Non-Anastomotic Complete ePTFE Axillobifemoral Bypass Disruption and Thrombosis Following Shoulder Dislocation

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INTRODUCTION

Expanded polytetrafluoroethylene (ePTFE) has been marketed since the 1970s. It has been used increasingly as a small artery substitute, including for extra-anatomic bypasses. The expanded polymer is manufactured by means of a heating, stretching, and extruding process that produces a microporous material extremely resistant to traction phenomena. Moreover, these grafts are available with external ring support to increase their resistance to kinking and external compression, especially in the setting of an extra-anatomic bypasses.

Anastomotic disruption of ePTFE axillobifemoral bypass is a well known complication, with an incidence of up to 5%, but non-anastomotic rupture is considered an exceedingly rare complication. This is the report of a non-anastomotic ePTFE axillobifemoral bypass complete transverse disruption and analysis of the retrieved specimen.

REPORT

A 70 year old man presented with left shoulder dislocation associated with a haematoma. The dislocation was reduced immediately. Two weeks later, the patient presented with Rutherford 2b bilateral lower limb ischaemia related to the thrombosis of an ePTFE axillobifemoral bypass. The graft had been implanted five years previously for treatment of an aorto-enteric fistula secondary to an infected aortobifemoral bypass. The initial surgical plan was thrombectomy and graft revision, but a pulsatile haematoma was noted at the upper part of the hemithorax, and complete disruption of the ePTFE graft was found. The segment of the graft containing the lesion was removed and a small interposition graft between the non-disrupted portions of the axillobifemoral bypass was performed following graft thrombectomy. The patient recovered uneventfully.

The retrieved specimen was sent to GEPROVAS (European Research Group on Grafts used in Vascular Surgery) as part of a European retrieval explant programme and was submitted to a standardised protocol for evaluation. Macroscopic evaluation showed that the sample consisted of two prosthetic segments included in a pseudoaneurysm. The internal side of the graft was free from thrombus; the inner and outer walls were encapsulated in fibrous tissues (Fig. 1). Histological analysis (haematoxylin-eosin staining) showed complete disruption of the graft wall, the intimal surface of which demonstrated incomplete pseudo-intima formation, and the outside areas of which showing foreign body reactions with giant cells and collagenous fibrosis extending into the graft. Tissue transmural ingrowth was detected. The external capsule was made up of collagen...
fibre growth in the outer layer and massive infiltration by foam cells in the inner layer (Fig. 2).

The explant was then cleaned using a 0.26 % aqueous solution of sodium hypochlorite. Images of the samples were captured after each change of the cleaning solution to exclude damage associated with the cleaning process. The explant was then rinsed with highly diluted solution of hydrogen peroxide to stop all reactions. After the cleaning process, the exact correspondence of both fragments was found (Fig. 3). Macroscopic evaluation after cleaning identified an ePTFE Gore-Tex* (WL Gore, Flagstaff, AZ, USA) standard wall, 8 mm diameter graft. The rupture occurred at the level of a ringed external support. Ongoing tears on the posterior wall of the graft at the level of the external support were identified. Pictures of all points of interest were captured with a Keyence VHX-600 digital microscope demonstrating a partial rupture at the level of the external support and a partial wrapping detachment at the edge of the transverse rupture (Fig. 4).

DISCUSSION

This is the description of a case of a non-anastomotic rupture of an axillofemoral bypass. The most serious complication associated with the axillofemoral bypass procedure is axillary pullout syndrome, which is a disruption of the proximal axillary artery anastomosis resulting in a pseudoaneurysm. This disruption can occur as the result of undue stress on the proximal anastomosis during full abduction of the arm if the graft is placed in too lateral a position beyond the pectoris minor tendon. Consequently, it is recommended to perform a proximal “cobra head” anastomosis through the subpectoralis minor route in the first or second part of the axillary artery to allow a full range of arm movement without causing tension at the anastomosis.2
The present case differs from other cases of axillary anastomotic disruption, because disruption occurred in a non-anastomotic situation, which is an extremely rare complication. Only few cases of non-anastomotic disruption have been reported in the literature (Table 1, Supplementary data). The most frequently reported cause of disruption of an ePTFE axillofemoral bypass graft at a non-anastomotic site is external force, such as that accompanying trauma. In this report, the patient presented with shoulder dislocation two weeks earlier, but the analysis of the explanted graft revealed that the rupture occurred at the level of an external ring. One might assume that the external ring caused repeated microtrauma, exacerbated by the distension of the graft during the systole and the movement of the rib cage, resulting in weakening and finally rupture of the ePTFE graft.

Only five cases of atraumatic ePTFE non-anastomotic ruptures have been reported.1–7 In such cases, tensile strength, infection, or damage to the material (manufacturing process, traumatic handling, or clamp applications) might be responsible. Akiyama et al. described a case of pseudoaneurysm with disruption of a ringed ePTFE axillofemoral bypass graft that resulted in graft thrombosis.3 The complication was found to have been caused by a technical error because the graft was so short that it deformed the proximal Anastomosis after being tunnelled subcutaneously on the pectoralis major muscle. The graft was therefore placed under excessive longitudinal tension which resulted in its disruption and pseudo-aneurysm formation. Consequently, it seems mandatory to tunnel the graft in the right position and with the right tension. Shibutani et al. reported a case of pseudoaneurysm with disruption of a ringed ePTFE axillofemoral bypass.4 Histological analysis revealed a torn graft edge, consistent with a rupture caused by excessive force, but scanning electron microscopy showed that the internal structure of the prosthesis was intact. The cause of rupture thus remained unknown. Lotun et al. reported two lesions localised within

| Author         | Year | Graft                      | Trauma | Aetiology                   | Presentation | Delay (months) | Material | Brand of graft | External support |
|----------------|------|----------------------------|--------|------------------------------|--------------|---------------|----------|----------------|-----------------|
| Orringer       | 1972 | Left axillofemoral bypass  | Yes    | Fall                         | Pseudoaneurysm | MD            | ePTFE    | MD Gore        | no              |
| Nunn           | 1972 | Left axillofemoral bypass  | Yes    | Fall                         | Pseudoaneurysm | MD            | MD       | MD             | MD              |
| Buche          | 1992 | Left axillofemoral bypass  | Yes    | Fall                         | Pseudoaneurysm | 10 mo         | ePTFE    | WL Gore        | no              |
| Piazza         | 1993 | Axillobifemoral bypass     | Yes    | Goalkeeper in a soccer game  | Pseudoaneurysm | 1 y        | ePTFE    | WL Gore        | yes             |
| Onoe           | 1994 | Left axillofemoral bypass  | Yes    | MD                           | Pseudoaneurysm | 5 y         | ePTFE    | MD             | yes             |
| Akiyama        | 1996 | Axillobifemoral bypass     | No     | Inappropriate tunnel          | Pseudoaneurysm | 3 mo         | ePTFE    | WL Gore        | yes             |
| Krüger         | 1999 | Axillobifemoral bypass     | Yes    | Car accident                 | Pseudoaneurysm | 3 y         | ePTFE    | MD             | yes             |
| Oz             | 2002 | Left axillofemoral bypass  | No     | Unknown                      | Aneurysm     | 3 y         | ePTFE    | MD             | yes             |
| Lotun          | 2006 | Axillobifemoral bypass     | No     | External compression         | Seroma       | 14 y        | ePTFE    | MD             | yes             |
| Grochow        | 2008 | Axillobifemoral bypass     | Yes    | Chronic abrasion in a wheelchair | Pseudoaneurysm | 10 y        | ePTFE    | MD             | yes             |
| Kitowski       | 2010 | Axillobifemoral bypass     | Yes    | Fall                         | Pseudoaneurysm | 6 y        | ePTFE    | MD             | yes             |
| Shibutani      | 2012 | Right axillofemoral bypass | No     | Unknown                      | Pseudoaneurysm | 6 y        | ePTFE    | WL Gore        | yes             |
| Mousa          | 2013 | Left axillofemoral bypass  | Yes    | Fall                         | Pseudoaneurysm | 10 y       | ePTFE    | MD             | yes             |
| Barth          | 2016 | Right axillofemoral bypass | Yes    | Fall                         | Pseudoaneurysm | 2 y        | ePTFE    | MD             | no              |
| Bensaid        | 2017 | Right axillofemoral bypass | Yes    | Car accident                 | Pseudoaneurysm | 2 mo       | ePTFE    | MD             | yes             |
| Valverde       | 2017 | Left axillofemoral bypass  | Yes    | Fall                         | Pseudoaneurysm | 2 y        | ePTFE    | MD             | yes             |
| Kennedy        | 2019 | Right axillofemoral bypass | No     | Unknown                      | Pseudoaneurysm | 1 mo       | ePTFE    | Imbra          | yes             |

ePTFE = expanded polytetrafluoroethylene; MD = missing data.

* Reference details for cases listed in Table 1 are available as Supplementary data.
the wall of a ringed ePTFE axillofemoral bypass graft. The authors assumed that the pathophysiological process was similar to seroma formation. This may have occurred in a region of the graft which may not have been adequately supported and was therefore considered to be vulnerable. As removal of the rings may disrupt the external covering of the graft, it seems advisable to remove as few reinforcement rings as possible. Oz et al. reported a true aneurysm of an axillofemoral graft without any trauma history. Resection of the aneurysmal segment was planned, but the patient refused surgery which is why neither histopathological nor physicochemical analysis of the aneurysmal segment of the graft could be performed. Kennedy et al. reported complete rupture of a ringed ePTFE axillofemoral bypass graft, with both ends separated by approximately 6 cm. The analysis based on image review alone suggested no manufacturing defect as such, but the graft could not be physically tested because of concerns over pathogen contamination.

Non-anastomotic disruption of a ringed ePTFE graft has also been described in an above knee femoropopliteal bypass. The rupture occurred within the straight femoral part of the graft seven years after implantation without history of trauma. Two episodes of acute occlusion had been resolved previously by thrombo-embolectomy. The whole bypass showed macro- and microscopically visible deterioration of the wall with widening of micropores, compressed fibrils, and complete disruption. The deterioration mechanism might be the same as observed with axillofemoral bypasses: the external rings caused repeated microtrauma, exacerbated by the distension of the graft during systole and disturbances in the knee joint area, resulting in a weakening and finally rupture of the ePTFE graft. An association with mechanical stress might also be discussed in this case as two thrombo-embolectomy manoeuvres were performed four years after implantation. It seems unlikely that damage to the wall during these manoeuvres would lead to graft disruption three years later, but mechanical stress to the graft during the period of thrombosis distal to the knee joint might have accelerated the degeneration of the wall by superimposed reflected pulsewaves.

In conclusion, there is a risk of non-anastomotic disruption of ePTFE grafts; however, mechanisms of failure remain hypothetical. Tunnelling the graft into the right position without excessive tension or kinking, and removing as few rings as possible should decrease the risk of disruption. Complete analysis of failure mechanisms, even from an isolated report, is therefore mandatory. Even with a small amount of material, a standardised protocol of analysis including clinical data collection, pre-operative imaging, meticulous macroscopic examination of the ruptured graft, cleaning with dedicated processes followed by high magnification microscopy and scanning electron microscopy can help in determining the rupture profile, while in vitro analysis might be helpful to evaluate the mechanical behaviour of the grafts through longitudinal tensile stress, circumferential tensile stress, and burst strength.

CONFLICT OF INTEREST
None.

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APPENDIX A. SUPPLEMENTARY DATA
Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejvssr.2019.06.004.

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