	Case series	Not available	Not available	Taipei, Taiwan	7
Mathis [38]	2011	Rectal	N	Case series	Single centre	Jan 1994–Jan 2005	Rochester, USA	6
Park JS [39]	2011	Rectal	N	Comparison	Multicentre	Jan 1997–Dec 2009	Kyoto, Japan	7
Xenos [40]	2011	Colorectal	Y	Case series	National database	2005–2009	ACS-NSQIP, KY, USA	7
Larson [41]	2010	Rectal	N	Comparison	Single centre	2004–2007	Rochester, USA	7
Park JS [42]	2010	Rectal	N	Comparison	Single centre	Dec 2007–Jun 2009	Daegu, Korea	7
Gouvas [43]	2009	Rectal	N	Comparison	Single centre	Jan 1998–Mar 2004–Mar 2007	Athens, Greece	8
Nig [44]	2008	Rectal	N	RCT	Single centre	Sept 1994–Feb 2005	Hong Kong, China	3 (Jadad)
Fowkes [45]	2007	Colorectal	N	Case series	Single centre	April 2001–May 2006	Leeds, UK	6
Guillou [46]	2005	Colorectal	N	RCT	Multicentre	July 1996–July 2002	Bristol, UK	3 (Jadad)
Larsen [47]	2005	Rectal	N	Case series	Single centre	Jan 1991–Aug 2003	Oslo, Norway	7
Kakuda [47]	2003	Rectal	N	Case series	Single centre	Jan 1990–Jun 2002	California, USA	7
Leroy [48]	2003	Rectal	N	Case series	Single centre	Nov 1991–Dec 2000	Strasbourg, France	6
Camilleri [49]	2001	Rectal	N	Comparison	Single centre	1992–1997	Dundee, UK	8

criteria (Fig. 1). In total, included studies comprised of 13 case series, 23 comparative studies, and 2 randomised controlled trials. The characteristics of the included studies are summarised in Table 1.

**Quality assessment and risk of bias**

All studies scored at least six or above in the Newcastle Ottawa Scale [50]. The two randomised control trials were assessed with the Jadad score. See Table 1 for scores.

**Prevalence of venous thromboembolism in all rectal surgery**

Twenty-eight studies reported the rate of VTE in rectal surgery. Ten studies reported DVT and PE separately. These studies were not included in calculation of VTE prevalence as there was no way of determining if patients reported to have PE were the same as the patients with DVT. A number of studies used the ACS-NSQIP database to report VTE in rectal surgery for cancer. In order to prevent overlap of cases, only Chapmans study

was used for this analysis as it had the largest cohort [18].

The prevalence of VTE in patients undergoing rectal surgery was 1.25% (95% CI 0.86–1.63). The distribution of results is demonstrated in Fig. 2.

**Prevalence of deep venous thrombosis in all rectal surgery**

Prevalence of DVT was reported by 32 studies. Studies by Xenos, Holubar, Nurkin, and Park were excluded from this analysis due to risk of overlap with other studies using the ACS-NSQIP database [29, 43, 47, 49]. The prevalence of DVT in patients having rectal surgery was 0.68% (95% CI 0.48–0.89). The distribution of results is demonstrated in Fig. 3.

**Prevalence of pulmonary embolism in all rectal surgery**

Twelve studies reported pulmonary embolism occurring in patients undergoing rectal surgery. Again, studies by

Study	Events	Sample Size	Outcome	SE	CI lower	CI upper
Dosokey 2017	2	118		0.0169	0.0120	-0.0065 0.0404
Law 2017	2	391		0.0051	0.0036	-0.0020 0.0122
Goto 2017	4	328		0.0122	0.0061	0.0002 0.0241
Gorgun 2016	1	56		0.0179	0.0179	-0.0171 0.0529
Lee 2016	6	231		0.0260	0.0106	0.0052 0.0468
Buchs 2015	1	33		0.0303	0.0303	-0.0291 0.0897
Huang 2015	1	916		0.0011	0.0011	-0.0010 0.0032
Liu 2015	2	111		0.0180	0.0127	-0.0070 0.0430
Rao 2015	2	82		0.0244	0.0172	-0.0094 0.0582
Zeng 2015	2	294		0.0068	0.0048	-0.0026 0.0162
Bökkerink 2015	3	477		0.0063	0.0036	-0.0008 0.0134
Nelson 2015	114	6414		0.0178	0.0017	0.0145 0.0210
Georgiou 2014	3	100		0.0300	0.0173	-0.0039 0.0639
Liang 2013	6	344		0.0174	0.0071	0.0035 0.0314
Wallaert 2012	21	1377		0.0153	0.0033	0.0087 0.0218
Kang 2012	375	72055		0.0052	0.0003	0.0047 0.0057
Liang 2011	1	28		0.0357	0.0357	-0.0343 0.1057
Park 2011	1	210		0.0048	0.0048	-0.0046 0.0141
Desouza 2011	3	82		0.0366	0.0211	-0.0048 0.0780
Greenblatt 2011	81	5420		0.0149	0.0017	0.0117 0.0182
Buchberg 2011	171	6153		0.0278	0.0021	0.0236 0.0320
Larson 2010	1	100		0.0100	0.0100	-0.0096 0.0296
Park 2010	1	123		0.0081	0.0081	-0.0078 0.0241
Ng 2008	3	99		0.0303	0.0175	-0.0040 0.0646
Fowkes 2007	2	55		0.0364	0.0257	-0.0140 0.0868
Larsen 2005	1	86		0.0116	0.0116	-0.0112 0.0344
Guillou 2005	2	292		0.0068	0.0048	-0.0026 0.0163
Camilleri 2001	1	106		0.0094	0.0094	-0.0091 0.0279
Summary	Random Effects	I <sup>2</sup> = 88.79		0.0125	0.0020	0.0087 0.0163

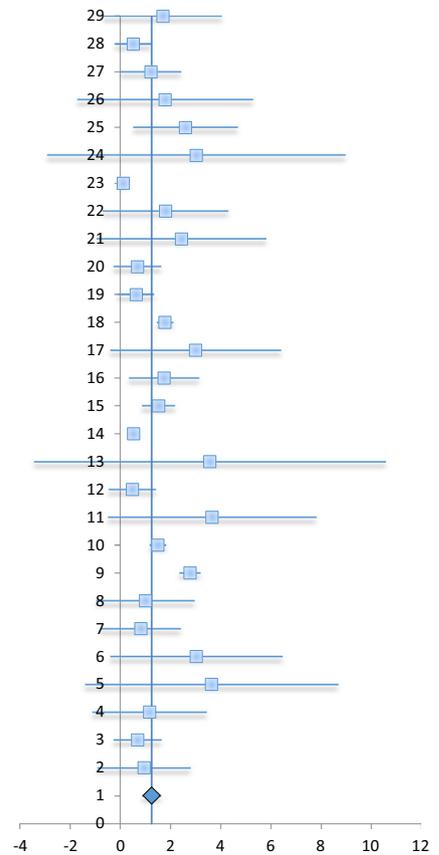


Fig. 2 VTE prevalence in rectal surgery

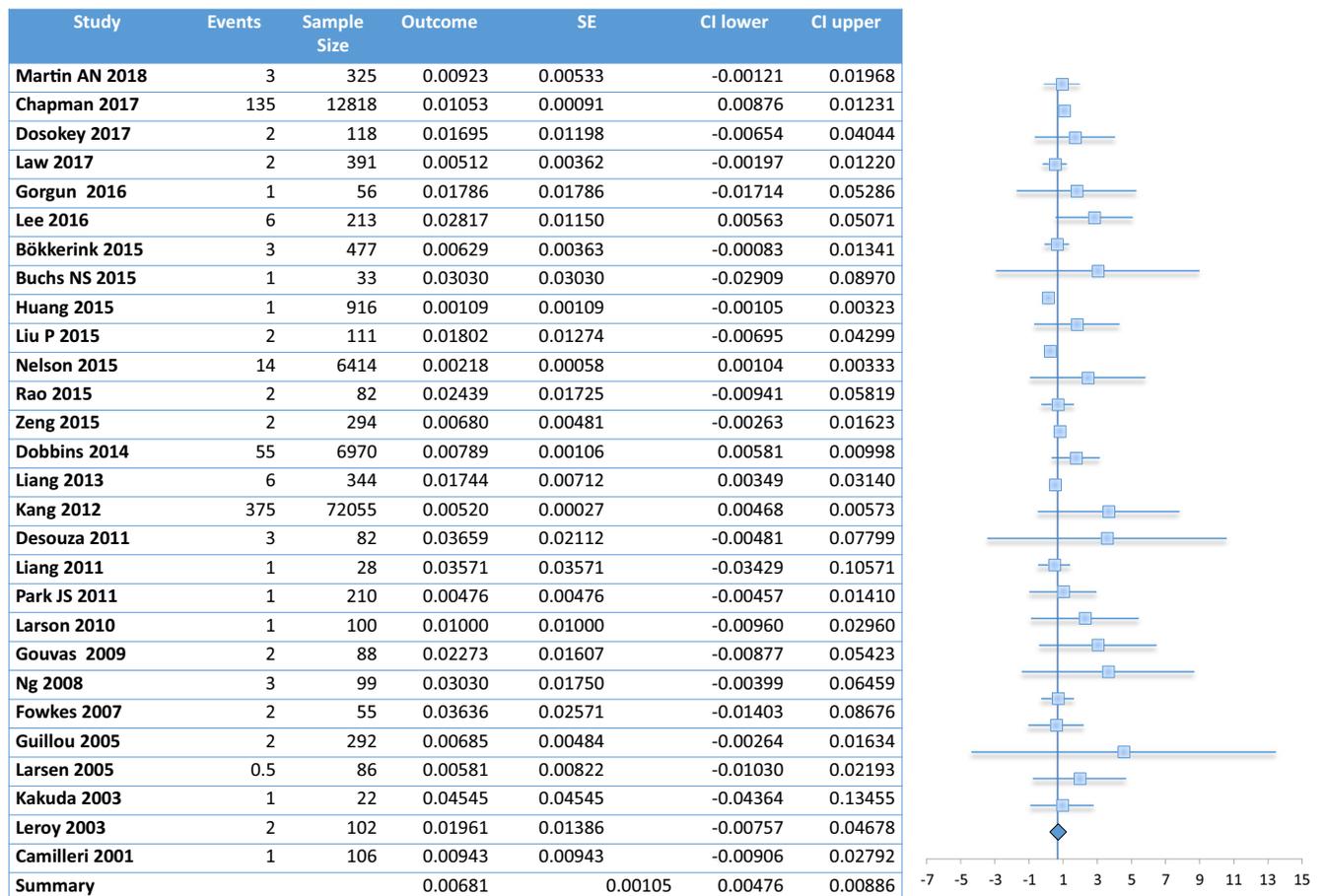


Fig. 3 DVT prevalence in rectal surgery

Xenos, Holubar and Nurkin were excluded from our analysis to prevent overlap from the ACS-NSQIP database [29, 43, 49]. The prevalence of PE in rectal surgery was 0.57% (95% CI 0.47–0.68). The distribution of results is demonstrated in Fig. 4.

### Prevalence of venous thromboembolism in rectal surgery for cancer vs. benign disease

No studies made a comparison of rectal surgery for benign disease vs. cancer. We were able to gather data

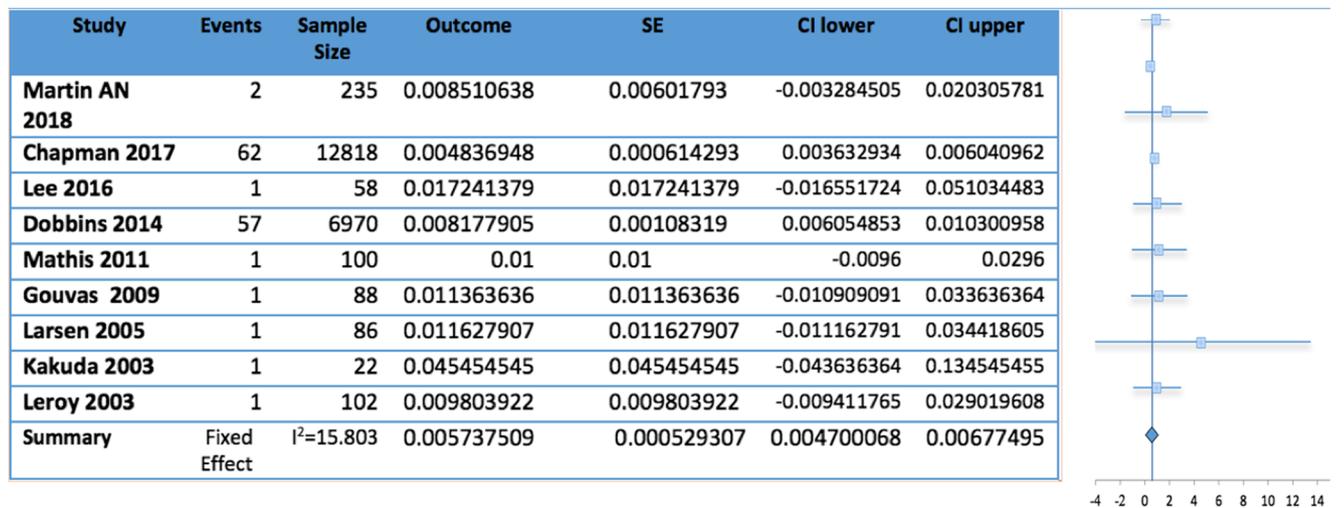


Fig. 4 PE prevalence in rectal surgery

Study	Events	Sample Size	Outcome	SE	CI lower	CI upper
Wallaert 2012	21	1377	0.015250545	0.003327942	0.008727779	0.02177331
Mathis 2011	1	100	0.01	0.01	-0.0096	0.0296
Fowkes 2007	2	55	0.036363636	0.025712974	-0.014033792	0.086761065
Summary	Fixed Effect	$I^2 = 111.47$	0.015048472	0.003134129	0.00890558	0.021191364

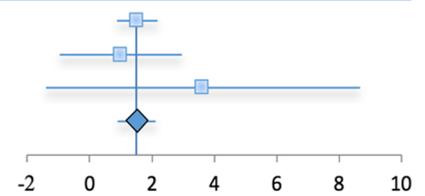


Fig. 5 VTE prevalence in benign disease

from studies on benign and malignant disease for our own analysis. Three studies reported VTE prevalence in patients having rectal surgery for benign disease. The mean prevalence from these studies was 1.5% (95% CI 0.89–2.12) (Fig. 5). Twenty-four studies reported VTE prevalence in patients having rectal surgery for cancer. The mean prevalence of these was 0.92% (95% CI 0.60–1.23). The distribution of these results is displayed in Fig. 6.

**Prevalence of venous thromboembolism in open vs. minimally invasive rectal surgery**

Nine studies compared surgical technique/approach. We compared open resection vs. minimally invasive surgical (MIS) resection. Our analysis demonstrated that the

prevalence of VTE in patients undergoing rectal surgery is lower in those having MIS compared to open surgery [0.58% (16/2770) vs. 2.22% (250/11278); RR 0.54, 95% CI 0.33–0.86] (Fig. 7).

Within the MIS cohort, we were able to perform a small subgroup analysis comparing laparoscopic vs. robotic surgery using three studies that made this comparison. There was no difference in the prevalence of VTE whether laparoscopic or robotic surgery was used as the MIS modality to perform rectal resection [0.36% (1/280) vs. 1.03% (3/290); RR 0.53, 95% CI 0.12–2.34] (Fig. 8).

Fourteen studies reported prevalence of VTE in open surgery. When combined, these observed a prevalence of VTE in 1.49% (95% CI 0.68–2.30) (Fig. 9). For the MIS cohort, the prevalence was 0.52% (95% CI 0.27–0.77) (Fig. 10). Within

Study	Events	Sample Size	Outcome	SE	CI lower	CI upper
Dosokey 2017	2	118	0.0169	0.0120	-0.0065	0.0404
Goto 2017	4	328	0.0122	0.0061	0.0002	0.0241
Law 2017	2	391	0.0051	0.0036	-0.0020	0.0122
Gorgun 2016	1	56	0.0179	0.0179	-0.0171	0.0529
Lee 2016	6	231	0.0260	0.0106	0.0052	0.0468
Bökkerink 2015	1	106	0.0094	0.0094	-0.0091	0.0279
Buchs NS 2015	1	33	0.0303	0.0303	-0.0291	0.0897
Huang 2015	1	916	0.0011	0.0011	-0.0010	0.0032
Liu P 2015	2	111	0.0180	0.0127	-0.0070	0.0430
Rao 2015	2	82	0.0244	0.0172	-0.0094	0.0582
Zeng 2015	2	294	0.0068	0.0048	-0.0026	0.0162
Georgiou 2014	3	100	0.0300	0.0173	-0.0039	0.0639
Liang 2013	6	344	0.0174	0.0071	0.0035	0.0314
Kang 2012	375	72055	0.0052	0.0003	0.0047	0.0057
Desouza 2011	3	82	0.0366	0.0211	-0.0048	0.0780
Greenblatt 2011	81	5240	0.0155	0.0017	0.0121	0.0188
Liang 2011	1	28	0.0357	0.0357	-0.0343	0.1057
Park JS 2011	1	210	0.0048	0.0048	-0.0046	0.0141
Larson 2010	1	100	0.0100	0.0100	-0.0096	0.0296
Park JS 2010	1	123	0.0081	0.0081	-0.0078	0.0241
Ng 2008	3	99	0.0303	0.0175	-0.0040	0.0646
Guillou 2005	2	292	0.0068	0.0048	-0.0026	0.0163
Larsen 2005	1	86	0.0116	0.0116	-0.0112	0.0344
Camilleri 2001	1	106	0.0094	0.0094	-0.0091	0.0279
Summary			0.0092	0.0016	0.0060	0.0123

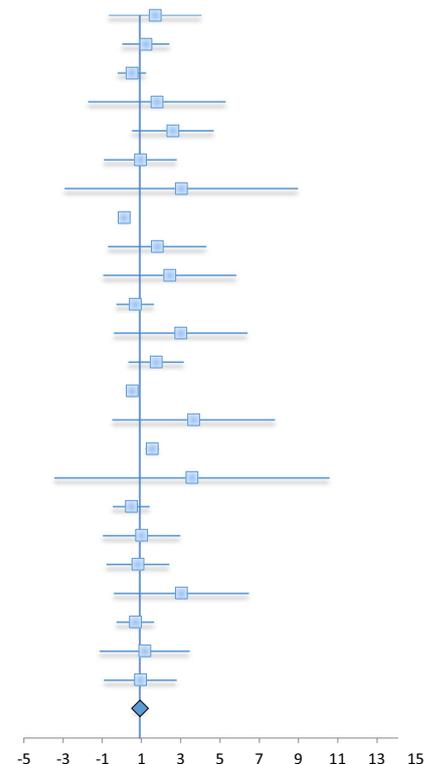


Fig. 6 VTE prevalence in cancer

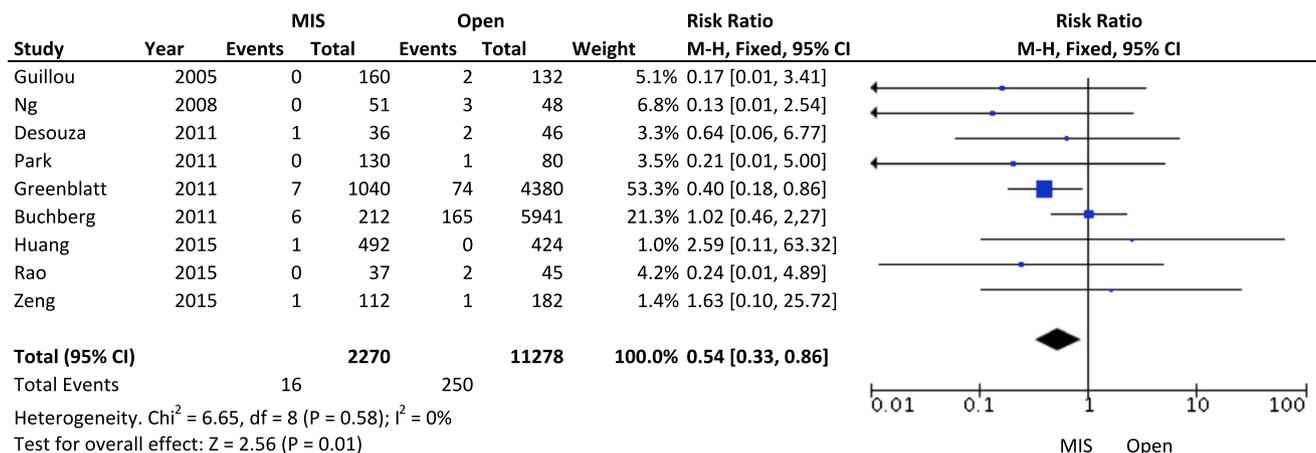


Fig. 7 MIS V open surgery

this, the prevalence for laparoscopic surgery was 0.49% (95% CI 0.24–0.75) (Fig. 11) (15 studies) vs. 0.59% (CI – 0.02–2.3) for robotic surgery (Fig. 12) (4 studies).

### Discussion

Some studies have reported an incidence of VTE in 4–17% of patients having major colorectal surgery [5, 50–53]. However, the majority of these are asymptomatic, with no major morbidity. Despite this, VTE (especially PE) is a feared complication following surgery, and the use of in-hospital (plus extended duration thromboprophylaxis) following major general surgical procedures to prevent DVT and PE is supported by level 1 evidence [54, 55]. To date, there has been limited data on the prevalence and factors associated with VTE in patients having rectal surgery. This review observed that the prevalence of VTE in patients undergoing rectal surgery of 1.25%. This review also makes clear that the overwhelming majority of the evidence relating to the prevalence of VTE in rectal surgery is retrospective, with only five studies in this analysis specifically examining the rate of VTE as their primary endpoint. All five of these studies examined the broader category of colorectal surgery as opposed to more specifically rectal surgery.

From our analysis, we found an aggregate prevalence of DVT of 0.68% from 32 studies (629 events from a sample of 102,887). The PE rate we discovered was 0.57% from 12 studies (127 events from a sample of 20,479). This was a surprising result as we would have anticipated the PE rate to be considerably lower than DVT. Interestingly, only one study (Lee et al.) specifically reported prevalence of PE [25].

Buchberg et al. [3] utilised a large national database from the Healthcare Cost and Utilization Project Nationwide Inpatient Sample (NIS) to assess the prevalence of VTE following colorectal surgery. Specifically, they sought to evaluate if laparoscopy reduced the prevalence of VTE. They noted higher rates of VTE in both laparoscopic and open surgery (2.87% and 2.78% respectively). However, the number of open resections was substantially more ( $n = 5941$  open vs.  $n = 212$  laparoscopic resection). Using the same database, Wallaert et al. noted a lower VTE rate (1.53%) when rectal surgery was performed for inflammatory disease [7]. Interestingly, we observed that minimally invasive surgical techniques appeared to be associated with a significantly lower rate of VTE when compared with open procedures (prevalence 0.52% vs. 1.49%). We also observed a higher rate of VTE in those having resection for benign pathology 1.5%

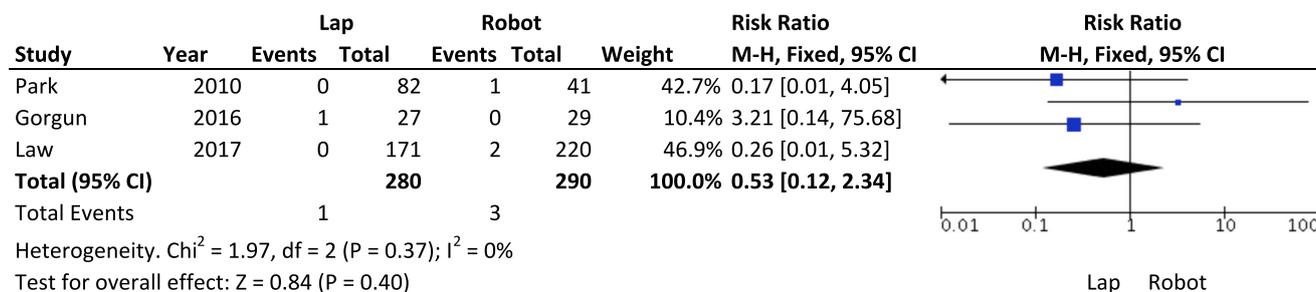


Fig. 8 Lap V robot surgery

Study	Events	Sample Size	Outcome	SE	CI lower	CI upper
Dosokey 2017	2	118	0.0169	0.0120	-0.0065	0.0404
Bökkerink 2015	3	477	0.0063	0.0036	-0.0008	0.0134
Huang 2015	0.5	424	0.0012	0.0017	-0.0021	0.0044
Liu P 2015	2	111	0.0180	0.0127	-0.0070	0.0430
Rao 2015	2	45	0.0444	0.0314	-0.0172	0.1060
ZENG 2015	1	182	0.0055	0.0055	-0.0053	0.0163
Georgiou 2014	3	100	0.0300	0.0173	-0.0039	0.0639
Buchberg 2011	165	5941	0.0278	0.0022	0.0235	0.0320
Desouza 2011	2	46	0.0435	0.0307	-0.0168	0.1037
Greenblatt 2011	74	4380	0.0169	0.0020	0.0130	0.0207
Park JS 2011	1	80	0.0125	0.0125	-0.0120	0.0370
Ng 2008	3	48	0.0625	0.0361	-0.0082	0.1332
Guillou 2005	2	132	0.0152	0.0107	-0.0058	0.0362
Camilleri 2001	1	106	0.0094	0.0094	-0.0091	0.0279
Summary			0.0149	0.0041	0.0068	0.0230

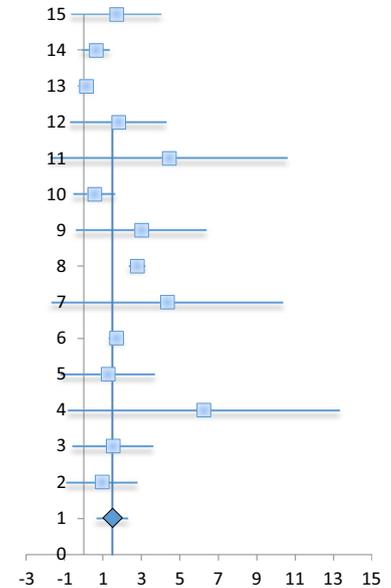


Fig. 9 VTE in open surgery

(95% CI 0.89–2.12) vs. those for cancer resection 0.92% (95% CI 0.60–1.23). Reasons for this, including confounding factors, are not easily identified, but it is notable that the benign cohort has a substantially smaller sample size. To date, only two randomised controlled trials have reported VTE in rectal surgery, Guillou et al and Ng et al [44, 46]. Overall, their VTE rate was 0.68% and 3.03%. Guillou et al. reported VTE in rectal surgery as a subgroup analysis

of their primary endpoint in colorectal surgery. In their comparison, Ng et al. observed 0% incidence of VTE in laparoscopic surgery and 6.25% incidence in open surgery. These findings are in keeping with our finding that MIS is associated with a lower rate of VTE in rectal surgery patients than open resection. One concern over giving earlier thromboprophylaxis post-operatively is the risk of post-operative haemorrhage [56]. However, there is reasonable

Study	Events	Sample Size	Outcome	SE	CI lower	CI upper
Law 2017	2	371	0.005390836	0.003811896	-0.002080481	0.012862153
Gorgun 2016	1	56	0.017857143	0.017857143	-0.017142857	0.052857143
Huang 2015	1	492	0.00203252	0.00203252	-0.00195122	0.00601626
Rao 2015	0.5	37	0.013513514	0.019110994	-0.023944035	0.050971062
ZENG 2015	1	112	0.008928571	0.008928571	-0.008571429	0.026428571
Liang 2013	6	344	0.01744186	0.00712061	0.003485465	0.031398256
Buchberg 2011	6	212	0.028301887	0.011554197	0.005655661	0.050948113
Desouza 2011	1	36	0.027777778	0.027777778	-0.026666667	0.082222222
Greenblatt 2011	7	1040	0.006730769	0.002543992	0.001744546	0.011716993
Liang 2011	1	28	0.035714286	0.035714286	-0.034285714	0.105714286
Park JS 2011	0.5	130	0.003846154	0.005439283	-0.006814841	0.014507148
Larson 2010	1	100	0.01	0.01	-0.0096	0.0296
Ng 2008	0.5	51	0.009803922	0.013864839	-0.017371163	0.036979006
Fowkes 2007	2	55	0.036363636	0.025712974	-0.014033792	0.086761065
Guillou 2005	0.5	160	0.003125	0.004419417	-0.005537058	0.011787058
Summary	Fixed Effect	$I^2=0.6675$	0.005243772	0.001275335	0.002744115	0.007743429

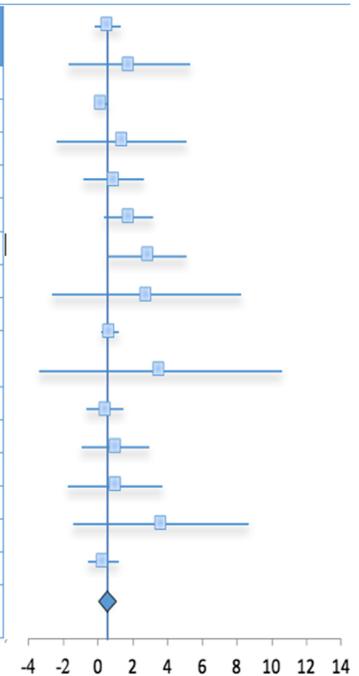


Fig. 10 VTE prevalence in MIS

Study	Events	Sample Size	Outcome	SE	CI lower	CI upper
Law 2017	0.5	171	0.002923977	0.004135127	-0.005180873	0.011028826
Gorgun 2016	1	27	0.037037037	0.037037037	-0.035555556	0.10962963
Huang 2015	1	492	0.00203252	0.00203252	-0.00195122	0.00601626
Rao 2015	0.5	37	0.013513514	0.019110994	-0.023944035	0.050971062
ZENG 2015	1	112	0.008928571	0.008928571	-0.008571429	0.026428571
Liang 2013	6	344	0.01744186	0.00712061	0.003485465	0.031398256
Buchberg 2011	6	212	0.028301887	0.011554197	0.005655661	0.050948113
Greenblatt 2011	7	1040	0.006730769	0.002543992	0.001744546	0.011716993
Liang 2011	1	28	0.035714286	0.035714286	-0.034285714	0.105714286
Park JS 2011	0.5	130	0.003846154	0.005439283	-0.006814841	0.014507148
Larson 2010	1	100	0.01	0.01	-0.0096	0.0296
Park JS 2010	0.5	82	0.006097561	0.008623253	-0.010804016	0.022999138
Ng 2008	0.5	51	0.009803922	0.013864839	-0.017371163	0.036979006
Fowkes 2007	2	55	0.036363636	0.025712974	-0.014033792	0.086761065
Guillou 2005	0.5	160	0.003125	0.004419417	-0.005537058	0.011787058
Summary	Fixed Effect	I <sup>2</sup> = 0.3995	0.004950905	0.001275951	0.002450041	0.00745177

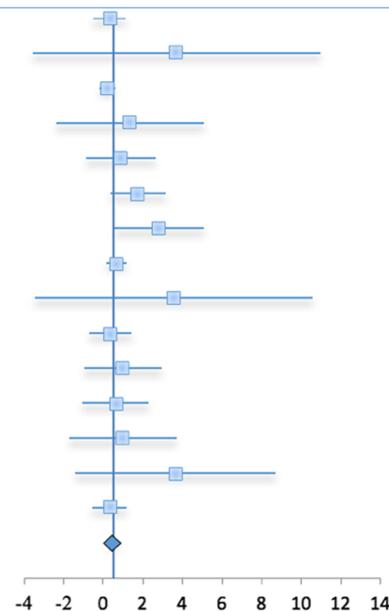


Fig. 11 VTE prevalence in laparoscopic surgery

evidence to suggest this risk is relatively low [12, 57]. As a result, some organizations like the American College of Chest Physicians [11] and the European Society for Medical Oncology have now recommended extended thromboprophylaxis following major cancer surgery [58, 59]. Interestingly, the National Comprehensive Cancer Network guidelines only recommend extended thromboprophylaxis in high VTE risk patient. However, a recent review by Rausa et al. did not observe a difference in rates of symptomatic pulmonary embolism between the standard and extended thromboprophylaxis [60].

Ultimately, VTE is a multifactorial event and therefore complete prevention is not attainable, even with extended or alternative methods of prophylaxis. Patient factors, comorbidities, features of the disease (extent, systemic complications and prior therapies, etc.) and operative approaches all affect a patient’s risk profile [3–9].

The main limitation of our study is the heterogeneity between the 38 studies included for analysis. The studies investigate a wide variety of topics attributable to colorectal surgery such that the prevalence of VTE in most of them is reported as a secondary outcome and our results are impacted by this.

There is considerable variability between the sizes of the included studies, and these were conducted over a time frame of 18 years (2001–2018). Moreover, only two studies had a prospective and randomised nature. The fact that the majority of the patients contributing to the size of our sample are selected from non-randomised observational studies impacts the robustness of our results. Just five studies had VTE as a primary outcome measure; all of these were based on colorectal surgery and did not specifically relate to rectal surgery. However, we exclusively included patients that had only rectal surgery from this data. As the literature relating to VTE specifically in rectal surgery was sparse, we had to include a further 33 studies that reported VTE rates in rectal surgery

Study	Events	Sample Size	Outcome	SE	CI lower	CI upper
Law 2017	2	220	0.009090909	0.006428243	-0.003508448	0.021690266
Gorgun 2016	0.5	29	0.017241379	0.024382992	-0.030549286	0.065032045
Desouza 2011	1	36	0.027777778	0.027777778	-0.026666667	0.082222222
Park JS 2010	1	41	0.024390244	0.024390244	-0.023414634	0.072195122
Summary	Fixed Effect	I <sup>2</sup> = 267.01	0.011296303	0.00588653	-0.000241296	0.022833901

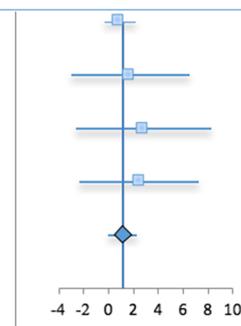


Fig. 12 VTE in robotic surgery

as a secondary outcome. These shortcomings reduced the availability of information with regard to thromboprophylaxis type and duration and diagnostic criteria for VTE. Furthermore, it meant that useful comparisons between symptomatic diagnoses and non-symptomatic diagnoses could not be made. Despite these limitations, our study demonstrates that the prevalence of VTE in patients undergoing rectal surgery appears to be lower than previous historical accounts, especially when minimally invasive approaches to resection are feasible. Advice to extend VTE thromboprophylaxis after rectal cancer surgery may represent overtreatment in this context.

## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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