



REVIEW

Deep Venous Thrombosis after Arterial Surgery a Literature Review

M. Bani-Hani, M. Titi, H. Al-khaffaf*

East Lancashire Hospitals NHS Trust, Burnley General Hospital, Department of General/Vascular Surgery, Casterton Avenue, Burnley, Lancashire BB10 2PQ, United Kingdom

Submitted 26 March 2008; accepted 3 July 2008
Available online 5 September 2008

KEYWORDS

Deep vein thrombosis;
Arterial surgery;
Vascular surgery;
AAA;
Pulmonary embolism

Abstract *Objective:* To quantify the risk of DVT in arterial surgery, and to assess the need for prophylaxis.

Methods: A search was carried out through Medline, Embase and Cochrane databases to identify published studies on DVT in arterial surgery. To quantify the risk of DVT both randomised and prospective non-randomised studies were included for analysis. However, to assess the need for prophylaxis only randomised controlled trials were considered.

Results: Twenty three prospective studies that evaluated DVT in arterial surgery were identified. Ten reported data about DVT in aortic surgery, seven studies evaluated DVT in general vascular surgery, three studied DVT in infra-inguinal vascular surgery and three studied DVT incidence in patients after limb amputations.

Conclusion: There is a wide variation in the reported incidence of DVT in arterial surgery (2%–24%). This is mostly due to the diversity of screening methods used and the inclusion or exclusion of below knee DVT.

There is insufficient evidence to make a valid conclusion regarding the routine use of anti-coagulants prophylaxis in arterial surgery. However, until such evidence becomes available, DVT prophylaxis in patients undergoing arterial surgery will continue to be guided by evidence gained from studies of general surgical patients.

© 2008 European Society for Vascular Surgery. Published by Elsevier Ltd. All rights reserved.

Introduction

In contrast to general and orthopaedic surgery the incidence of DVT following arterial surgery has attracted very little attention. Despite being the surgical specialty that mostly deals with vessels, clots, and thrombo-embolic phenomena, vascular surgery seems to have no guidelines

* Corresponding author. Tel.: +44 1282 804642; fax: +44 1282 804124.

E-mail address: alkhaffaf@hotmail.com (H. Al-khaffaf).

when it comes to post-operative DVT prophylaxis. NICE guidelines highlight the lack of specific evidence in this field (particularly for patients not receiving thromboprophylaxis) and rely on conclusions derived from general surgery without taking into account the characteristics of vascular patients or the surgical procedure itself.¹

On the other hand, and despite the strong recommendation in high risk group of vascular patients, the American College of chest physicians (ACCP) recommendation comes with concerns regarding the methodological quality (grade 1C+). While the evidence for the low risk group was essentially weak (grade 2B).²

The fact that most vascular patients are generally older, with limited mobility, and higher rate of co-morbidities puts this group of patients at a higher risk of developing deep venous thrombosis. However, the anecdotal experience of most vascular surgeons suggests that practically this is not the case.³ This has been generally attributed to the essential step of intra-operative heparin used in nearly all arterial procedures, which is thought to be the peak time for most clot formation.^{4,5} On the other hand, the fact that bleeding complications are far more serious in this particular group of patients⁶ and most of them are already on antiplatelets (aspirin and or clopidogrel) can make some surgeons rather reluctant to use additional anti-coagulants in these circumstances. In a recent review published in the Cochrane library,⁷ we demonstrated the lack of quality evidence for DVT prophylaxis in aortic surgery.

Methods

A search was performed through Medline, Embase, and Cochrane databases for published studies in the English language that have evaluated Deep Venous Thrombosis in arterial surgery. We used the keywords "DVT", "Deep vein thrombosis", "Pulmonary embolism", "Arterial surgery", "vascular surgery", "Aortic surgery", "Infra-inguinal revascularisation" and "amputations". Full texts of all relevant articles were obtained and analysed for the pre-determined parameters. We also searched for additional trials through reference lists of retrieved studies.

To quantify the risk of DVT both randomised and prospective non-randomised studies reporting data of DVT incidence in arterial operations (regardless of the prophylactic method) were included for analysis. However, to assess the need for prophylaxis and safety of intervention, only randomised controlled trials (RCTs) comparing anticoagulants (with or without mechanical methods) to controls were included.

All studies were analysed for the incidence of DVT, procedures performed, methods of screening for DVT, prophylactic method used, incidence of pulmonary embolism, mortality, difficulties encountered and recommendations made by the authors.

Results

Twenty three prospective studies that evaluated DVT in arterial surgery were identified (see Table 1). For the purpose of this review they were classified according to the type of intervention into four groups: Aortic surgery, General arterial surgery, peripheral non-aortic

reconstructive surgery, and amputations. Carotid cases were only included as a part of general vascular studies^{8,9} and as expected, our search failed to identify any study that evaluated DVT in carotid surgery alone.

Ten studies reported data about DVT in aortic surgery, of which three were randomised controlled trials, and seven prospective but non-randomised studies. Seven studies evaluated DVT in vascular procedures in general (including some aortic cases); of which four were randomised. Unfortunately all the studies that investigated infra-inguinal revascularisation and amputations were non-randomised. Naturally, there was an element of overlap between Aortic and general vascular cases, and definite separation between the two groups was impossible in some studies.

In the **aortic-only** group only three studies were randomised (RCTs) among which two only compared anti-coagulants to control. Killewich *et al.*¹⁰ reported an incidence of 2% in both groups, while Belch *et al.*⁶ estimated a DVT incidence of 24% in the no-treatment group. However, the latter study was not completed because of significant hemorrhagic complications.

All the other seven non-randomized aortic studies ($n = 407$) did not adopt any anticoagulant regimen and reported an incidence that ranged between 0–20.5% averaging 9.2%. Notably, this incidence comes down to 2.6% if calf DVT is excluded.

Only a single study looked at the risk of DVT in EVAR¹¹ and reported a DVT incidence of 6% only.

In the **general arterial surgery** group seven studies were identified; four RCTs ($n = 660$) and three prospective non-randomized studies ($n = 114$). In RCT group only Spebar *et al.* study⁹ compared anticoagulants (heparin) to control and reported an incidence of 12.5% and 10.5% respectively, with no significant difference between the two. However the number of cases included was very small ($n = 43$).

In the **peripheral non-aortic** group three prospective non-randomised studies were identified and none of them used heparin prophylaxis with a DVT incidence that varied between 2.8% and 8%.

In the **amputations** group no RCTs were identified and only two prospective studies were considered. These reported a variable incidence of DVT between (0–12.5percent). Additional 21 cases were studied as a part of general vascular operations in Fletcher¹² study with DVT incidence of 14.3%.

Discussion

There was a large discrepancy in the reported incidence of DVT. Apart from the variations in the settings, sample characteristics and experimental protocols the main differences can be attributed to two main reasons. Firstly, the diversity of screening methods used and their sensitivity and specificity. Secondly, the controversial issue of below knee DVT, which is highly emphasised in some studies and totally ignored by others.

DVT in aortic surgery

Among the three RCTs in this group two only compared anti-coagulants to control. Interestingly both studies recommended no anticoagulation for different reasons.

The only completed study that fulfilled all the inclusion criteria was Killewich *et al.*¹⁰ study on a hundred patients' sample, half of whom were given aggressive DVT prophylaxis in the form of a combination of low-dose, unfractionated heparin sodium 5000U subcutaneously every 12 hours, and calf-length IMC device intraoperatively and continued postoperatively for 7 days or until the patient was fully ambulatory. The other half had no prophylaxis at all. It reported a very low incidence of DVT of 2% in both control and intervention group using colour flow duplex scan at one day and four weeks post operatively. Notably, below knee DVT was not addressed and considered insignificant. Although only one patient in each group developed DVT, the control case propagated into a non-fatal PE. The authors attributed this to higher co-morbidity, and longer hospitalisation period in that particular patient. Consequently, the authors recommended only selective prophylaxis in high-risk groups but not routine anticoagulation.

On the other hand, Belch *et al.* study reported the highest DVT incidence in a randomised trial (24%). They also reported the highest rate of hemorrhagic complications in a randomised trial which led to early termination of the study just after recruiting one third of the intended 150 cases. Significant bleeding complications in this trial included one case of major GI bleed and four other cases of retroperitoneal haemorrhage that led to two deaths. Consequently, the results did not reach statistical significance. However, the authors calculated the risk of DVT to be 24% in the control group. Interestingly, Belch *et al.* included all below knee DVT cases in their count although only one case extended above the calf which can make the incidence of "significant " DVT 2% if Killewich definition was used!

Nevertheless, Belch *et al.* recommended DVT prophylaxis in aortic surgery with avoidance of anticoagulants to reduce the risk of major post-operative bleeding. Notably, similar high rate of bleeding complications have not been reported in any other study despite using similar and even higher heparin dose regiment.

The third RCT by Speziale *et al.*¹³ on a 92 patients compared UFH to LMWH and not to no-treatment control and reported a DVT incidence of 8.6% and 6.5% respectively detected by FUT and Doppler ultrasound.

The relatively higher incidence of DVT in the no-prophylaxis group comes mainly from two prospective non-randomised studies with DVT incidences, 20%,¹⁴ and 18%¹⁵ while all the other studies reported an incidence between 0%–7.7percent.

Angelides *et al.* reported a high incidence of DVT (20%)¹⁴ on a sample of 88 patients. Cases were diagnosed by Fibrinogen uptake test only (which is known to over-estimate DVT), and two thirds of the detected cases were below the knee. In fact only 6 patients of the eighteen DVT cases had proximal extension confirmed by venography (which makes the incidence of DVT 6.6% if below knee cases are excluded).

Similarly Olin JW *et al.*¹⁵ reported another high DVT incidence of 18% on a small sample of fifty aortic patients detected by venography. Despite the fact that 78% of the detected DVTs were in the calf, they recommended treatment of those cases, and serial Doppler follow up if anticoagulants are contra-indicated. They supported their

recommendation by Philbrick and Becker¹⁶ review that suggests a calculated risk of pulmonary embolism in calf DVT to be 10%. But this was a general calculated risk including all-cause DVT that is not specific to surgical or vascular patients. In addition, Philbrick and Becker clearly stated that data concerning untreated patients were particularly scarce. Their no-treatment group included five studies which were classified according to the authors [nine methodological standards] into three methodologically weak (Bauer 1942, Hull 1981, Moser and LeMoine 1981)^{17–19} and two moderately strong studies (Kakkar 1969 and Doouss 1976) and neither of those studies documented their criteria to diagnose PE. And even in the major point of concern (calf DVT proximal propagation) the two moderately strong studies varied significantly as Kakkar VV ($n = 39$) reported a propagation rate of 23% while Doouss TW ($n = 124$) reported proximal propagation in only 5.6% of calf DVTs.

Consequently, other studies continued to consider calf DVT as clinically insignificant, supporting their argument by further evidence from other randomised controlled trials in other specialties.²⁰

DVT in EVAR

Eagleton *et al.*¹¹ studied fifty cases of EVAR (three of them done as emergency) and reported a DVT incidence of 6% only. However, the diagnosed DVT cases were actually a very high risk group as one of them had intra-operative femoral vein injury, and the other was on chemotherapy for lung cancer. Therefore they couldn't provide enough evidence to justify DVT screening or prophylaxis in this group. It's worth mentioning here that 18% of the patients were already on warfarin and 56% were on Aspirin which were not stopped preoperatively.

DVT in general arterial operations

In the RCT group only Spebar *et al.*⁹ study compared anti-coagulants (heparin) to control in 43 vascular patients and reported DVT incidence of 10.5% in the control group and 12.5% in the heparin group, with no significant difference between the two. Diagnosis was made using Fibrinogen uptake test. However, venography confirmed only one case (which was an aortic case on prophylaxis that progressed to PE making the incidence of confirmed DVT in this study 2.3 percent. Nevertheless, the sample size was too small to generalise results).

The second randomised study by Harjola P. *et al.*²¹ on 400 cases compared the use of Acetylsalicylic acid and Dipyridamole to control in patients undergoing peripheral vascular reconstructive surgery. They reported a DVT incidence of 7.2% in control group and 3.3% in the combined anti-platelets treatment group. Two of the DVT cases in the control group progressed to fatal PE, but there was no details about the operation they had, or the risk factors related to those cases specifically. Unfortunately the diagnosis of DVT was only on clinical suspicion confirmed by venogram.

The third randomised trial by Urbanyi B²² compared the use of heparin, heparin-dihydroergotamine or dextran-60 in vascular surgery in general with no control group. Almost one

Table 1 A table of studies Included in the review

Study	type	No. of Pts.	Procedures	DVT incidence	PE incidence	Anti-coag. use	Dx. Tool	PE Mortality	conclusion
Aortic Cases									
Angelides MS (1977)	Prospective	88	AAA:68, others:18	20.50%	none	none	Fibrinogen uptake test(FUT)	none	Aortic surgery patients should have DVT prophylaxis
Belch JF (1979)	RCT	49	Aortic bifurcation graft	24% control, 8% LMWH	none	50%LMWH 50% Saline	FUT scan twice then venogram	6.1% (3 cases)	Significant incidence of DVT, but conventional anti-coag is inappropriate
Satiani B (1979)	Prospective	22	9 AAA, 13 Aorto femoral	0%	none	none	FUT + Plethresmography confirmed by venogram	none	Impending Plethresmography is recommended for DVT evaluation in Aortic surgery
Satiani B (1980)	Prospective	69	AAA, 1 aorto femoral	0%	none	none	FUT + Plethresmography confirmed by venogram	none	DVT is rare in Aortic surgery- no need for prophylaxis
Reily MK (1982)	Prospective	100	Aorto iliac surgery	13%	1%	none	FUT + Doppler U/S confirmed by Venogram	none	Results do not support prophylactic caval interruption
Byrne B (1984)	prospective	28	AAA repair, Aorto bifemoral grafts	7.10%	none	none	Fibrinogen uptake test(FUT)	none	single dose intra-operative heparin protects surgical pts against DVT
Speziale E (1988)	RCT	92	AAA repair, Aorto femoral bypass	6.5% LMWH, 8.6% UFH	none	50% on LMWH, 50% on UFH	FUT confirmed by Doppler	none	LMWH is effective & well tolerated
Olin JW (1993)	Prospective	50	Aortio bifemoral, bi-iliac, interposition graft	18%	none	None	Venogram on 5th post op. day	none	treat below knee DVT, & serial Doppler F/U if anticoagulants are contra-indicated
Killewich LA (1997)	RCT	98	Aortic reconstructive surgery	2%	1% in control	UFH + calf compression Vs control	Duplex U/S at 1, 3, 7days post op.	none	incidence is low, aggressive intervention did not change the outcome
Eagleton MJ (2002)	Prospective	50	EVAR	6%	none	None (18% already on warfarin)	Duplex U/S 1st day post op & 4wks later	none	the 3 DVT cases were v.high risk(DVT screening and prophylaxis not justified)
General Vascular									
Harjola PT (1980)	RCT	400	Reconstructive Arterial surgery	7.2% control, 3.3% cobined antipaltelets	0.50%	Dipyridamole, Acetylsalicylic Acid	Venogram on clinical suspecion	0.50%	Dipyridamole & Acetylsalicylic acid have synergistic anti-thrombotic effect
Spebar MJ (1981)	RCT	43	AAA, Carotids, sympathectomy,LL procedures...	12.5% UFH, 10.5% in control	2.3% (on heparin)	Heparin	FUT confirmed by venogram	none	Peroperative heparin prophylaxis is unnecessary
Urbanyi B (1982)	RCT	130	Carotids, Aortic and others	2.4% UFH or UFH-dihydergot, 6.4% on Dextran-60	none	Heparin or heparin-dihydergot, Dextran-60	FUT confirmed by venogram	none	All interventions are equally effective in preventing DVT after arterial surgery

Gossetti B (1988)	Prospective	40	25 Aorto femoral, 8 fem-pop, 7 extra anatomical	2.50%	none	LMWH	FUT, Doppler U/S	none	LMWH effective & safe in preventing DVT in high risk arterial surgery
Farakas JC (1993)	Prospective	233	Aortic, fem-distal	7.5%, 3.7%	none	Heparin, Enoxapirin	Duplex confirmed by venogram	None	Enoxapirin is safe & effective
Fletcher JP (1997)	Prospective	142	Aortic, fem-distal, amputations, others	7.7% aortic cases	none	UFH, compression devices	Duplex ultrasound only	None	moderate risk of DVT despite standard prophylaxis
Hollyoak M (2001)	Prospective	50	22 AAA repair, 28 LL procedures	41% in AAA, 18% in LL	one case	none	Color flow Duplex	one (excluded)	High incidence but small sample
Infra-inguinal Myhre HO (1974)	Prospective	25	Fem pop: 24, Aortoiliac:1	8%	none	Dextran 2days, venogram then warfarin		no	low incidence of DVT as a cause of LL oedema after LL arterial surgery
Passman MA (2000)	Prospective	71	infra-inguinal re-vascularization	2.80%	none	no routine prophylaxis	Duplex U/S	none	routine prophylaxis is not recommended except for specific indication
Morrison ND (1976)	prospective	66 + 369	Fem pop bypass grafting	8%	NA	Dextran	Venogram	NA	Dextran is effective anticoag. Measure that does not affect morbidity
Amputations Barnes RW (1976)	Prospective	35 + 52	Below/above knee amputation	none	1 pt	none	Doppler U/S	none	Prophylaxis is unnecessary in Amputations
Yeuger RA (1995)	Prospective	72	below knee:31, above knee: 41	12.50%	none	not routinely (14% were on warfarin)	Duplex	no	DVT prophylaxis is not recommended
Burke B (2000)	Prospective	8	below knee amputation	50%	none	none	Doppler U/S at 2&4 wks	no	high incidence of DVT, long F/U needed

third of the 130 cases in this study were carotid endarterectomy cases. They reported a DVT incidence of 2.4% in the heparin and combination group and 6.4% in the dextran group. Notably, out of the ten DVT cases diagnosed by FUT four cases only were confirmed by a positive venogram.

The fourth randomised study by Farakas *et al.*²³ reported a DVT incidence of 3.4% on heparin/LMWH prophylaxis, unfortunately there was no control (no-treatment) group.

The reported DVT incidence in the other three prospective non-randomized studies varied hugely between 2.5% and 41%. Gossetti *et al.*²⁴ reported a DVT incidence of 2.5% ($n = 40$) with LMWH prophylaxis. However, all those fibrinogen uptake test detected cases were proven negative by Duplex ultrasound scan. While Fletcher *et al.*¹² reported a DVT incidence of 9.1% ($n = 121$) using heparin prophylaxis. Diagnosis was made using Duplex ultrasound only. On the other hand Hollyoaks *et al.*²⁵ reported an exceptionally high incidence of DVT (41%) detected by colour Doppler scan on a small sample of fifty vascular patients (22 aortic procedures) using no prophylaxis. The authors concluded that the results could not be generalised because of the small number of cases included. Furthermore, this particular group of patients had a higher mortality rate and a higher complications rate than the usual for the authors own practice. Notably 80% of the detected DVT cases were in the calf veins (if excluded incidence becomes 8.2%).

Infra-inguinal reconstructive surgery

Two studies dealt exclusively with infra-inguinal procedures. Both were prospective non randomized trials. The first study by Passman *et al.*²⁶ used no prophylaxis and reported a DVT incidence of 2.8% in 71 cases using Doppler scan. While Morrison *et al.*²⁷ used Dextran prophylaxis, and reported a DVT incidence of (8%) diagnosed by venography.

Yet again the available contradicting evidence is not enough to judge the use of anticoagulants in DVT prophylaxis after arterial reconstructive surgery.

As a general rule earlier studies used no DVT prophylaxis and did not demonstrate a significant advantage of using anticoagulants. However, the small size of the samples and design of the studies limits the value of their conclusions. On the other hand and under the influence of strong evidence from general and orthopaedic surgery more recent studies found it difficult to justify not using anticoagulants in their protocols and passed their results under the umbrella of DVT in general surgery without having a real (no-treatment) control. Although ethically sound, such approach may not reflect the actual incidence of DVT in vascular surgery and totally ignores the risk of bleeding in this specialty.⁶

Other than the small size samples in the majority of these studies, there seemed to be two major points of controversy that need to be clarified before addressing the main question of DVT prophylaxis in arterial surgery. Firstly, the variation in screening tools used and secondly the importance of below knee DVT. Earlier studies used fibrinogen uptake test which significantly overestimated DVT incidence while venography was too invasive to apply in large scale studies. However the advances in ultrasound Doppler tools made it the preferred screening tool in later studies. Unfortunately Doppler studies are not sensitive in

detecting calf DVT which forced the authors to decide before hand about the significance of calf DVT choosing from the available evidence which is quite controversial. In figures, the calculated incidence of DVT in arterial surgery would drop from 12% to 6% in aortic cases and 4% in other peripheral re-constructive surgeries if calf DVT is considered non-significant!

DVT in vascular amputations

The three prospective studies looking at DVT in amputations reported a variable incidence between (0–50percent). Additional 21 cases were studied as a part of general vascular operations in Fletcher study with DVT incidence of 14.3%.¹²

We excluded Burke *et al.* study²⁸ which reported the highest incidence of DVT (50%) on a very small sample of eight below knee amputations. Authors attributed their high result to the use of protective cast in rehabilitation. Nevertheless, the authors admit that they could not exclude pre-operative DVT. Furthermore, three of the four DVT cases were found to have protein S deficiency, one of them combined with protein C deficiency.

Yeager *et al.*²⁹ studied 72 amputations (31 above-knee and 41 below-knee) using no prophylaxis, reporting a DVT incidence of 12.5%. However, six of the diagnosed nine DVT cases were picked up pre-operatively, and only three cases (4.1%) post operatively using Duplex scan. The authors concluded that the operative procedure itself may play a minor role in the pathogenesis of DVT associated with lower extremity amputations, recommending regular peri-operative duplex scanning for DVT rather than prophylaxis. They also recommended further prospective evaluation of their approach.

The main drawback on this study is that 14% of the patients were actually on warfarin. In addition, the patients were followed up only during hospitalisation with no further follow up in the rehabilitation period.

The other study by Barnes *et al.*³⁰ included only 35 cases enrolled prospectively while the rest of the 87 included cases were considered retrospectively. They reported no cases of DVT in vascular amputee. However, they reported one case of confirmed PE three weeks post operatively after the patient's fall on the stump. Duplex scan was used for screening.

In Fletcher *et al.* study the 21 amputation cases had a high incidence of DVT (14%) despite being on heparin prophylaxis. DVT diagnosed by Duplex ultrasound scanning. Unfortunately there was no control group to quantify the benefit of heparin in this case, especially that this group also had the highest rate of morbidity (33%) and mortality (23.8%).

In conclusion, the existing pre-operative risk of DVT in vascular amputation patients does not seem to be affected much by the procedure, and further studies are needed before deciding to adopt prophylactic measures in this group.

Pulmonary embolism (PE)

The significance of DVT comes from its most feared complication of pulmonary embolism, and the high mortality related to it. In a retrospective study Korwin *et al.*³¹ 1979

(with no details of the diagnostic method) reported a 10.3% incidence of PE after aortic surgery (with 29% mortality) and recommended vena-caval filter for aortic patients. However, those results were not reproduced by any later study. Practically there was no confirmed mortality due to PE in aortic surgery patients regardless of the prophylactic method. And excluding the Korwin study, pulmonary embolism was reported in four aortic cases only, one was clinically suspected PE mortality but post mortem exam was not performed²⁵ while the other three cases were non fatal, one of them confirmed by V/Q scan,³² another was on heparin prophylaxis,⁹ and the last was a high risk patient with complicated prolonged post operative recovery.¹⁰

On the other hand there was only three documented cases of PE in all the other vascular cases^{21,33} with two mortalities, but unfortunately we do not have further information about them. Thus the total number of reported cases of PE in vascular patients is seven (0.4%), with two mortalities (0.1%) out of a total number of 1848 cases in this review. In accordance with the previous review by Satiani *et al.*³⁴ which reported the incidence of PE in aortic patients to be less than 0.7%, and fatal PE to be as rare as 0.2%. Notably the joint vascular research group also reported a low incidence of PE (0.014) after aortic aneurysm surgery.³⁵

Major bleeding

Interestingly, the only randomised trial that recommended prophylaxis did not support the use of anti-coagulants in vascular patients because of high rate of hemorrhagic complications. However this high rate was not reported in any of the other studies despite the use of similar anticoagulant regimens. Farakas *et al.*²³ reported the incidence of major haemorrhage to be 2.7% and Fletcher *et al.*¹² reported an incidence of 2.5% while all the other studies did not report any clinically significant bleeding.

Variation of DVT incidence and screening methods

The clinical diagnosis of DVT is often masked by post operative limb swelling and hyperaemia of reperfusion, a fact that significantly contributes to the problem of "over diagnosing" DVT which is well recognised in fibrinogen uptake test (FUT). Fibrinogen uptake test is reported to have accuracy of 90–94% but fails to detect higher iliac thrombi, and recognised to have a false positivity between 20–30% of the cases. In the Satiani *et al.* study in 1979 none of the ten cases detected by FUT proved to be positive, and in his later study only three of the 16 positive cases were confirmed by venography. Similarly, all cases detected by FUT in Spebar *et al.* study proved to be negative by venography except a single obvious case above knee DVT. Reily *et al.* compared FUT and Doppler ultrasonography to gold standard (venography) and reported a false positivity rate of 31% and 20% respectively. Finally, as would be expected, studies that relied on clinical detection of DVT reported the lowest incidence.⁸

In 1977 Angelides *et al.*¹⁴ reported a DVT incidence of 20.5% if no prophylaxis was used. They relied totally on FUT scan. Two years later in 1979 Belch *et al.*⁶ tried to reduce

that incidence using heparin prophylaxis, and although they confirmed a similar incidence of 24% in the no-treatment group using FUT this study was terminated at an early stage because of the high rate of major bleeding and mortality related to anti coagulant use. In the same year Satiani *et al.*³⁶ tried to improve the sensitivity of DVT detection by adding impedance plethysmography to FUT but his findings doubted the earlier reports blaming the high false positivity of FUT for the results and reporting no evidence of DVT in aortic surgery on a small sample of 22 patients. Later in 1980 Satiani³⁴ further confirmed his findings on a larger series of 69 patients (138 limbs) reporting an incidence 1.4% on no prophylaxis. Along the same lines Harjola *et al.* reported a DVT incidence of 7.2% in vascular patients on no prophylaxis using venography as diagnostic tool.

In 1982 Reily³² further confirmed the unacceptably high false positivity associated with FUT as he combined it with Doppler ultrasound and venographic confirmation. He reported a statistically insignificant DVT incidence of 13% (on no prophylaxis) in 100 patients who underwent aortoiliac surgery with no prophylaxis. Nevertheless, Byrne *et al.*³³ used FUT again in 1984 ($n = 28$) and reported DVT incidence of 7.1% recommending no prophylaxis. Interestingly, Speziale¹³ reported a similar DVT incidence of 7.5% in heparinised patients as he compared UFH to LMWH in aortic patients using the combination of FUT and Doppler ultrasound. Urbanyi B *et al.* reported a DVT incidence of 2.4% on heparin and 6.4% on dextran with no significant difference between the two using FUT and venographic confirmation.

In 1993 Olin JW¹⁵ attempted to clarify the picture using direct venographic diagnosis on the 5th post operative day and reported a DVT incidence of 18%. However 78% of those were calf DVTs which were considered significant depending on Philbrick and Becker review.¹⁶ As the latter did not have enough data in the surgical settings and did not provide strong evidence particularly in the no-treatment group; others like Killewich *et al.*¹⁰ still believed that calf DVT is not significant. So in 1997 they excluded calf DVT and reported an incidence of 2% in aortic reconstructive surgery regardless of the prophylactic measure used. This time colour flow duplex was used as a diagnostic tool.

In general the use of venography was kept for confirmatory stage while the screening methods varied widely, and with time there was an increasing trend towards using Duplex scans for screening purposes, adding the new advances in colour Doppler techniques made it the ideal screening tool for a large scale study that is needed to clear all the controversy surrounding DVT in vascular field.

Ideally the answer to the DVT argument in arterial surgery should be tackled by a large-scale (possibly multi-centre) randomised controlled trial. However, there will be a few hurdles to such approach. Firstly, the ethical dilemma of depriving *high-risk* patients from anticoagulant prophylaxis and subsequently finding the best *control* group. Secondly, in the age where endovascular intervention has replaced many open procedures, it might be difficult to find enough surgeons willing to take part in such a study. Thirdly, as demonstrated in this review other points of controversy need to be addressed prior to designing such study including: the significance of below knee DVT, the best screening tool, incidence and relevance

of sub-clinical PE, ideal prophylactic measures, and safety of anti-coagulants in arterial surgery. In addition, the higher-risk patients with prolonged recovery and added comorbidities may need to be addressed in a separate arm of the study for obvious reasons.

Conclusion

Collectively the available evidence is insufficient to make a valid conclusion regarding the use of anticoagulant prophylaxis in arterial surgery.

Despite the controversy surrounding DVT in arterial surgery, there seems to be one favourable point of agreement between all the studies, which is the small incidence of pulmonary embolism, as well as the rare mortality related to it (only two confirmed cases, and one suspected). Although this finding suggests a genuine protective effect of intra operative heparin, it may also reflect a major failure in study designs to precisely define the extent of this phenomenon.

Until all these questions are answered DVT prophylaxis in vascular patients will continue to be guided by evidence of prophylaxis gained from studies of general surgical patients.

References

- Hill J, Treasure T. Reducing the risk of venous thromboembolism (deep vein thrombosis and pulmonary embolism) in inpatients having surgery: summary of NICE guidance. *BMJ* 2007; **334**(7602):1053–4.
- Geerts WH, Pineo GF, Heit JA, Bergqvist D, Lassen MR, Colwell CW, et al. Prevention of venous thromboembolism: the Seventh ACCP Conference on Antithrombotic and Thrombolytic Therapy. *Chest* 2004; **126**(3 Suppl):338S–400S.
- Robinson MH, Studley JG, Powis SJ. Anticoagulation in abdominal aortic aneurysm surgery: the approach of vascular surgeons in Great Britain and Ireland. *Eur J Vasc Surg* 1989; **3**(2):141–3.
- Jennings S, Cass AJ, Heather BP, Greenhalgh RM. Coagulation changes during major surgery and relationship to post-operative deep vein thrombosis. *J Cardiovasc Surg (Torino)* 1981; **22**(4):327–9.
- Nicolaidies AN. Prevention of deep venous thrombosis. *Geriatrics* 1973; **28**:69–75.
- Belch JJ, Lowe GD, Pollock JG, Forbes CD, Prentice CR. Low dose heparin in the prevention of deep-vein thrombosis after aortic bifurcation graft surgery. *Thromb Haemost* 1980; **42**(5):1429–33.
- Bani-Hani MG, Al Khaffaf H, Titi MA, Jaradat I. Interventions for preventing venous thromboembolism following abdominal aortic surgery. *Cochrane Database Syst Rev* 2008; (1). CD005509.
- Saarinen J, Sisto T, Laurikka J, Salenius JP, Tarkka M. The incidence of postoperative deep vein thrombosis in vascular procedures. FINNVASC Study Group. *Vasa* 1995; **24**(2):126–9.
- Spebar MJ, Collins Jr GJ, Rich NM, Kang IY, Clagett GP, Salander JM. Perioperative heparin prophylaxis of deep venous thrombosis in patients with peripheral vascular disease. *Am J Surg* 1981; **142**(6):649–50.
- Killewich LA, Aswad MA, Sandager GP, Lilly MP, Flinn WR. A randomized, prospective trial of deep venous thrombosis prophylaxis in aortic surgery. *Arch Surg* 1997; **132**(5):499–504.
- Eagleton MJ, Grigoryants V, Peterson DA, Williams DM, Henke PK, Wakefield TW, et al. Endovascular treatment of abdominal aortic aneurysm is associated with a low incidence of deep venous thrombosis. *J Vasc Surg* 2002; **36**(5):912–6.
- Fletcher JP, Batiste P. Incidence of deep vein thrombosis following vascular surgery. *Int Angiol* 1997; **16**(1):65–8.
- Speziale F, Verardi S, Taurino M, Nicolini G, Rizzo L, Fiorani P, et al. Low molecular weight heparin prevention of post-operative deep vein thrombosis in vascular surgery. *Pharmatherapeutica* 1988; **5**(4):261–8.
- Angelides NS, Nicolaides AN, Fernandes J, Gordon-Smith I, Bowers R, Lewis JD. Deep venous thrombosis in patients having aorto-iliac reconstruction. *Br J Surg* 1977; **64**(7):517–8.
- Olin JW, Graor RA, O'Hara P, Young JR. The incidence of deep venous thrombosis in patients undergoing abdominal aortic aneurysm resection. *J Vasc Surg* 1993; **18**(6):1037–41.
- Philbrick JT, Becker DM. Calf deep venous thrombosis. A wolf in sheep's clothing? *Arch Intern Med* 1988; **148**(10):2131–8.
- Bauer G. A roentgenological and clinical study of the sequels of thrombosis. *Acta Chir Scand* 1942; **86**(Suppl. 74):1–126.
- Hull R, Hirsh J, Sackett DL, Taylor DW, Carter C, Turpie AG, et al. Replacement of venography in suspected venous thrombosis by impedance plethysmography and 125I-fibrinogen leg scanning: a less invasive approach. *Ann Intern Med* 1981; **94**(1):12–5.
- Moser KM, LeMoine JR. Is embolic risk conditioned by location of deep venous thrombosis? *Ann Intern Med* 1981; **94**(4 pt 1):439–44.
- Lotke PA, Ecker ML, Alavi A, Berkowitz H. Indications for the treatment of deep venous thrombosis following total knee replacement. *J Bone Joint Surg Am* 1984; **66**(2):202–8.
- Harjola P, Meurala H, Frick MH. Prevention of deep venous thrombosis and thrombo-embolism by dipyridamole and acetylsalicylic acid after reconstructive arterial surgery. *J Cardiovasc Surg (Torino)* 1980; **21**(4):451–4.
- Urbanyi B. Prophylaxis against thromboembolism in vascular surgery. In: Spillner GSPFHSV, editor. *A randomised clinical trial*. *Vasc Surg* 1982; **16**(4):253–9.
- Farkas JC, Chapuis C, Combe S, Silsiguen M, Marzelle J, Laurian C, et al. A randomised controlled trial of a low-molecular-weight heparin (Enoxaparin) to prevent deep-vein thrombosis in patients undergoing vascular surgery. *Eur J Vasc Surg* 1993; **7**(5):554–60.
- Gossetti B, Irace L, Gattuso R, Intrieri F, Aracu A, Ciocca F, et al. Prevention of deep venous thrombosis in vascular surgical procedures by LMW-heparin. *Int Angiol* 1988; **7**(3 Suppl):25–7.
- Hollyoak M, Woodruff P, Muller M, Daunt N, Weir P. Deep venous thrombosis in postoperative vascular surgical patients: a frequent finding without prophylaxis. *J Vasc Surg* 2001; **34**(4):656–60.
- Passman MA, Farber MA, Marston WA, Carlin RE, Owens LV, Burnham CB, et al. Prospective screening for postoperative deep venous thrombosis in patients undergoing infrainguinal revascularization. *J Vasc Surg* 2000; **32**(4):669–75.
- Morrison ND, Stephenson CB, Maclean D, Stanhope JM. Deep vein thrombosis after femoropopliteal bypass grafting with observations on the incidence of complications following the use of dextran 70. *N Z Med J* 1976; **84**(572):233–6.
- Burke B, Kumar R, Vickers V, Grant E, Scremin E. Deep vein thrombosis after lower limb amputation. *Am J Phys Med Rehabil* 2000; **79**(2):145–9.
- Yeager RA, Moneta GL, Edwards JM, Taylor Jr LM, McConnell DB, Porter JM. Deep vein thrombosis associated with lower extremity amputation. *J Vasc Surg* 1995; **22**(5):612–5.
- Barnes RW, Slaymaker EE. Postoperative deep vein thrombosis in the lower extremity amputee: a prospective study with Doppler ultrasound. *Ann Surg* 1976; **183**(4):429–32.
- Korwin SM, Callow AD, Rosenthal D, Ledig B, Deterling Jr RA, O'Donnell Jr TF. Prophylactic interruption of the inferior vena cava: immediate and long-term hemodynamic effects. *Arch Surg* 1979; **114**(9):1037–40.
- Reilly MK, McCabe CJ, Abbott WM, Brewster DC, Moncure AC, Reidy NC, et al. Deep venous thrombophlebitis following

- aortoiliac reconstructive surgery. *Arch Surg* 1982;117(9): 1210–1.
- 33 Byrne P, Provan JL, Ameli FM, Mackenzie RL, Jones DP. The role of intraoperative heparin in reducing the incidence of post-operative deep venous thrombosis. *Surg Gynecol Obstet* 1984; 158(5):419–22.
- 34 Satiani B, Kuhns M, Evans WE. Deep venous thrombosis following operations upon the abdominal aorta. *Surg Gynecol Obstet* 1980;151(2):241–5.
- 35 Thompson JF, Mullee MA, Bell PR, Campbell WB, Chant AD, Darke SG, et al. Intraoperative heparinisation, blood loss and myocardial infarction during aortic aneurysm surgery: a Joint Vascular Research Group study. *Eur J Vasc Endovasc Surg* 1996; 12(1):86–90.
- 36 Satiani B, Tetelman MR, Van Aman M, Evans WE. Deep vein thrombosis following aortic surgery: prospective evaluation of I125 fibrinogen and impedance plethysmography. *Am Surg* 1979; 45(8):507–11.