Impact of Post-EVAR Graft Limb Kinking in EVAR Limb Occlusion: Aetiology, Early Diagnosis, and Management

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WHAT THIS PAPER ADDS
The aim of this study was to review preventive and treatment management of one of the most common complications of endovascular aneurysm repair, which surprisingly, is little described in the literature. This study aimed to objectively identify high risk patients for kinking and make recommendations for intra-operative diagnosis and management, as well as management of limb occlusion.

Objective/background: Endograft limb occlusion is a potential complication of endovascular aneurysm repair (EVAR), being one of the major causes of secondary interventions and rehospitalisation. The aim of this review is to report on the impact of endograft kinking in endograft limb occlusion, as well as on risk factors, prevention, early diagnosis, and management.

Methods: A systematic review and meta-analysis was conducted according to the recommendations of the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analyses) statement.

Results: After a MEDLINE and Scopus search, 55 articles (27,509 patients) were included in the qualitative analysis and eight in the quantitative analysis. In this meta-analysis, 179 at risk limbs were treated by pre-emptive stenting, which significantly reduced the risk of limb occlusion: not pre-emptively stenting limbs at risk had a negative impact on graft limb patency (odds ratio 4.30, 95% confidence interval 1.45—12.78). Post-operatively, a kink was identified in 422 patients (1.5%), contributing to 42.8% of all limb occlusions. Relevant data support that completion angiography is an inadequate means of diagnosing high risk limbs, proposing cone beam computed tomography and intravascular ultrasound as adjuncts. The post-operative limb occlusion rate ranged from 0% to 10.6%, affecting 984 patients. Several risk factors for limb occlusion have been identified. Regarding treatment, most patients were submitted to femorofemoral bypass (52.3%) or to deployment of a bare metal stent, either alone or associated with catheter directed thrombolysis or mechanical thrombectomy (26.4%). Complications and outcome after re-intervention for limb occlusion are described infrequently in the literature, but single studies have reported on re-occlusion, major amputation, and limb occlusion related mortality rates.

Conclusion: Pre-EVAR planning should focus on identification of risk factors for kinking. Adjunctive stenting is an effective prophylaxis for selected high risk limbs, yet intra-operative identification remains problematic. Also, it is noteworthy that most limb occlusions occur in the first year after EVAR, emphasising the importance of careful early follow up of high risk patients.

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INTRODUCTION

Endovascular abdominal aneurysm repair (EVAR) has been accepted widely for minimally invasive management of infrarenal abdominal aortic aneurysms (AAAs).

A potentially catastrophic complication after EVAR is endograft limb occlusion, with incidence rates ranging from

0% to 7%. This issue has been addressed only minimally in the literature, but it may account for a third of post-EVAR re-interventions.[1—4]

Most endograft limb occlusions occur as a result of mechanical complications, especially endograft kinking. EVAR in patients with common iliac artery (CIA) anatomy outside the instructions for use (IFU) may be particularly at risk of endograft limb compression and/or kinking and thrombosis.[5] Development of kinks can be related to tortuosity in the iliac arteries, endograft twisting during deployment, compression by the organised thrombus within the excluded aneurysm, or decreased lateral wall force from increased forward blood flow. In addition, the nature of the graft fabric may contribute to thrombogenicity in the presence of a stenosis.[6]

Subjectivity in the threshold for intra-operative adjuncts and/or re-intervention for graft limb stenosis or kinking, lack of adherence to morphological guidelines specified in the manufacturer's IFU, and the degree of iliac morphological complexity are known to affect the success of EVAR.[4] Currently the criterion for intervention is predominantly the relief of symptoms.[4]

The aim of this paper is to report on the impact of endograft kinking in endograft limb occlusion, on risk factors, primary prevention, and management.

METHODS

Search strategy

A systematic review was conducted according to the recommendations of the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) statement. The literature search was last updated on March 2018; the full search strategy is in Appendix S1 (Supplementary Material).

Data extraction and assessment of study quality

Two reviewers (A.C., C.N.) were responsible for study selection, data extraction, and study quality assessment. Data collected and analysed included year of publication, type of study (classified as case control, observational retrospective, observational prospective, and randomised control trial [RCT]), type of endograft, number of patients in the cohort, rate of kinking/occlusion, time to occlusion (in months), follow up (in months), clinical presentation, identified risk factors, treatment, preventive primary stenting, and outcome.

The reviewers (A.C., C.N.) systematically assessed the methodology of non-randomised studies (cohort and case control studies) using the Newcastle—Ottawa scale.[7]

RCTs were analysed by the two independent reviewers using the Cochrane Assessment Tool.[8]

The methodological quality analysis is summarised in Table S1 (Supplementary Material).

Statistical analysis

WinPepi software was used to analyse the data. Two groups were defined depending on whether or not patients defined as being at high risk of kinking and occlusion were submitted to pre-emptive stenting. Treatment effect was expressed as the odds ratios (OR) with 95% confidence intervals (CIs).

Higgins and Thompson's Heterogeneity Index (H) measures of the impact of heterogeneity in a meta-analysis, independent of the number of studies and the treatment effect metric, with a H < 1.5 indicating low heterogeneity. I^2 is derived from H and describes the proportion of total variation in study estimates that is due to heterogeneity.

A random effects model was used for meta-analysis if I^2 exceeded 50%; otherwise, a fixed effect model was applied.[9]

RESULTS

Initially a total of 735 potentially relevant articles were selected. After reviewing the records at title or abstract level, 73 articles were read in full and 43 were judged eligible for inclusion. Backward citation led to the inclusion of 12 additional articles (Appendix S1). A total of 55 articles discussing 27,509 patients were included. These included four case control studies, 29 retrospective single centre studies, five prospective single centre studies, three RCTs, and the remaining 14 were retrospective multicentre studies. A total of 53 studies presented an estimated incidence of limb occlusion, ranging from 0% to 10.6%, affecting 984 patients. Mean follow up ranged from one to 72 months (Table S2; Supplementary Material) A graphic representation as a scatter plot of limb occlusion rate according to study and number is present in Fig. 1.

A kink was identified in 422 patients (1.5% of the total). Considering all graft limb occlusions, a graft limb kink was present in 42.8% of cases. Other identified risk factors for limb occlusion included significant calcification, iliac artery tortuosity, CIA stenosis, narrow distal aorta, small AAA (<59 mm), oversizing, body mass index > 30 kg/m^2, use of stent grafts outside the IFU, use of first generation stent grafts, placement of stent grafts in the external iliac artery (EIA), stent graft migration, artery dissection, learning curve, and use of adjunctive bare metal stents (BMS) (Table S3; Supplementary Material).

An additional 291 patients (356 limbs) were submitted to intra-procedural use of BMS to avoid kinking (Fig. 2). BMS included eight Zilver stents (Cook Medical, Bloomington, IN, USA), 21 Genesis stents (Cordis Endovascular, Warren, NJ, USA), 83 Wallstents (Boston Scientific, Maple Grove, MN, USA), and 37 SMART stents (Cordis Endovascular, Warren, NJ, USA). In one study, Wallstents and Palmaz Stents (Cordis Endovascular, Warren, NJ, USA) were used in a population of 64 patients, depending on whether kinking or external compression were identified, respectively. In the remainder, the type of BMS was unknown. In most cases, BMS were deployed landing in the EIA, but information on BMS diameter is scarce.

In eight studies, two groups were defined depending on whether or not graft limbs at risk of kinking/compression were submitted to pre-emptive BMS; afterwards, whether

pre-emptive BMS had an impact on the risk of graft limb thrombosis was analysed. In Fig. 2 individual ORs with 95% CIs are shown, as well as the overall OR with Forest plot.

During EVAR follow up data concerning the clinical presentation of graft limb kinking/occlusion were absent in the majority of studies (78.1%). For the remaining 213 patients (21.9%), most presented with intermittent claudication ($n = 115$; 53.9%), followed by acute leg ischaemia ($n = 69$; 32.4%), an incidental finding in asymptomatic patients ($n = 14$; 6.6%), critical leg ischaemia ($n = 14$; 6.5%), and asthenia in one patient.

Considering graft limb occlusion treatment, several treatment alternatives were considered (Table 1). Conservative management was an option in seven patients (2.3%), who were all clinically asymptomatic.

Surgical options included extra-anatomic bypasses, which were the most common option ($n = 156$; 52.3%). Other surgical options included surgical thrombectomy, aortoiliac bypass ($n = 2$) and there was also an anecdotal reference to endoprosthesis explantation in a patient with iliac limb thrombosis associated with a type I endoleak (Table S2).

Deployment of a BMS was a common option, either alone or after thrombectomy, catheter directed thrombolysis, or Angiojet (Boston Scientific) mechanical thrombectomy ($n = 78$; 26.4%).

Complications and outcome after re-intervention for limb occlusion are described infrequently in the literature. Ronsivalle et al. described re-occlusion after intervention in five patients (29%), major amputation in one (12%) patient, and occlusion related mortality in two (6%).[2] Maleux et al. described two cases of re-occlusion and one occlusion related mortality in the group of patients submitted to thrombolysis and BMS deployment ($n = 9$). One case of femorofemoral bypass infection was also described (from a total of 19 patients).[10]

Torsello et al. accounted for four cases of occlusion related deaths (40%), one of them due to femorofemoral bypass infection.[11] Maldonado et al. presented a series of 15 graft limb occlusions, with one case of peri-operative death (6.7%) and two cases of major amputation (13.3%).[12]
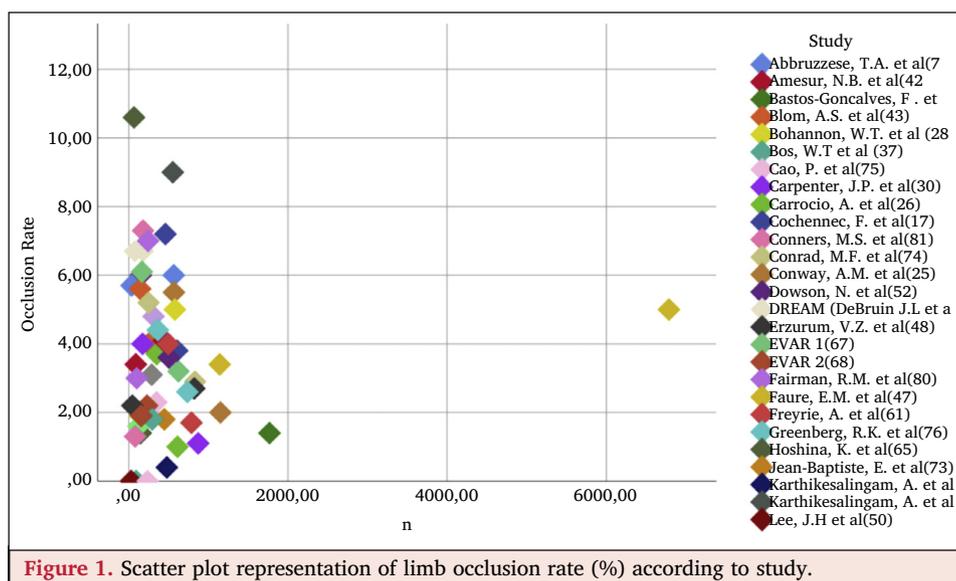
DISCUSSION

Kinking is a poorly understood phenomenon that has been defined as a doubling of peak systolic velocity (PSV) throughout the artery and confirmed with subsequent pressure measurement on angiography.[13] Stent graft kinking and infolding can result in flow restricting stenosis, graft thrombosis, and occlusion. Depending on their location and degree of angulation they can also result in type I endoleaks.[14]
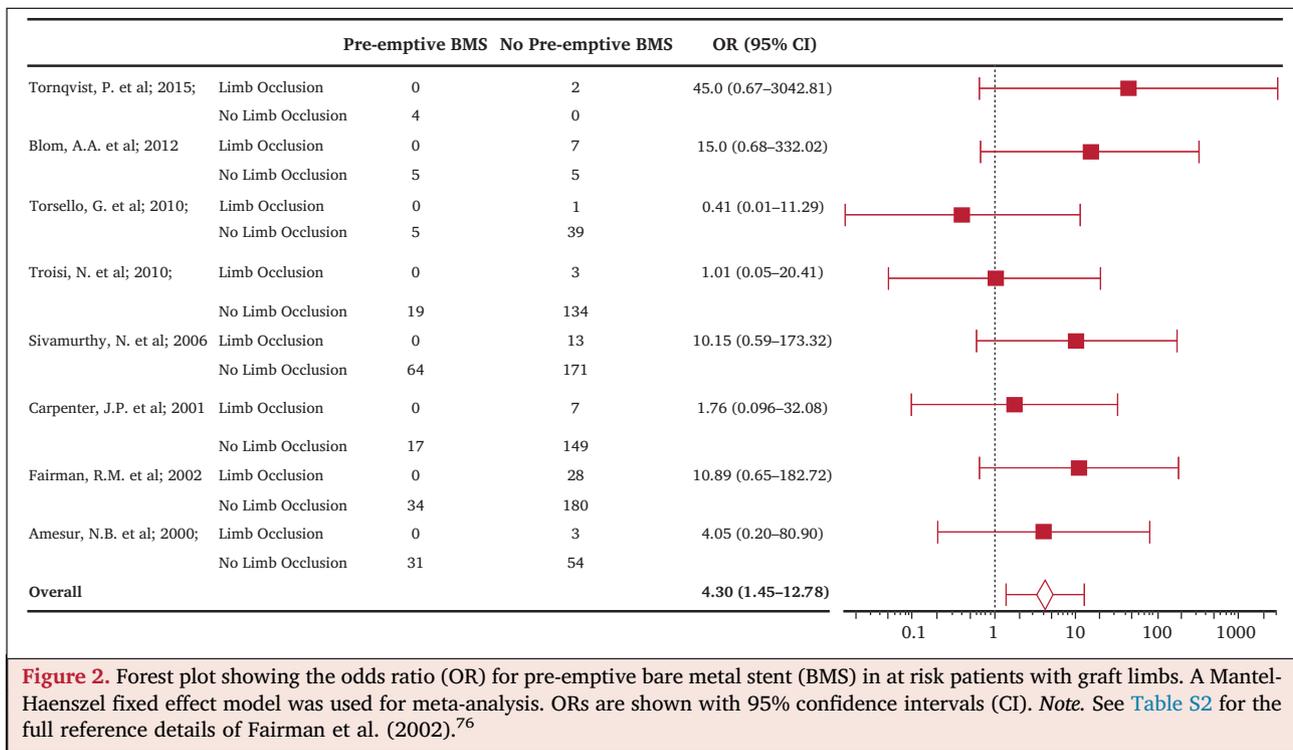
The most common causes of limb occlusion were the presence of a kinked graft limb or native arterial stenosis distal to the stent graft, resulting in outflow impairment and thrombosis.[14] According to Cochennec et al., kinking is the underlying cause in 56% of occluded limbs.[15] In this systematic review, a graft limb kink was present in 42.8% of all cases of graft limb occlusion.

Risk factors for kinking/limb occlusion

Historically, previously used unsupported endografts were associated with a higher incidence of limb occlusion than second generation supported endografts.[10] At four year follow up of a series of 291 patients treated with first generation stents, 56.7% revealed some degree of kinking of the endovascular aortic graft.[16]

Currently, with third generation endografts, the exact aetiology behind the kinking phenomenon is unknown; however, there are several theories. It has been postulated that stent graft migration from the distal or proximal anchoring sites is a possible cause for stent kinking, whereas other theories suggest that advancing the stent graft during deployment is followed by re-expansion to its original length over time, known as "the accordion effect." Changes in aneurysm morphology, resulting in longitudinal shrinkage, could also result in stent graft kinking. Early

Figure 1. Scatter plot representation of limb occlusion rate (%) according to study.

		Pre-emptive BMS	No Pre-emptive BMS	OR (95% CI)
Tornqvist, P. et al; 2015;	Limb Occlusion	0	2	45.0 (0.67–3042.81)
	No Limb Occlusion	4	0	
Blom, A.A. et al; 2012	Limb Occlusion	0	7	15.0 (0.68–332.02)
	No Limb Occlusion	5	5	
Torsello, G. et al; 2010;	Limb Occlusion	0	1	0.41 (0.01–11.29)
	No Limb Occlusion	5	39	
Troisi, N. et al; 2010;	Limb Occlusion	0	3	1.01 (0.05–20.41)
	No Limb Occlusion	19	134	
Sivamurthy, N. et al; 2006	Limb Occlusion	0	13	10.15 (0.59–173.32)
	No Limb Occlusion	64	171	
Carpenter, J.P. et al; 2001	Limb Occlusion	0	7	1.76 (0.096–32.08)
	No Limb Occlusion	17	149	
Fairman, R.M. et al; 2002	Limb Occlusion	0	28	10.89 (0.65–182.72)
	No Limb Occlusion	34	180	
Amesur, N.B. et al; 2000;	Limb Occlusion	0	3	4.05 (0.20–80.90)
	No Limb Occlusion	31	54	
Overall				**4.30 (1.45–12.78)**

Figure 2. Forest plot showing the odds ratio (OR) for pre-emptive bare metal stent (BMS) in at risk patients with graft limbs. A Mantel-Haenszel fixed effect model was used for meta-analysis. ORs are shown with 95% confidence intervals (CI). *Note.* See Table S2 for the full reference details of Fairman et al. (2002).[76]

kinks, diagnosed either intra-operatively or during the initial follow up, are probably due to tortuosity of the iliac vessels or obtuse angled aortic bifurcation.[14]

Another possible cause, described as "oxbow lake" deformity, occurs when a tortuous, elongated vascular segment is artificially straightened by an endograft. The lax arterial segment distal to the device folds itself, kinks and abuts the stent compromising the vascular lumen.[17]

Iliac artery tortuosity

Objective quantification of the iliac tortuosity using computed tomography angiography (CTA) can be achieved

Table 1. Data on treatment options for endograft limb occlusion.

Treatment	n (%)
Conservative[5,19,52]	7 (2.4)
Femorofemoral bypass[5,34,37,45–48]	156 (52.7)
Axillofemoral bypass[37,46]	11 (3.7)
Aorto-iliac bypass[12]	2 (0.7)
Endoprosthesis explantation (concomitant type 1 endoleak)[30]	1 (0.3)
Thrombectomy alone[19,37]	9 (3)
Thrombectomy + bare metal stent (BMS)[5,11,34,46,48,49]	53 (17.9)
BMS alone[5,50]	22 (7.4)
Additional stent graft deployment[19,51]	1 (0.3)
Thrombolysis alone[11]	3 (1)
Thrombolysis + BMS[52]	27 (9.1)
Bailout external iliac artery to IIA endograft technique[41]	1 (0.3)
Angiojet + BMS[12]	3 (1)
Total	296

Note. BMS = bare metal stent; IIA = internal iliac artery.

with different indices. The CIA index of tortuosity and double iliac sign have positive correlation with adverse graft limb events.[18]

Primary adjunctive stenting based solely on intra-operative imaging or in both pre- and intra-operative imaging was compared by Oshin et al.[19] Graft limb occlusion was eliminated in their series by the aggressive use of pre-emptive BMS in patients with iliac artery tortuosity.

In this review, iliac artery tortuosity was a significant cause of kinking and occlusion in nine different studies (Table S3).

Extension to the EIA

The risk of stent graft limb thrombosis is higher when deployment is extended into the EIA, owing to a greater likelihood of extrinsic compression or kinking, the use of smaller devices, and reduced runoff as a consequence of hypogastric artery occlusion and reliance on flow into the femoral vessels.[20,21]

This risk factor is one of the most scrutinised and referred to in the literature, with nine different studies stressing its importance (Table S3).

Conway et al. presented a series in which 31 limb occlusions occurred, 17 (3%) patients in the CIA group had an occluded graft limb vs. 14 (15%) patients in the EIA group ($p < .0001$; hazard ratio 0.1, 95% CI 0.03−0.20).[21] Carroccio et al. reported graft extension to the EIA in 96 of 702 limbs. Eight limbs (8.3%) thrombosed as opposed to 18 of 606 (2.9%) graft limbs deployed at the CIA ($p = .01$).[22]

However, in a case control study from Mantas et al.,[5] which analysed 439 patients, the stent graft was extended to the EIA in four cases (22.2%) vs. seven controls (13%),

with no significant difference in graft limb complications ($p = .45$). They concluded that extension of the endograft into the EIA did not prove to be a significant factor.

Narrow distal aorta

In the setting of a narrow distal aneurysmal lumen, usually due to high thrombus burden, endograft deployment may be complicated by folding and collapse of the aortic body or limbs, making catheterisation and ballooning impossible.[23]

Intuitively a narrow distal aorta should result in increased iliac limb occlusion; however, in practice this is reported infrequently.[23–26] According to O'Neill et al.,[25] only five case reports have been published in the literature that mention a narrow distal aorta as a cause for limb occlusion. In this review, only one further single case report referring to this risk factor was found,[23] but this is probably due to underreporting.

Intra-graft mural thrombus

Mestres et al. found that the presence of intra-graft mural thrombus significantly increased the risk of endograft occlusion,[27] while Wegener et al. found no association with graft occlusion, and the thrombotic deposits disappeared completely during follow up in 15% of cases without specific therapy.[28]

Stent oversizing

Excessive oversizing is a potentially avoidable cause of graft limb occlusion. When an endograft limb diameter hugely exceeds the native vessel diameter, a degree of graft infolding may be found, which is a potential cause of decreased flow.[22]

CIA endograft oversizing exceeding 15% has the same impact as iliac artery angulation $\geq 60°$ and iliac perimeter calcification $\geq 50\%$, and could equally result in limb occlusion.[29]

van Zeggeren et al. found an oversizing of 20–35% in 15% of graft limb occlusions and extreme oversizing ($>35\%$) in 20% of graft limb occlusions.[3]

Type of stent graft

There is a paucity of data comparing long term resistance to limb occlusion among different aortic endograft designs.[15,30] However, EUROSTAR Registry database analysis concluded that stent graft related factors have a significant and independent impact on the outcome. Specifically, kink resistance depends upon structural aspects of the device, and differences in performance can be expected among stent grafts, with third generation devices performing better.[30]

A single centre experience over a three year period of a helical nitinol/polyester iliac limb design (Aorfix; Lombard Medical Technologies, Didcot, UK) in EVAR with tortuous iliac arteries revealed a significant reduction in early iliac limb occlusion rates.[31]

Previously reported clinical experience with the Excluder device (W. L. Gore & Associates, Flagstaff, AZ, USA) had a 0% limb occlusion rate, which was particularly remarkable as the endograft was preselected for use in the most challenging iliac anatomy.[32]

Recently, to address the issue of narrow, calcified, and tortuous iliac arteries, Cook Medical developed a new generation of iliac limbs: Zenith Spiral Z. As opposed to older generation Zenith limbs, they are constructed of full thickness woven polyester fabric sewn into two self expanding stainless steel Cook-Z stents and a continuous nitinol spiral stent with braided polyester and monofilament polypropylene suture with a 14–16-Fr profile. A recent study analysed 50 EVAR cases performed with the Zenith LP main body in combination with Spiral-Z Iliac Legs and no limb occlusions were diagnosed at six month follow up, even in challenging iliac anatomies usually considered as contraindications to EVAR.[33]

Diagnosis

Completion digital subtraction angiography (CDSA) after supportive stiff wires have been removed should be performed to evaluate contrast progression and detect any subtle kinks or narrowing of the iliac limbs. However, as CDSA is a two dimensional representation of a three dimensional object, such images may be misleading, especially with tortuous anatomy. Oshin et al. described 11 occlusions in a group of patients submitted to selective ad hoc adjunctive stenting in limbs perceived to be at greatest risk of occlusion. The study concluded CDSA is an inadequate means of determining high risk limbs.[19]

In another study, stent graft compression and kink were found more often with cone beam computed tomography (CBCT) than with CDSA alone and could be corrected promptly. CDSA diagnosed two cases of compressions/kinks vs. six cases diagnosed with CBCT. Intra-operatively, four pre-emptive BMS were deployed. At one month follow up CTA, the remaining two cases of compressions/kinks diagnosed with CBCT were confirmed and subsequently treated. Indeed, CBCT seems superior to CDSA at diagnosing compressions/kinks intra-operatively.[34]

Pullback pressure measurements can help identify haemodynamically significant lesions, but they are relatively insensitive, even after flow through the femoral arteries has been restored.[35]

Implementation of routine intravascular ultrasound (IVUS) evaluation following EVAR can detect graft redundancy and resultant graft infolding, frequently undetected by CDSA.[36] A policy of routine IVUS use by Amesur et al. resulted in a paradigm shift.[36] IVUS was not available for the first 24 patients in the study and no pre-emptive Wallstents were placed. On follow up, three graft limb thromboses occurred 2–6 weeks post-procedure. After routine IVUS use, graft narrowing was observed in 41 limbs (27 patients), all successfully treated by placement of Wallstents with no graft limb thrombosis on follow up.[36]

However, additional IVUS requires extra time and additional expense, with unknown predictive value.[18,35]

Doppler ultrasound (DUS) imaging is being used increasingly as a standalone study to monitor EVAR patients

in a cost effective manner that avoids contrast agents and ionizing radiation. A large series of DUS EVAR surveillance identified PSV >300 cm/s within the stent graft and a PSV ratio >3.5 as predictors of occlusion (the first criteria with 100% sensitivity and 98% specificity) recommending referral of such patients for treatment.[37]

Another study identified a threshold of 2.5 fold increase in PSV as a criterion for haemodynamically significant stenosis/kinking.[4]

Regarding intra-operative and follow up diagnosis of graft limb kinking it is noteworthy that after EVAR, endograft limbs continue to move and re-model and it may take 24 h for the full extent of graft limb kinking to become apparent.[21] Also, most limb occlusions occur in the first year after EVAR, which emphasises the importance of careful follow up and patient information, especially during the first year (Table S2).[3]

Treatment

Pre-operative strategies to reduce the risk of iliac limb occlusion involve careful patient and device selection, with adherence to the manufacturer's IFU, and identification and treatment of adverse anatomical factors.[20]

Preventive treatment. Limb occlusion is a severe complication after EVAR, with substantial occlusion related morbidity and mortality. Therefore, it is of paramount importance to identify patients at risk of limb occlusion.[18] The most important feature of graft limb occlusion prevention is maintenance of a high index of suspicion.[38]

Regarding adjunctive selective primary stenting, in this meta-analysis a total of 179 limbs were submitted to intra-procedural stenting which significantly reduced the risk of limb occlusion (Fig. 2). No pre-emptive stenting of graft limbs at risk had a negative impact on graft limb thrombosis at follow up (OR 4.30, 95% CI 1.45−12.78).

Agreed indications for pre-emptive BMS use are excessive angulation, graft stenosis/kinking, overlap stenosis/kinking, and dissection or stenosis of peripheral vessel.[18,19]

Oshin et al., described a comparative analysis between selective ad hoc and aggressive adjunctive stenting revealing 11 occlusions in first group, in which five (1.7%) adjunctive stents had been deployed, but no occlusion in the latter group, which had received 33 (11.2%) stents ($p < .001$). The success of the stenting policy in this study supports the use of self expanding stents as an adjunct to the primary procedure.[19]

Sivamurthy et al. used BMS to treat angiographically documented kinking and external compression.[35] They also routinely inserted a Wallstent (Boston Scientific) in EIA implantation cases. In their cohort of 446 limbs, 85 were stented. No stented limbs thrombosed and no complications occurred as a result of stenting vs. 13 occlusions in the unstented group.

As effective as adjunctive stenting seems to be, it is not without risks. The friction between graft limb stents and the endograft fabric may lead to erosion of the fabric producing late endoleaks.[26] This complication was described for the first time in a case report of a major endoleak as a result of penetration of the graft material by nitinol struts.[39]

While BMS have been shown to reduce iliac limb occlusion rates, the use of more flexible devices, such as the Aorfix graft, in tortuous iliac anatomy can also substantially reduce the rate of early iliac limb occlusion following EVAR. A comparative analysis was performed between historical controls ($n = 129$) and patients treated after the adoption of a strategy of treating highly angulated iliac anatomy with the Aorfix (Lombard) stent graft or, alternatively, with Zenith (Cook) main body and Aorfix iliac limbs. Iliac limb occlusions were 6.2% with historical controls vs. 0% with the new strategy.[40]

Treatment of endograft limb occlusion. Patient condition, severity of ischaemia, and surgeon preference should all be taken into account when making a decision.[41] Endograft limb occlusion treatment reveals a myriad of treatment options, emphasizing the lack of evidence for a structured management approach.

Surgical options

Surgical thrombectomy is associated with concerns regarding the possibility of graft damage or dislodgment and endoleak. However, this argument has not been validated by a series in which no endoleak or graft dislodgement occurred after thrombectomy in modular graft designs.[42]

Earlier experience tended towards extra-anatomic bypass with five year patency rates >90%.[5,15] In this review, extra-anatomic bypass was the most common option ($n = 167$; 56%). Outcomes are seldom described, with descriptions of graft infection or major amputation being rare.

Endovascular options

Endovascular options include thrombus removal techniques (catheter directed thrombolysis and mechanical thrombectomy devices), as well as techniques for graft limb realignment (percutaneous balloon angioplasty and BMS/stent graft deployment), which can be used alone or in combination. Recent reports have encouraged an endovascular approach with or without thrombolysis.[5,24]

Thrombolysis

Thrombolysis has been shown to be an effective modality in restoring patency in thrombosed vascular grafts. The underlying limb stenosis can then be identified and treated by BMS placement. Although thrombolysis therapy is an attractive option, it has its drawbacks: it is time consuming, and may be complicated by leg emboli, haemorrhage, and endoleak de novo due to the lysis of the thrombus in the aneurysm sac.[15]

BMS

The choice of stent and deployment technique may have an important role in the durability of benefit for adjunctive stenting.[19] Published bench top mechanical studies are

mostly limited to small numbers of stent models, many of which are currently off market or have been replaced with newer generation devices.[43] Stents used in this review included Wallstent (Boston Scientific), SMART nitinol stent (Cordis Endovascular), Zilver (Cook Medical), and Luminnex (Bard, Murray Hill, NJ, USA). Unfortunately, there are no data in the literature on comparative studies between different stents deployed in this setting. With the exception of Wallstent (Boston Scientific), they were all nitinol self expanding BMS with variable mechanical characteristics.

Although deployment of the BMS usually centres on the focal narrowing within the iliac limb, this may actually create a further kink at the end of the stiff BMS within the stent graft limb and lead to future problems. Therefore, in tortuous iliac anatomy, the area of BMS relining should extend from proximal to the kink along the remainder of the iliac limb and into the EIA to allow a smooth transition and better conformability from a stiff iliac limb into native vessel.[20]

Outcome

Data on outcome are scarce in the reviewed literature; however, analysis of series that reported on complications and outcome reveal that graft limb occlusion may be associated with a dismal prognosis. Major amputation, re-occlusion, and occlusion related death are seldom described in the literature, with small series presenting anecdotally high rates.[2,10–12]

Risk of bias

Methodological quality assessment (Table S1) revealed that the most common bias in cohort studies was the absence of data on follow up or insufficient follow up for outcomes to occur. In RCTs the main limitation was incomplete outcome data, as all included RCTs were developed to study outcomes other than graft limb kinking and thrombosis.

CONCLUSIONS

Limb occlusion is a complication of EVAR and remains a major cause of secondary intervention and re-hospitalisation.

Graft limb kinking is seemingly one of the most common causes of such complications. Several risk factors for kinking have been addressed, including iliac artery tortuosity, stent graft deployment in the EIA, narrow distal aorta, mural thrombus, and type of stent graft.

A recent European Society of Vascular Surgery Guidelines update recommended that in patients treated for AAA with new onset or worsening lower limb ischaemia, immediate evaluation of graft related problems, such as limb kinking or occlusion, should be performed (class I, level C evidence). However, the guidelines lack recommendations for pre-emptive BMS deployment, diagnosis, and treatment of graft limb kinking and occlusion.[44]

In conclusion, preventive intra-operative BMS is a safe strategy and significantly reduces graft limb thrombosis in limbs at risk. However, early diagnosis is an issue, so the substantial occlusion related morbidity calls for strategies to identify patients at risk of limb occlusion following EVAR. Also, patients with multiple risk factors need closer follow up during the first post-EVAR year.

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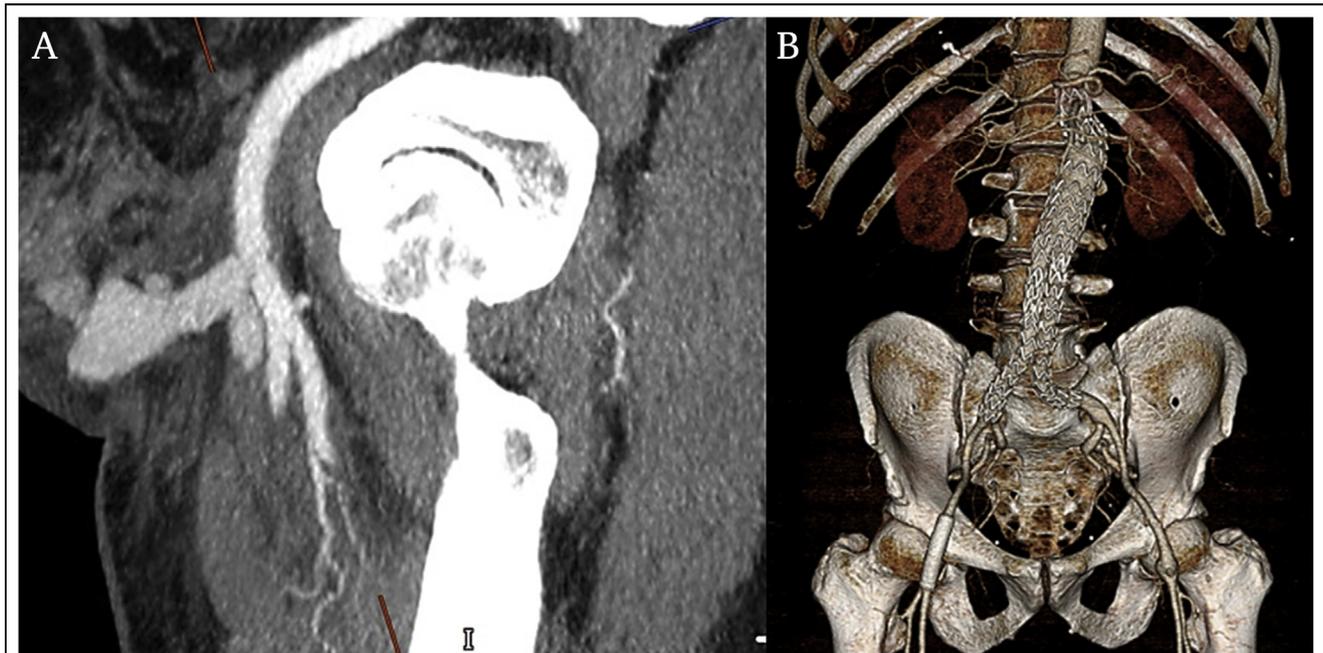
COUP D'OEIL

Retrograde Femoral Arterial Endoprosthesis Insertion for Access Site Haemorrhage After Percutaneous Endovascular Aneurysm Repair

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A 72 year old man developed common femoral artery haemorrhage on day 1 after emergency percutaneous endovascular repair of a 7.4 cm abdominal aortic aneurysm (A). He was of high anaesthetic risk due to concomitant biliary and chest sepsis. Deployment of a 10 × 50 mm Viabahn stent (B) (W.L. Gore & Associates, Flagstaff, AZ, USA) via percutaneous 10 F retrograde superficial femoral artery access under local anaesthetic achieved immediate haemostasis. Arterial puncture closure was via an 8 F Angio-Seal VIP (Terumo, Bagshot, UK). He was discharged on lifelong apixaban. Computed tomography scan at one month showed no bleeding, haematoma resolution, and good runoff from the stent (B).

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