

Review Article

Deep Venous Thrombosis After Proximal Hamstring Tendon Repair: A Systematic Review

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Keywords: prophylaxis, hamstring, deep vein thrombosis, repair, proximal, review

<https://doi.org/10.60118/001c.129787>

Journal of Orthopaedic Experience & Innovation

Background

DVT remains a concern following repair of the proximal hamstring tendons, yet the rate of occurrence of this potential post-operative complication has not been previously characterized. The purpose of this study was to characterize the factors related to the development and treatment of DVTs following proximal hamstring repair.

Methods

A systematic literature review was conducted in accordance with PRISMA guidelines. PubMed and EMBASE were searched to identify studies from database origin to May 2022. Studies were included if they discussed proximal hamstring repair, postoperative outcomes for at least 6 months, patient demographics, number of tendons injured, occurrence of DVT postoperatively, and specified acute or chronic injury. A repeated search was performed in May 2023 and no further articles were identified. A total of 590 studies were identified, 8 of which (422 patients, 464 proximal hamstring repairs) met the inclusion criteria.

Results

From the 422 patients included in the study, there were a total of 426 injuries sustained. Of the 426 hamstring injuries, 222 (47.8%) were categorized as acute and 204 (44%) were chronic. Nine cases of DVT were identified in the postoperative period, which made up 2.1% (9/422) of the study population or 1.9% (9/464) of the surgical cases. Two of the nine (22.2%) DVTs occurred in patients undergoing repair for chronic proximal hamstring

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[Conflicts of Interest Statement for Shreya Saraf](#)

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tendon ruptures. Three of nine (33.3%) DVTs occurred in patients who suffered a complete proximal hamstring tendon avulsion. Two of the nine (22.2%) occurred in patients with an acute, complete tear of the proximal hamstring tendon. For two of the DVTs, there was no information on the specific type of injury. All 9 DVTs occurred following an open surgical approach.

Conclusion

There is limited data available regarding the incidence of DVT following repair of proximal hamstring tendon injuries, as well as a lack of consistent protocols for post-operative DVT prophylaxis. Most DVTs occurred in patients with a complete proximal hamstring tendon avulsion. Further studies are needed to clearly define rate of DVT and investigate common postoperative protocols for DVT prophylaxis.

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INTRODUCTION

Proximal hamstring tendon injuries are commonly seen in athletes from a variety of sports and are often the result of rapid hip flexion while the knee is extended (Lightsey et al. 2018; Miller, Gill, and Webb 2007). These injuries are typically classified using a 3-level grading scale based on magnetic resonance imaging (MRI) findings, with higher grades indicating a more severe injury. Grade 1 injuries involve <5% of the muscle and are consistent with a muscle strain. Grade 2 injuries, which are partial tears, involve 5%–50% of the tendon thickness. Grade 3 injuries are complete tears or avulsions involving 100% tendon thickness (Heer et al. 2019). Injuries can vary in terms of which hamstring muscles are involved or the specific injury site (either muscle-tendon junction or tendon-bone junction). The treatment of proximal hamstring tendon injuries depends on the severity. Nonoperative treatment is indicated if no tear is present or if the tear involves only a single tendon with minimal retraction. This treatment typically consists of rest, ice, nonsteroidal anti-inflammatory drugs (NSAIDs), and limited weight-bearing for up to 4 weeks (Guanche 2015). Operative treatment is indicated if there is a two-tendon tear with >2 cm of retraction or if the tear/avulsion involves more than two tendons (Miller, Gill, and Webb 2007; Guanche 2015).

Hamstring repair involves reattaching the avulsed tendons to the ischial tuberosity with suture anchors and this can be performed either open or endoscopically (Miller, Gill, and Webb 2007). Operative treatment is further classified into acute and chronic repairs. Acute repair is usually defined as surgical treatment of the avulsed tendon(s) performed within 4 weeks of injury, while chronic repair occurs more than 4 weeks after the injury (Cohen et al. 2012; Harris et al. 2011; Moatshe, Chahla, Vap, et al. 2017).

Several complications can develop following operative treatment of proximal hamstring injuries including re-rupture,

reoperation, surgical wound dehiscence, sciatica-type pain, weakness, repair failure, wound infection, and deep vein thrombosis (DVT) (Bodendorfer, Curley, Kotler, et al. 2018; Bowman et al. 2019; Van der Made et al. 2015). The most common complications include peri-incisional numbness (5.4%) and neurologic problems (8%), while re-rupture, reoperation, and infection/wound complications occur at rates of 2.2%, 2.6%, and 3.3%, respectively (Bodendorfer, Curley, Kotler, et al. 2018). Scarring of the sciatic nerve can occur following proximal hamstring repair if the nerve bundle is not well-protected. Chronic hamstring tears can also lead to scarring potentially from the injury itself (Bodendorfer, Curley, Kotler, et al. 2018). DVT remains a concern following repair of the proximal hamstring tendons, yet the rate of occurrence of this potential post-operative complication has not been previously characterized. The purpose of this study was to characterize the factors related to the development and treatment of DVTs following proximal hamstring repair. We hypothesized that DVT would occur more commonly following repair of chronic proximal hamstring tendon avulsion injuries compared to acute injuries.

MATERIALS AND METHODS

A systematic review of the literature was conducted in accordance with Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Page et al. 2021). A search of the PubMed and EMBASE databases was performed by two independent reviewers from database origin until May 2022. The following search terms were used: “tear”, “avulsion”, “rupture”, and “proximal”. MeSH and title/abstract (tiab) terms were also utilized in the search: “hamstring muscles [MeSH]”, “hamstring tendons [MeSH]”, “hamstring[tiab]”, “semimembranosus[tiab]”, “semitendinosus[tiab]”, “biceps femoris[tiab]”, “femoral biceps[tiab]”. Boolean operators “OR” and “AND” were used to combine synonyms and categories. A subsequent database search was performed in May 2023, which did not populate any further articles to be included in this review.

Titles and abstracts were screened to assess eligibility based on inclusion/exclusion criteria. Studies were included if they discussed surgical repair of proximal hamstring injuries, contained details on postoperative outcomes for a period of at least 6 months, contained a detailed description of the acute or chronic nature of the injury, included a description of the number of tendons injured, and patient

demographics (e.g., age, gender, time since injury, mechanism of injury). Studies were excluded if they were case reports, review articles, anatomic reviews, surgical technique reviews, cadaveric studies, were not published in English, and focused on muscle groups other than the hamstrings. Studies that did not discuss surgical complications were also excluded. The full texts of included studies were reviewed by two authors, and any discrepancies were resolved by a third author. The following information was extracted: patient demographics, type of hamstring tendon injury, complications following repair, DVT prophylaxis, and DVT treatment. Risk of bias was assessed according to the ROBINS-I risk of bias tool for the included non-randomized studies, which incorporates an assessment of bias due to confounding, selection of participants, deviations from intended interventions, completeness of outcomes data, selection of outcomes reported, and other sources of bias.

RESULTS

The initial search yielded a total of 590 studies. After removing duplicates, 483 studies remained. Titles and abstracts were screened, and 436 studies were removed for not meeting the inclusion criteria, leaving 47 studies for full text review. Of those 47 studies, 8 specifically commented on DVT as a complication of proximal hamstring repair and were included ([Figure 1](#)). From these 8 non-randomized studies, 7 (87.5%) were case series (level IV evidence), and 1 (12.5%) was a therapeutic trial (level III evidence) ([Table 1](#)).

While surgical technique varied for all 8 studies, they each utilized an open repair. Only one study (12.5%) documented the use of DVT prophylaxis (Cohen et al. 2012). All 52 patients (26 male; 26 female) undergoing proximal hamstring repair were prescribed four weeks of aspirin postoperatively. No note was made of dose or compliance for any patient, including the patient who developed a DVT (Cohen et al. 2012). From the 8 studies included in this review, a total of 9 cases of DVT were identified in the postoperative period, which made up 2.1% (9/422) of the study population or 1.9% (9/464) of the surgical cases. All 9 (100%) of the DVTs occurred following an open repair. Additionally, all patients who were found to have a DVT were subsequently treated with anticoagulation therapy, with successful resolution of the DVT.

DVT INCIDENCE

Willinger et al. reported 2 cases of DVT in their study in patients who had an acute, complete tear of their proximal hamstring tendon (Willinger et al. 2019). Whereas, in a 2008 study by Sallay et al., a patient who had undergone repair for chronic proximal hamstring tendon rupture was diagnosed two weeks postoperatively with a DVT (Sallay et al. 2008). According to their study, the patient lived out of town and after flying home he became symptomatic. He was subsequently treated with anticoagulant therapy by their home physician and recovered fully. The study did not specify which anticoagulant was used or length of treat-

ment time. Ebert et al. examined outcomes in patients following repair of a chronic proximal hamstring tendon avulsion and reported one occurrence of DVT earlier in the postoperative period and recovered with no further complications (Ebert, Gormack, and Annear 2019). A study conducted by Sarimo et al. reported one case of DVT that was successfully treated with anticoagulant therapy, such that symptoms had subsided by final follow up (Sarimo et al. 2008). There were no specifics given regarding which type of anticoagulant was used nor how long after surgery the DVT occurred. One patient in the study by Cohen et al. developed a DVT at an unspecified time following surgery and was treated with unspecified anticoagulant therapy for 3 months (Cohen et al. 2012). The patient had received four weeks of aspirin for DVT prophylaxis. Léger-St-Jean et al. reported one instance of DVT in their study that occurred in the contralateral leg but did not specify treatment or length of time between surgery and diagnosis (Léger-St-Jean et al. 2019). A patient included in the study performed by Kanakamedala et al. developed a DVT 6 weeks postoperatively and was successfully treated with unspecified anticoagulation therapy of unknown duration (Kanakamedala et al. 2022). They stated that this patient had a history of a superficial deep venous thrombosis. In the study by Willinger et al., two patients developed DVTs following repair of an acute tendon tear (Willinger et al. 2019). The acute/chronic nature of the tear was not defined for the other 5 patients (55.6%) who experienced a DVT. In 2014, Barnett et al. reported a DVT in one patient following a proximal hamstring repair. This was successfully treated with warfarin for an unknown period of time (Barnett, Negus, Barton, et al. 2015). In 2 (25%) of the studies, a patient was diagnosed with a DVT and a pulmonary embolism (PE) (Barnett, Negus, Barton, et al. 2015; Kanakamedala et al. 2022). In one study, the PE and DVT were treated with warfarin for an unspecified duration, which resulted in resolution. It was not specified whether the duration of warfarin treatment was altered by the presence of the DVT with concomitant PE. The patient subsequently developed a hematoma requiring surgical intervention (Barnett, Negus, Barton, et al. 2015). The other study did not specify anticoagulant used or duration of use (Kanakamedala et al. 2022).

SURGICAL TECHNIQUE

Surgical technique was described in each of the 8 studies. Cohen et al. and Léger-St-Jean et al. reported the use of a transverse incision (Cohen et al. 2012; Léger-St-Jean et al. 2019). Barnett et al., Kanakamedala et al., Sarimo et al., Willinger et al., Sallay et al., and Ebert et al., utilized longitudinal incisions (Barnett, Negus, Barton, et al. 2015; Kanakamedala et al. 2022; Sarimo et al. 2008; Willinger et al. 2019; Sallay et al. 2008; Ebert, Gormack, and Annear 2019). Studies varied in the number of suture anchors used. For example, the procedure included in studies conducted by Kanakamedala et al., Léger-St-Jean et al., Sarimo et al., Willinger et al., and Sallay et al. used two anchors, while Cohen et al. stated that their surgical technique included the use of 5 anchors (Kanakamedala et al. 2022; Léger-St-

Table 1. Demographics and clinical outcomes of patients from collected studies shown here. Factors concerning DVT occurrence also listed.

<u>Author</u>	<u>Design</u>	<u>Level of Evidence</u>	<u>Male/ Female</u>	<u>Age, years</u>	<u>Injury Mechanism</u>	<u>Injury Severity</u>	<u>Injury type- Chronic vs Acute</u>	<u>Surgical Technique</u>	<u>Postoperative Complications</u>	<u>DVT Prophylaxis</u>	<u>DVT Treatment</u>	<u>Characteristics of DVT patient</u>
Cohen et al (Guanche 2015)	Case series: outcome in 52 patients after surgical repair of a proximal hamstring injury that was either acute or fail nonoperative management	4	26 male, 26 female	Average: 47.7 years Range: 17-66	27 slip-and- fall, 1 heavy lifting, 23 sports- related (6 waterskiing, 6 running, 4 skiing, 2 softball, 1 baseball, 2 football, 2 tennis)	38 complete avulsions, 12 2-tendon tears (one of whom had bony avulsion), 2 1-tendon tear	40 acute, 12 chronic	Transverse incision, 5 suture anchors placed on ischial tuberosity	20 incisional numbness, 5 posterior thigh numbness, 1 DVT	4 weeks of postoperative aspirin (dose unspecified)	Anticoagulation for 3 months	None specified
Barnett et al (Lightsey et al. 2018)	Case series: outcome in 132 patients after surgical repair of a proximal hamstring injury	4	77 male, 55 female	Average: 42.5 years (SD 12.2)	10 falls, 100 sports- related (29 waterskiing, 24 splits, 13 sprinting, 11 rugby, 7 soccer, 5 tennis, 4 surfing, 3 martial arts, 2 netball, 2 skiing) 20 other	96 complete avulsions, (36 acute, 60 chronic), 36 partial avulsions (2 acute, 34 chronic)	38 acute, 94 chronic	5-7cm longitudinal incision, 3 anchors with additional number-5 Ethibond sutures (Ethicon, Somerville, NJ) threaded through the anchors and inserted into the ischial tuberosity	8 postoperative hamstring tightness, 5 hamstring cramping, 2 pain at ischial tuberosity, 6 sciatica-like pain, 1 posterior thigh numbness, 1 new onset hip pain, 1 pulmonary embolus with subsequent hematoma after warfarin therapy, 1 superficial wound infection, 2 re- rupture, 1 DVT	None specified	Warfarin (duration unspecified)	None specified
Leger- St- Jean et al (Barnett, Negus, Barton, et al. 2015)	Therapeutic trial; outcome in 38 proximal hamstring injuries among 34 patients treated	3	27 male, 16 female; 9 unspecified and excluded from study due to lack of follow-	Average: 45.8 ± 15.7 years	10 falls, 16 sports (10 waterskiing, 6 running); only most common injuries listed	33 complete avulsions, 9 2-tendon tears, 3 1-tendon tear (among	22 acute, 16 chronic	10 cm longitudinal incision, 2 anchors placed in lateral aspect of ischial tuberosity	2 re-rupture, 1 osteomyelitis, 4 sciatica- like symptoms, 1 DVT	None specified	None specified	DVT was noted to occur in the contralateral leg

Author	Design	Level of Evidence	Male/ Female	Age, years	Injury Mechanism	Injury Severity	Injury type- Chronic vs Acute	Surgical Technique	Postoperative Complications	DVT Prophylaxis	DVT Treatment	Characteristics of DVT patient
	acutely with surgery; all 4 patients with 2 surgeries were from separate injuries at different times		up			the 47 patients identified via author's record review, exact numbers among the 34 patients who completed follow-up are unknown)						
Sarimo et al (Sterne, Hernán, Reeves, et al. 2016)	Case series: outcome in 41 patients with complete proximal hamstring avulsions treated operatively	4	21 male, 20 female	Average: 46 years Range: 18-71 years	22 sports-related (9 cross country skiing, 3 waterskiing, 3 downhill skiing), 15 slip-and-fall, 4 other	41 complete avulsions	14 acute, 27 chronic	Longitudinal incision; 2-4 anchors inserted, autologous free graft from the ipsilateral distal iliotibial tract used in 1 patient	2 re-rupture, 4 neuralgia-type pain, 1 superficial wound infection, 1 partial dehiscence, 1 postoperative seroma, 1 DVT	None specified	Anticoagulation (duration unspecified)	None specified
Sallay et al (Ebert, Gormack, and Annear 2019)	Case series: outcome in 25 patients with complete hamstring ruptures treated operatively	4	13 male, 12 female	Average: 43.5 years Range: 20-69 years	Mechanism not specified	25 complete avulsions	18 acute, 7 chronic	Longitudinal incision in all chronic cases; either transverse or longitudinal incision in acute cases; 2-4 titanium suture anchors used	4 stiffness after activity, 2 constant stiffness, 2 numbness and tingling, 1 DVT	None specified	Anticoagulation (duration not specified)	DVT occurred in patient undergoing repair of chronic injury (167 days between injury and operation); patient noted to have flown at 9 days postoperatively; DVT diagnosed 2 weeks postoperatively
Ebert et al (Harris et al. 2011)	Case series: outcomes in 6 patients	4	2 male, 4 female	Average: 47.5 years	4 sports-related (1 surfing, 1	6 complete avulsions	6 chronic	Longitudinal incision, distal ipsilateral	1 second operation to remove	None specified	Unspecified	None specified

Author	Design	Level of Evidence	Male/ Female	Age, years	Injury Mechanism	Injury Severity	Injury type- Chronic vs Acute	Surgical Technique	Postoperative Complications	DVT Prophylaxis	DVT Treatment	Characteristics of DVT patient
	with chronic proximal hamstring avulsion injuries treated using ipsilateral distal tendon autologous free graft			Range: 30-61 years	running, 1 roller skating, 1 soccer), 2 other			hamstring graft from the gracilis and semitendinosus; 2 suture anchors placed on lateral ischial footprint; 2 anchors placed on the posterior ischium	hardware causing irritation, 1 DVT			
Kanakamedala et al (Page et al. 2021)	Case Series: outcomes in 46 patients after surgical repair of proximal hamstring injury; only 38 complete sets of patient-reported outcomes collected	Not listed	16 Male, 22 Female	Average: 51.4 years Range: 18-65 years	25 mechanical fall, 7 running, 4 water skiing, 10 various sports activities	28 three-tendon injury, 9 two-tendon injury, 1 One-tendon injury	19 acute, 19 chronic	Open approach with transverse incision; sutures from anchors used to reattach at ischial tuberosity; in chronic cases with concern for significant tendon retraction, longitudinal incision was used	2 sciatic nerve symptoms, 1 atraumatic re-rupture, 1 superficial wound infection, 1 chronic draining sinus tract, 1 DVT	None specified	Anti-coagulation therapy (duration unspecified)	DVT diagnosed 6 weeks postoperatively; patient had history of superficial venous thrombosis
Willinger et al (Engler, Bragg, and Miller 2019)	Case series: outcome in 94 patients after surgical repair of proximal hamstring tendon	4	Average: 53.8 years	53 male, 41 female	Mechanism not specified	36 partial tendon tear, 58 complete tendon tear	71 acute, 23 chronic	Horizontal incision made at gluteal crease; suture anchors used to reattach tendon at ischial tuberosity	1 Hematoma, 4 paresthesia, 1 wound infection, 36 sitting discomfort, 1 revision surgery due to postoperative hematoma, 2 DVT	None specified	None specified	No characteristics of DVT patients specified

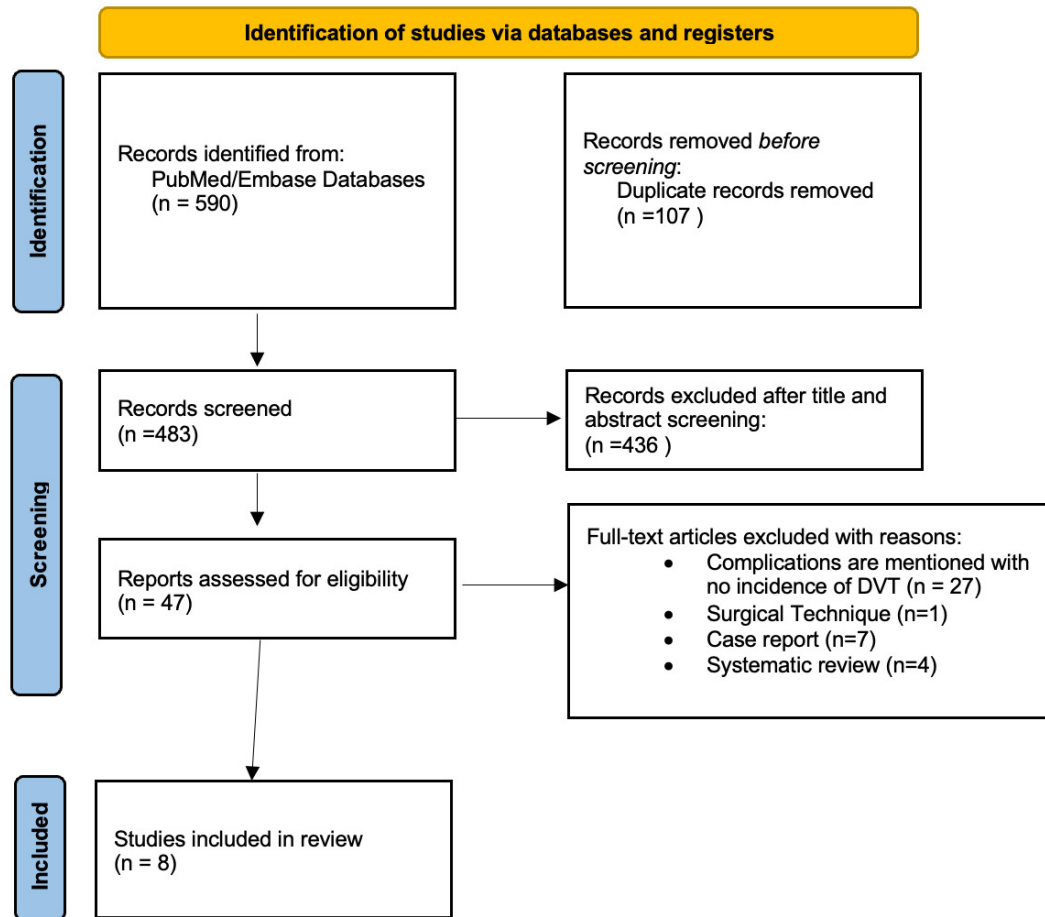


Figure 1. PRISMA Diagram

Jean et al. 2019; Sarimo et al. 2008; Willinger et al. 2019; Sallay et al. 2008; Cohen et al. 2012). Cohen et al., Barnett et al., Kanakamedala et al., Léger-St-Jean et al., Sarimo et al., Willinger et al., and Sallay et al. used suture anchors to reattach the torn or avulsed tendon directly to the ischial tuberosity (Cohen et al. 2012; Barnett, Negus, Barton, et al. 2015; Kanakamedala et al. 2022; Léger-St-Jean et al. 2019; Sarimo et al. 2008; Willinger et al. 2019; Sallay et al. 2008).

PATIENT OUTCOMES

One study (12.5%) examined the use of gracilis and semi-tendinosus tendons harvested from the ipsilateral distal hamstrings to attach the proximal hamstring stump to the suture anchors in the ischial tuberosity (Ebert, Gormack, and Annear 2019). All 6 patients were undergoing proximal hamstring repair for a chronic, retracted tear. Five of 6 (83.3%) patients were satisfied at 24 months postoperatively. The other 7 studies (87.5%) that used a suture anchor to reattach the torn or avulsed tendon directly to the ischial tuberosity included a mix of patients with chronic (168/420, 40%) and acute (246/420, 58.6%) injuries. Cohen et al. reported that 51 of 52 (98.1%) patients were satisfied with postoperative outcomes regarding function after proximal hamstring repair based on subjective questionnaire (Cohen et al. 2012). Similarly, Sallay et al. conducted a study eval-

uating patient-based results after a proximal hamstring repair via subjective questionnaire that showed 100% (25/25) of their patients were content with their progress following the surgery (Sallay et al. 2008). Léger-St-Jean et al. did not report satisfaction rates but did report Lower Extremity Functional Scale (LEFS) and Single Assessment Numeric Evaluation (SANE) scores of 85.7 ± 21.3 and 86.9 ± 11.7 , respectively (Léger-St-Jean et al. 2019). Two studies did not report patient satisfaction rates, but Willinger et al. measured postoperative outcomes via Lysholm score, Harris Hip Score (HHS), Tegner activity scale, Visual Analog Scale (VAS), and Return to sport (RTS) (Willinger et al. 2019). Kanakamedala et al. also did not report satisfaction rates, but included Perth Hamstring Assessment Tool (PHAT), Modified Harris Hip Score (MHHS), Visual Analogue Scale for pain (VAS), Pre-injury Tegner, and Post-operative Tegner scores (Kanakamedala et al. 2022).

RISK OF BIAS ASSESSMENT

The results of the risk of bias assessment of the 8 included studies using the ROBINS-I risk of bias tool are presented in Figure 2 (Sterne, Hernán, Reeves, et al. 2016). All 8 studies presented a moderate risk of bias due to confounding, as there were no prognostic variables used to predict baseline intervention. No patients switched between interventions

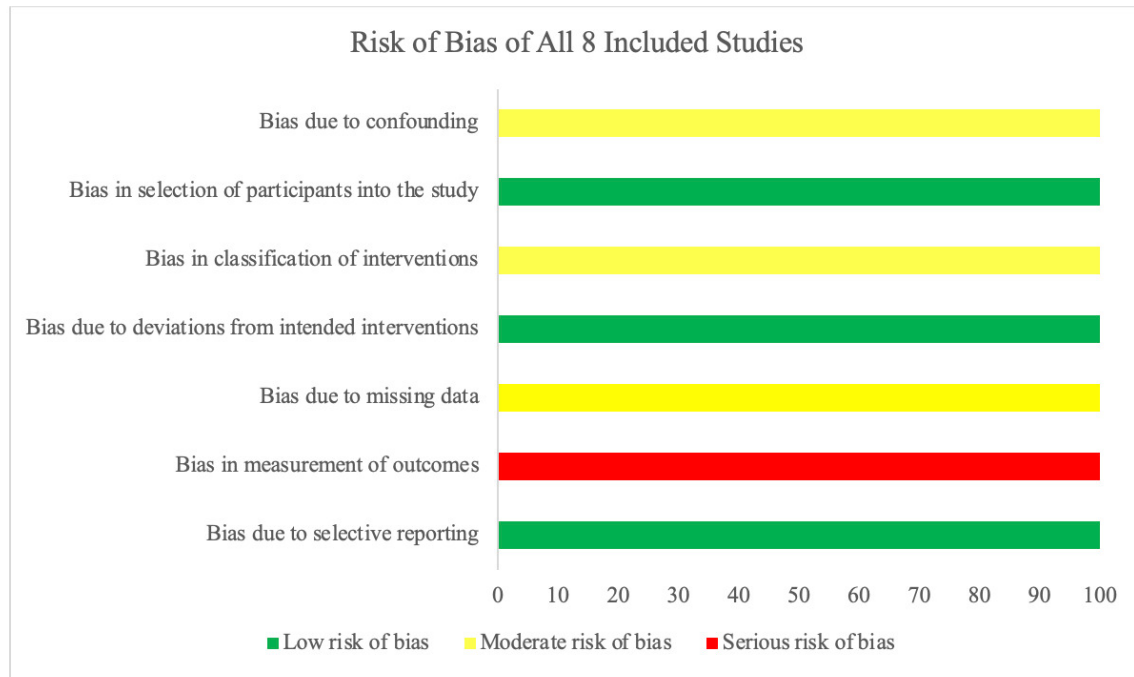


Figure 2. Risk of bias graph for all included studies (Lightsey et al. 2018; Guanche 2015; Harris et al. 2011; Page et al. 2021; Barnett, Negus, Barton, et al. 2015; Ebert, Gormack, and Annear 2019; Sterne, Hernán, Reeves, et al. 2016; Engler, Bragg, and Miller 2019). Risk of bias is presented as a percentage across all included studies (green = low risk; yellow = unclear/moderate risk; red high risk).

during the study period, as the only other alternative would have been nonoperative treatment (low risk of bias). No eligible patients were excluded from any of the studies, thus presenting low risk of bias due to selection of participants. None of the studies deviated from the intended intervention, and no studies used variable follow-up times (low risk of bias) (Sterne, Hernán, Reeves, et al. 2016). All 8 studies clearly classified treatment type; however, post-operative protocols for DVT prophylaxis were not specified in 7 studies (Barnett, Negus, Barton, et al. 2015; Kanakamedala et al. 2022; Léger-St-Jean et al. 2019; Sarimo et al. 2008; Willinger et al. 2019; Sallay et al. 2008; Ebert, Gormack, and Annear 2019). However, one study mentioned that they utilized 4 weeks of post-operative aspirin at an unspecified dose (moderate risk of bias) (Cohen et al. 2012). All eight studies used physicians not blinded to the treatment group (serious risk of bias [Cohen et al. 2012; Barnett, Negus, Barton, et al. 2015; Kanakamedala et al. 2022; Léger-St-Jean et al. 2019; Sarimo et al. 2008; Willinger et al. 2019; Sallay et al. 2008; Ebert, Gormack, and Annear 2019]. Finally, no studies showed bias due to selective reporting (low risk of bias).

This review used *MINORS* criteria shown in [Table 2](#) to examine the quality of non-randomized studies included in this paper (Slim et al. 2003). The scoring system had 12 individual elements; however, only comparative studies were evaluated in items 9-12. All eight studies used in this review were scored 0 if not reported, 1 if reported but not adequate, and 2 if reported and adequate. The maximum possible score for non-comparative studies was 16 and 24 for comparative studies. Based on the results of [Table 2](#), Bar-

nett et al., Ebert et al., and Sarimo et al. received a score of 16; Cohen et al. received a score of 15; Sallay et al., received a score of 13; and Kanakamedala et al., Léger-St-Jean et al., and Willinger et al. received a score of 23 (Cohen et al. 2012; Barnett, Negus, Barton, et al. 2015; Kanakamedala et al. 2022; Léger-St-Jean et al. 2019; Sarimo et al. 2008; Willinger et al. 2019; Sallay et al. 2008; Ebert, Gormack, and Annear 2019).

DISCUSSION

While previous studies have characterized the complications associated with repair of proximal hamstring injuries, this is the first systematic review to focus specifically on the incidence of DVT in this patient population. We identified 47 studies that discussed complications following repair of the proximal hamstring, 8 of which specifically evaluated the rate of DVT. All 8 of these studies had at least one patient that developed a DVT following proximal hamstring repair. The most DVTs occurred in patients with a complete proximal hamstring tendon avulsion, though the incidence was low. Based on the studies reviewed in this paper, it can be determined that the risk of post-operative DVTs is low compared to other post-operative complications evaluated.

In 2018, Bodendorfer et al. performed a meta-analysis for treatment of proximal hamstring avulsions and associated complications (Bodendorfer, Curley, Kotler, et al. 2018). The authors found an overall incidence of DVT or PE in 5 of the 767 patients (0.68%) operatively treated patients that were assessed. No distinction was made between DVT or PE in this regard. Four of the 5 (80%) patients who de-

Table 2. Methodological index for non-randomized studies (MINORS).

	Barnett et al (Lightsey et al. 2018).	Cohen et al (Guanche 2015).	Ebert et al (Harris et al. 2011).	Kanakamedala et al (Page et al. 2021).	Leger -St-Jean et al (Barnett, Negus, Barton, et al. 2015).	Sallay et al (Ebert, Gormack, and Annear 2019).	Sarimo et al (Sterne, Hernán, Reeves, et al. 2016).	Willinger et al (Engler, Bragg, and Miller 2019).
1. A stated aim of the study	2	2	2	2	2	2	2	2
2. Inclusion of consecutive patients	2	2	2	2	2	2	2	2
3. Prospective collection of data	2	2	2	2	2	2	2	2
4. Endpoint appropriate to the study aim	2	2	2	2	2	2	2	2
5. Unbiased evaluation of endpoints	2	2	2	2	2	2	2	2
6. Follow-up endpoint appropriate to the major endpoint	2	2	2	2	2	2	2	2
7. Loss to follow less than 5%	2	1	2	1	1	1	2	1
8. Prospective calculation of the study size	2	2	2	2	2	0	2	2
<i>Additional criteria in case of comparative study</i>								
9. An adequate control group				2	2			2
10. Contemporary groups				2	2			2
11. Baseline equivalence of groups				2	2			2
12. Adequate statistical analyses				2	2			2
Total MINORS score	16	15	16	23	23	13	16	23
Maximum possible score	16	16	16	24	24	16	16	24

veloped a DVT/PE had no information on the nature of the injury, while one patient's DVT occurred following repair of a complete, chronic avulsion. Two other DVT/PE patients (40%) had complete proximal hamstring avulsions; therefore, a total of 3 out of 5 identified DVT/PE cases (60%) occurred in the setting of a complete avulsion. The complete vs partial nature of the remaining 2 DVT/PE patients (40%) was not known (Bodendorfer, Curley, Kotler, et al. 2018). Similarly, our study found no clear association between the complete vs partial nature of the injury and the occurrence of a DVT. We also identified a similar chronicity of hamstring injury among the DVT patients, which may be the result of a prolonged surgical time or increased effort to mobilize the tendon with respect to an acute tendon injury.

A systematic review performed by van der Made in 2015 reported that of the 387 patients who underwent surgical treatment of proximal hamstring injuries, 3 developed a DVT following repair (Van der Made et al. 2015). While this study reported on patient demographics, mechanism of injury, acute vs chronic and the complete vs partial nature of the avulsion, none of these specifics were known for the 3 patients (0.78% of 387 total) who developed a DVT post-operatively (Van der Made et al. 2015). Similarly in 2011, Harris et al. conducted a systematic review of outcomes in patients following repair of proximal hamstring tendon avulsions (Harris et al. 2011). Of 286 patients that were treated surgically, the authors identified 2 (0.70%) instances of DVT. No data was reported regarding the nature (partial vs complete) or chronicity of the tear (Harris et al. 2011). Our study characterizes several of the factors related to the development and treatment of DVTs following proximal hamstring repair, providing more context to contribute to the literature. These include DVT prophylaxis as well as method and duration of DVT treatment. Some of the studies in our review did not include certain demographic data for the patients who developed a DVT postoperatively. The lack of information leaves a gap in knowledge regarding DVTs. To decrease the incidence of DVTs in patients following a proximal hamstring repair, possible risk factors must be identified in all cases to find a potential cause as to why this postoperative outcome occurs.

In 2021, Reza et al. performed a systematic review of 27 studies published between 2000 and 2019 to examine outcomes following proximal hamstring repair (Reza et al. 2021). Thirty different measurement methods were identified that included the postoperative results of 1,080 patients. 17 (56.7%) were patient-reported outcome measures (PROMs), such as patient surveys and Perth Hamstring Assessment Tool (PHAT), and 13 (43.3%) were clinical outcome measures (COMs), including return to sports and isokinetic hamstring strength using dynamometer. This study reported that most of the observed studies used more COMs than PROMs, and the authors concluded that a combination of COMs and PROMs was the most reliable method to test postoperative outcomes after proximal hamstring repair (Reza et al. 2021). In contrast to this study, our main focus was the occurrence of postoperative DVT; however, some of the studies in our review did mention the use of

subjective methods from patients to measure postoperative outcomes.

Engler et al. conducted a retrospective cohort study in 2019 examining the incidence of DVT in the setting of proximal hamstring repair (Engler, Bragg, and Miller 2019). Of 132 patients who underwent surgical repair of an acute, complete tear, 10 (7.5%) developed DVTs. Of these, 5 (50%) were diagnosed preoperatively, and all 5 (100%) occurred in patients who were not receiving DVT prophylaxis. The remaining 5 DVTs (50%) were diagnosed postoperatively, all 5 (100%) were in patients who were receiving either aspirin or enoxaparin for prophylaxis. Of the 10 DVTs, 6 (60%) were later found to have an identifiable risk factor, ranging from Factor V Leiden, smoking, contraceptives, a long plane flight, as well as varying degrees of preoperative and postoperative immobilization. With respect to immobilization, all patients were toe-touch weight-bearing for two weeks, with progression to partial then full weight-bearing at 4 weeks. All patients used a hip brace (except for 1 knee brace) for the same duration. Of note, among the 52 partial hamstring ruptures that were treated surgically, none developed a DVT (Engler, Bragg, and Miller 2019). Engler displayed a similar degree of detail regarding the partial vs complete nature of the injury as well as the prophylaxis received by patients, though it only describes acute injuries treated by a single surgeon, with all patients receiving similar postoperative care. Overall, this review identified several factors concerning DVT complication, including partial vs complete and acute vs chronic nature of the injury in patients who developed a DVT following repair of a proximal hamstring avulsion. Though these characteristics have been evaluated in previous studies, our study included other considerations regarding DVTs, such as prophylaxis and treatment methods.

LIMITATIONS

There are several limitations to this study. First, 39 of the 47 studies (82.9%) which discussed complications in the setting of proximal hamstring repair did not indicate whether any patients developed a DVT post-operatively. That could be for a variety of reasons, including that no patients developed a DVT or no DVT data was collected. Since neither of these instances are specifically mentioned, the actual incidence of DVT in these procedures may be higher or lower than suggested by the 8 included studies due to the lack of DVT data in the other 39 articles. Additionally, information such as age, patient sex, number of tendons involved, and time to surgery following injury was not specified for the patients who developed a DVT in most of the included studies. This made it difficult to discern correlations between patient demographics, the nature of their injury, and ultimately the presence or absence of a DVT during their postoperative course. Further, details regarding the type and duration of anticoagulation given to patients with DVT were not specified throughout all the studies examined, limiting further analyses between them. Finally, a meta-analysis could not be performed for our study due to the heterogeneity of data included in the studies. All stud-

ies included in this systematic review were level III or IV, excluding them from eligibility for meta-analysis.

CONCLUSION

Currently, there is limited data available regarding the incidence of DVT following repair of proximal hamstring avulsion injuries, as well as a lack of consistent protocols for post-operative DVT prophylaxis. Most DVTs occurred in patients with a complete proximal hamstring tendon avulsion. Orthopaedic surgeons should understand that pa-

tients undergoing repair of proximal hamstring avulsion injuries are at risk of developing a DVT and surgeons should, therefore, consider putting these patients on DVT prophylaxis postoperatively. Further studies are needed to clearly define the rate of DVT following proximal hamstring repair and the appropriate protocol for DVT prophylaxis.

Submitted: December 06, 2024 EDT. Accepted: February 14, 2025 EDT. Published: July 09, 2025 EDT.



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