Post-EVAR Graft Limb Kinking – Etiology, Impact as a Cause of Limb Occlusion and Management

A Systematic Review and Meta-Analysis

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Disclosure

Andreia P. Coelho

I have the following potential conflicts of interest to report:

☐ Consulting
☐ Employment in industry
☐ Stockholder of a healthcare company
☐ Owner of a healthcare company
☐ Other(s)

☒ I do not have any potential conflict of interest
INTRODUCTION

- **ENDOGRAFT LIMB OCCLUSION**
  - One of the major causes of secondary interventions and rehospitalisation after EVAR.
  - Surprisingly *data in the literature remains sparse*.

- **Limb Occlusion at 12 Months: 1-8% (IDE trials)**
  - Despite the fact that these rates far and away surpassed that of type I endoleaks in these same trials, the importance of improving limb patency has received comparatively little focus.
INTRODUCTION

**KINK DEFINITION?**

“A doubling of peak systolic velocity (PSV) throughout the limb, confirmed with subsequent pressure measurement on angiography”


“The most common causes for limb occlusion are the presence of a kink within the limb graft or arterial stenotic disease distal to the stent graft, resulting in outflow impairment and thrombosis”
INTRODUCTION
INTRODUCTION

- **No** published RCT’s;
- **No** published evidence regarding the ideal management strategy;
- **No** guidelines;
- **No** expert consensus;
The aim of this review is to report on the impact of endograft kinking in endograft limb occlusion as well as risk factors, primary prevention and management of endograft kinking and occlusion.
A systematic review and meta-analysis was conducted according to the recommendations of the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) statement.

Using the MEDLINE and SCOPUS databases and a literature search was performed with the following Query:

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Methods

Potentially relevant records identified by database searching;
Medline Records Screened n = 341
Scopus Records Screened n = 459

Excluded duplicates n = 735
Excluded by title/abstract review n = 292

Full-text articles reviewed for eligibility n = 73

Excluded by full text review n = 9
Backword citation n = 20

Studies included in qualitative synthesis n = 55
(27,509 patients)

Studies included in quantitative synthesis n = 8
(291 patients)

Record Search and Article Eligibility Evaluation:

Eligibility Criteria:
- Any publication reporting on endograft limb kinking or occlusion after EVAR.

Exclusion Criteria:
- Articles published before 2000
- Language other than Portuguese or English
- Not human research
RESULTS

Limb Occlusion Rate Range: 0-10.6% (n=984); Follow-up: 1-72 months;
## RESULTS

### LIMB GRAFT OCCLUSION ETIOLOGY

<table>
<thead>
<tr>
<th>RISK FACTOR CATEGORY</th>
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<td><strong>PROCEDURE RELATED RISK FACTORS</strong></td>
<td>Stentgraft outside IFU</td>
<td>Moulakakis, K.G. et al; van Zeggeren, et al; Abbruzzese et al;</td>
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- Preoperative CTA assessment of CIA tortuosity – 33 limbs were determined high risk and were stented

  - Limb occlusion was eliminated in their series of patients.

Van Zeggeren et al found an oversizing of 20-35% in 15% of limb graft occlusions and extreme oversizing >35% in 20% of limb graft occlusions.

**TECHNICAL ERROR** - Potentially avoidable cause for graft occlusion

### RESULTS

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- 17 (3%) patients in the CIA group had an occluded limb (1% of 1203 limbs at risk) vs. 14 (15%) patients in the EIA group (12% of 116 limbs at risk); p<0.0001, HR 0.1, 95% CI 0.03 to 0.20;

RESULTS

PREVENTIVE BMS TO AVOID KINKING

- 291 patients (356 limbs) were submitted to preemptive BMS
- Selective BMS?
RESULTS

PREVENTIVE BMS TO AVOID KINKING

Cohort of 446 limbs, 85 were stented; No stented limbs thrombosed and no complications occurred as a result of stenting compared to 13 occlusions in the unstented group.
Amesur et al. also virtually eliminated graft limb occlusion by selective preventive stenting of high risk patients.
PREVENTIVE BMS TO AVOID KINKING

Adjunctive stenting seems to be effective prophylaxis for selected high-risk limbs, yet their identification remains problematic.
NO pre-emptive stenting of limb grafts at risk had a negative impact in limb graft occlusion on follow-up;

- **OR 4.30** (c.i. 95% 1.45-12.78)
- Heterogeneity index (Higgins and Thompson’s): 1.0 (c.i. 95% 1.0-1.8).
CLINICAL IMPORTANCE OF KINKS?

In this study, kinking contributed to **42.8% of the total of limb occlusions.**

“kinking is the underlying cause in 56% of occluded limbs”
WHY DO 3\textsuperscript{RD} GENERATION STENTGRAFTS KINK?

- **The “ACCORDION EFFECT”**
  - Advancing the stentgraft during deployment is followed by re-expansion to its original length over time

- **CHANGES IN ANEURYSM MORPHOLOGY**
  - Longitudinal shrinkage

- **TORTUOSITY OF THE ILIAC VESSELS** or blunt-angled aortic bifurcation
  - EARLY KINKS
ARE ALL 3\textsuperscript{RD} GENERATION STENTGRAFTS ALIKE?

**Excluder Device** (W. L. Gore & Associates, Flagstaff, Ariz)

- Thinner and more flexible limbs
- 0\% limb occlusion\(^1\) – “which is especially remarkable because the graft was used in the most difficult iliac anatomy”


“Kink resistance depends upon structural aspects of a device, and differences in performance can be expected among stent-grafts.”
Results

Preventing Limb Occlusion

- Use of **MORE FLEXIBLE DEVICES** in tortuous iliac anatomy can also substantially reduce the rate of early iliac limb occlusion following EVAR.
  - **Excluder Device** (W. L. Gore & Associates, Flagstaff, Ariz)
  - **Aorfix** (Lombard Medical)

**Adjunctive Primary Stenting**

- Adjunctive selective primary stenting is **not** documented in RCTs
- **Accepted indications – LIMBS AT RISK:**
  - Stent-graft extension to the EIA; Excessive angulation; Graft stenosis/kinking; Overlap stenosis/kinking and dissection; Stenosis of peripheral vessel;
Most patients present with **Intermittent Claudication** or **Acute Limb Ischemia**
# RESULTS

## LIMB GRAFT OCCLUSION DIAGNOSIS

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<tr>
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<th>FOLLOW-UP DIAGNOSIS OF KINK/OCCLUSION</th>
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<tr>
<td>CA</td>
<td>US DOPPLER</td>
</tr>
<tr>
<td>▪ Performed after removal of stiff guidewires</td>
<td>▪ PSV &gt; 300 cm/s and PSV ratios &gt;3.5 are predictors for occlusion (100% sensitivity and 98% specificity)</td>
</tr>
<tr>
<td>CBCT</td>
<td>CTA</td>
</tr>
<tr>
<td>▪ Increased susceptibility and specificity compared to CA</td>
<td>▪ GOLD STANDARD</td>
</tr>
<tr>
<td>IVUS</td>
<td>PRESSURE MEASUREMENT</td>
</tr>
<tr>
<td>▪ Detects infolding and graft redundancy undetected in CA</td>
<td>▪ Identify hemodinamically significant lesions</td>
</tr>
<tr>
<td>▪ Requires extra-time and additional expense</td>
<td>▪ Insensitive test, even after arterial flow has been restored in the femoral arteries</td>
</tr>
<tr>
<td>▪ Unknown predictive value</td>
<td>US DOPPLER</td>
</tr>
</tbody>
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**GOLD STANDARD**
INTRAOPERATIVE DIAGNOSIS

- Completion Digital Subtraction Angiography (CA) after supportive stiff wires have been removed should be performed
  - *Oshin et al:* CA is an inadequate means of determining high-risk limbs.\(^1\)

---

Intra-operative Cone Beam Computed Tomography (CBCT) can increase sensitivity for kink diagnosis

Routine intravascular ultrasound (IVUS) – Controversial

- *Amesur et al: IVUS* led to the detection of graft infolding that was not noted on angiography. This prompted prophylactic stent placement, which resulted in the **virtual elimination of graft limb occlusion**.
- Extra time and additional expense, with unknown predictive value.
Despite screening with completion angiography immediately after stent-graft deployment and routine removal of stiff wires, **ENDOGRAFT LIMBS CONTINUE TO MOVE AND RE-MODEL AFTER EVAR**;

- It may take 24 hours for the full extent of kinking of the limb to become apparent.

It is noteworthy that **MOST LIMP OCCLUSIONS OCCUR IN THE FIRST YEAR AFTER EVAR** which emphasizes the importance of careful follow-up and patient information, especially during the first year after EVAR.
Treatment decision should depend on:

- Patients´ clinical status
- Severity of ischemia
- Anatomical criteria
- Surgeons´ preference
### RESULTS

#### LIMB GRAFT OCCLUSION TREATMENT

<table>
<thead>
<tr>
<th>TREATMENT</th>
<th>N(%)</th>
</tr>
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<tr>
<td>CONSERVATIVE</td>
<td>7 (2.3%)</td>
</tr>
<tr>
<td>FEMORO-FEMORAL BYPASS</td>
<td>156 (52.3%)</td>
</tr>
<tr>
<td>AXILLO-FEMORAL BYPASS</td>
<td>11 (3.7%)</td>
</tr>
<tr>
<td>AORTO-ILIAC BYPASS</td>
<td>2 (0.6%)</td>
</tr>
<tr>
<td>ENDOPROSTHESIS EXPLANTATION (CONCOMITANT TYPE 1 ENDOLEAK)</td>
<td>1 (0.3%)</td>
</tr>
<tr>
<td>THROMBECTOMY ALONE</td>
<td>9 (3%)</td>
</tr>
<tr>
<td>THROMBECTOMY + BMS</td>
<td>53 (17.8%)</td>
</tr>
<tr>
<td>BMS ALONE</td>
<td>24 (8.1%)</td>
</tr>
<tr>
<td>ADDITIONAL STENTGRAFT DEPLOYMENT</td>
<td>1 (0.3%)</td>
</tr>
<tr>
<td>THROMBOLYSIS ALONE</td>
<td>3 (1%)</td>
</tr>
<tr>
<td>THROMBOLYSIS + BMS</td>
<td>27 (9%)</td>
</tr>
<tr>
<td>BAILOUT EIA TO IIA ENDOGRAFT TECHNIQUE</td>
<td>1 (0.3%)</td>
</tr>
<tr>
<td>ANGIOJET + BMS</td>
<td>3 (1%)</td>
</tr>
<tr>
<td>TOTAL</td>
<td>298</td>
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</table>

- **BMS** (either **alone** or after **CDT** or **Mechanical Thrombectomy**)  
  - n=80 (26.8%)
RESULTS

SURGICAL OPTIONS

- **Extra-anatomic bypass** present 5-year patency rates above 90%.
  - In this review, extra-anatomic bypass was the most common option (n=167; 56%)
RESULTS

WHICH STENT?

- **No data** on the literature on comparative studies between different stents deployed in this setting

- **Primary BMS:**
  - **Self-Expanding Nitinol Stents**
    - SMART stent (n=37)
    - Genesis stent (Cordis Endovascular, Warren, NJ) (n=21)
    - Zilver stent (Cook Medical, Bloomington, Indiana) (n=8)
  - **Wallstent (Boston Scientific, Maple Grove, MN) (n=83)**
WHICH STENT?

- **No data** on the literature on comparative studies between different stents deployed in this setting.
- BMS deployment usually centers on the focal narrowing within the iliac limb;
  - Further kink at the end of the stiff BMS within the stent-graft limb and future problems.
  - 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.
Complications and outcome after re-intervention for limb occlusion are seldom described in the included literature.

**AFTER INTERVENTION:**
- Re-occlusion n=5 (29%)
- Major amputation n=1 (6%)
- Occlusion related mortality n=2 (12%)

**THROMBOLYSIS + BMS GROUP**
- Re-occlusions n=2 (22.2%)
- Occlusion related mortality n=1 (11.1%)

**FEMORO-FEMORAL BYPASS GROUP**
- 1 Graft infection (5.3%)
- Occlusion related Mortality n=4 (40%)
STUDY LIMITATIONS

- Methodological Quality Assessment:
  - In Cohort/Case Control Studies the main bias was the absence of data on follow-up or insufficient follow-up for outcomes to occur (New-Castle Ottawa Scale)
  - In RCT the main limitation was incomplete outcome data, as all included RCT were developed to study outcomes other than limb graft kinking and thrombosis (Cochrane Tool for Methodologic Quality Assessment)

- Heterogeneous Studies in Study Design

- Varying Imagiology Post-EVAR Follow-up Protocols

- Underreporting with PUBLICATION BIAS
CONCLUSIONS

1. Limb graft occlusion is one of the major causes for secondary interventions after EVAR

2. Limb kinking is the major cause for limb graft occlusion

3. Preventive intraoperative BMS is a safe strategy and **significantly reduces limb graft thrombosis** in limbs at risk
   
   a. **How can we diagnose a limb at risk?** CA is an ineffective strategy for kink diagnosis. CBCT? IVUS?

4. High risk patients should be followed-up closely in the 1st year post-EVAR

Data on preventive treatment of limb graft kinking and guidelines on treatment for limb graft occlusion are currently lacking. Thus, the substantial occlusion-related morbidity and mortality calls for strategies to **identify patients at risk of limb occlusion**.
Post-EVAR Graft Limb Kinking – Etiology, Impact as a Cause of Limb Occlusion and Management - A Systematic Review and Meta-Analysis

THANK YOU FOR THE ATTENTION
Post-EVAR Graft Limb Kinking – Etiology, Impact as a Cause of Limb Occlusion and Management

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