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Standardized Four-Fenestration Physician-Modified Endograft Using a Low Profile Platform for Urgent Complex Abdominal Aortic Aneurysms: A How We Do It Report

Luiz Felippe Milazzo*, Filippo Gorgatti, Francesco Zaraca, Marco Damiano Pipitone, Mistral Klend Sacha Njila, Giovanni Zambello, Reinhold Perkmann and Giovanni Coppi

Vascular and Thoracic Department, Central Hospital Bolzano, Italy

***Corresponding author:** Luiz Felippe Milazzo, MD, Vascular and Thoracic Department, Central Hospital Bolzano Bolzano, South Tyrol, Italy, Tel: 393475833335

Abstract

Objective: To describe a structured and reproducible technique for the creation and implantation of a four-fenestrated physician-modified endograft (PMEG) using the Terumo Aortic Treo Treo abdominal stent graft system in patients with complex abdominal aortic aneurysms (AAAs) requiring urgent repair.

Methods: A standardized protocol was developed including predefined anatomical selection criteria, centerline-based measurement methodology, and a consistent graft modification technique. Fenestration planning was performed using a graph-based template transferred onto a sterilized transparent polybond peel pouch to guide accurate positioning. The modification process and implantation strategy are described step-by-step. The technique is illustrated in a patient with a symptomatic AAA and prior Endovascular Aortic Repair (EVAR) complicated by a type IA endoleak requiring incorporation of four visceral vessels.

Results: Graft modification was completed in 90 minutes. Endovascular repair was successfully performed with incorporation of the celiac trunk, superior mesenteric artery, and bilateral renal arteries. There were no intraoperative complications. The patient was discharged on postoperative day 6. At 30 days, no major adverse events or reinterventions were observed. Computed tomography angiography at 3 months demonstrated exclusion of the aneurysm sac, absence of type I or III endoleak, and preserved patency of all target vessels.

Conclusions: This report describes a novel structured approach to PMEG creation using the Terumo Aortic Treo platform in an urgent setting.

The technique appears technically feasible and may facilitate procedural planning and execution. Further evaluation in larger series with longer follow-up is required to assess durability and reproducibility.

Keywords: Aorta; Abdominal aortic aneurysm; Endograft; Physician-modified endograft; FEVAR; Urgent repair

Introduction

Endovascular repair of complex Abdominal Aortic Aneurysms (AAAs), including short-neck, juxtarenal, and pararenal anatomies, remains technically challenging due to inadequate proximal sealing zones. Fenestrated and branched endografts have demonstrated favorable outcomes **[1];** however, custom-made devices are limited by manufacturing delays, restricting their use in urgent or symptomatic cases **[2,3].** Alternative strategies such as parallel grafting (chimney or periscope techniques) offer immediate availability but may be associated with increased risk of gutter-related endoleaks, particularly when multiple target vessels are incorporated. Off-the-shelf branched devices provide another option, although their applicability may be limited by anatomical constraints and the need for extended aortic coverage. Physician-Modified Endografts (PMEGs) enable intraoperative customization of commercially available devices and represent a potential solution in urgent settings **[2-5].** However, significant variability exists in patient selection, planning strategies, and modification techniques, which limits reproducibility and comparison across studies **[6,7].** The purpose of this report is to describe a structured and standardized approach to the creation and implantation of a four-fenestrated PMEG using the Terumo Aortic Treo platform, with emphasis on anatomical selection, measurement methodology, and graft modification.

How We Do It

Anatomical feasibility

This technique is applied in patients with complex AAAs requiring urgent repair, including symptomatic aneurysms, rapidly expanding aneurysms, or large aneurysms (>7 cm). Additional indications include type IA endoleak after prior EVAR **[8]**.

Patients with hemodynamic instability or rupture requiring immediate intervention without time for graft modification are not considered candidates.

Anatomical criteria include:

- Proximal sealing zone ≥15 mm above the mid-celiac artery
- Aortic diameter between 17 and 32 mm
- Neck angulation ≤60°
- Absence of significant thrombus or calcification in the sealing zone
- Visceral aortic diameter ≤40 mm
- Diameter discrepancy between supraceliac and pararenal aorta <30%
- Minimum spacing between target vessels ≥3 mm

Preoperative planning

Preoperative planning is performed using centerline analysis according to SVS standards to determine the vertical and circumferential position of each target vessel. These measurements are transcribed onto graph paper to create a precise technical blueprint **(Figure 1)**. This schematic is then transferred onto a transparent polybond peel pouch (Sterimed, France), allowing accurate replication of the design. The template is marked with a permanent marker and subsequently sterilized using standard steam protocols **(Figure 1)**.

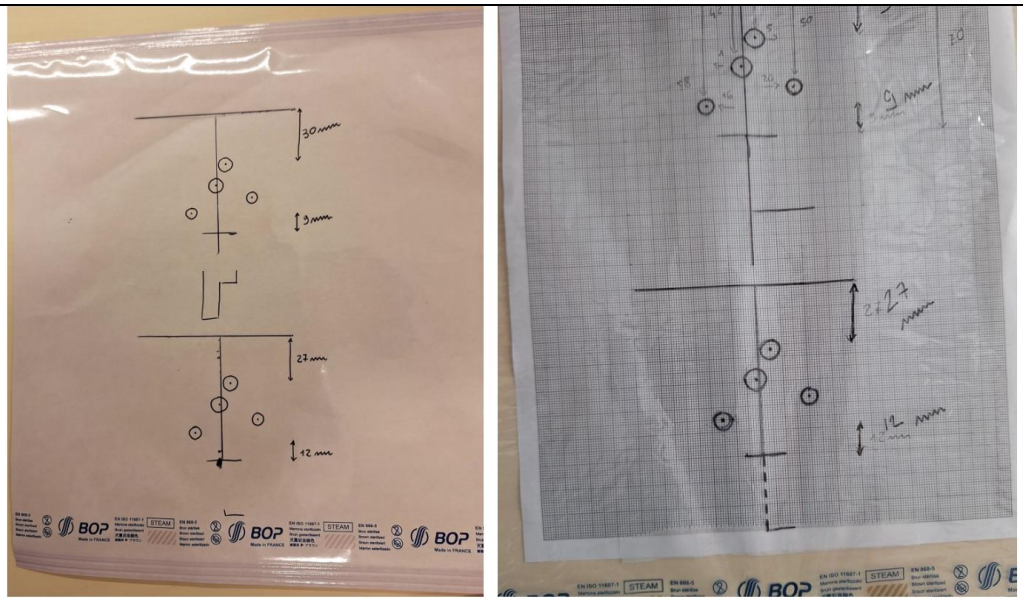

Figure 1: Technical sketch of the modified graft on graph paper transcribed into the polybond peel pouch. Note the various configurations planned to avoid the stent struts.

Endograft modification

The Terumo Aortic Treo stent graft is partially deployed on a sterile back table up to the flow divider while maintaining the proximal segment constrained. A longitudinal anterior reference line is marked on the graft fabric, with the contralateral gate positioned at 90° relative to this axis.

The sterilized transparent template is then aligned with the graft, ensuring correspondence between its longitudinal axis and the anterior reference line. Fenestration sites are adjusted to avoid interference with stent struts, and all measurements are verified **(Figure 2A)**.

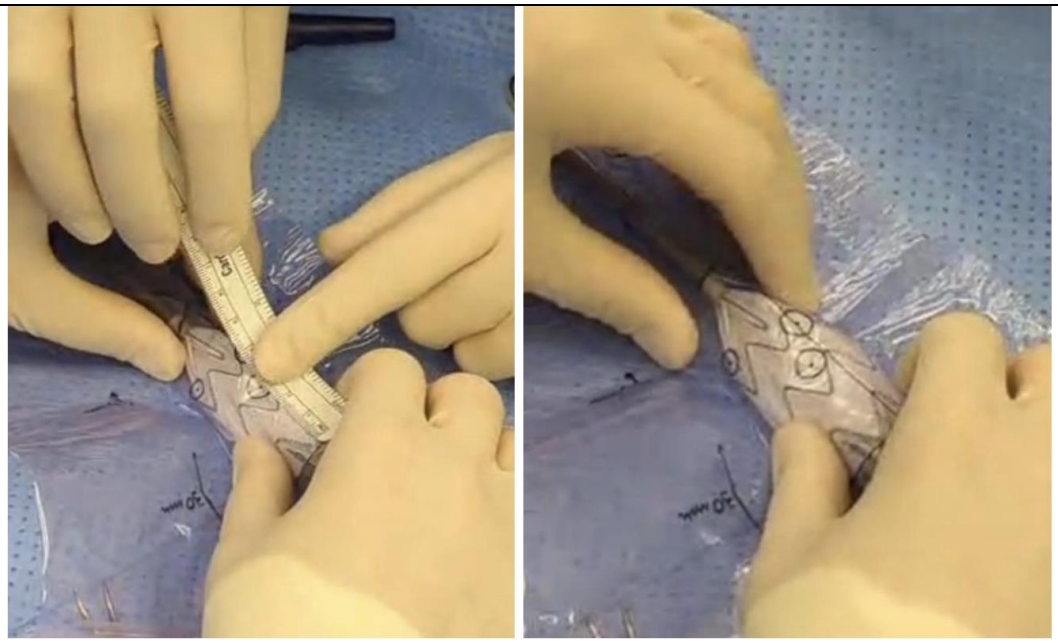

Figure 2A: Sterilized transparent polybond peel pouch is positioned over the graft.

The template and graft are punctured using a 20-gauge needle to mark the center of each fenestration **(Figure 2B).**

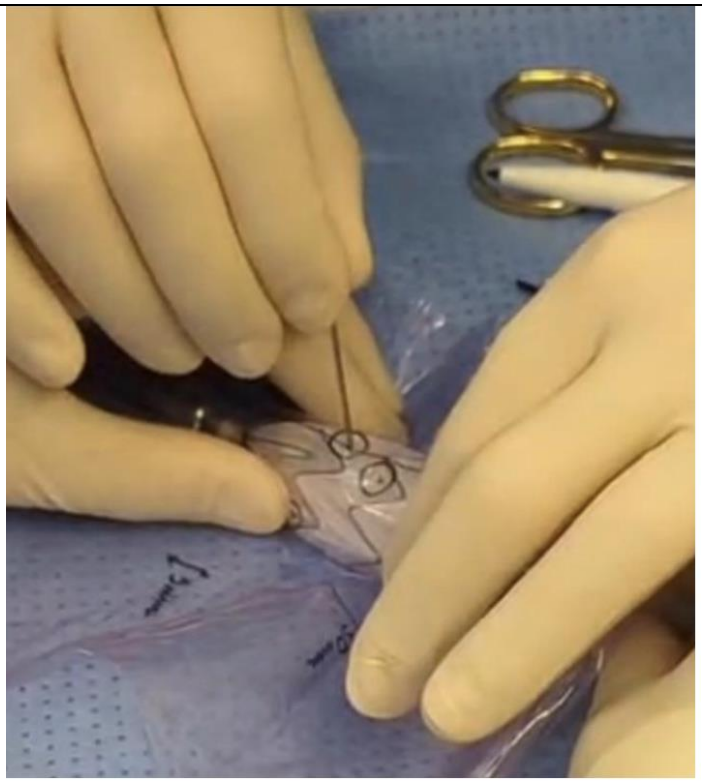

Figure 2B: Sterilized transparent polybond peel pouch being punched by a 20-gauge needle.

Openings are created using cautery and sized according to target vessels:

- Renal arteries: approximately 6 × 6 mm
- Superior mesenteric artery and celiac trunk: approximately 8 × 8 mm

Each fenestration is reinforced using three super-elastic, kink-resistant, and shape memory nitinol wires from a snare kit and one tip of a 0.018-inch guidewire (Atrieve Vascular Snare kit; Argon medical devices and 0,018" Advantage guidewire; Terumo Medical Corporation) secured with a continuous 5-0 nonabsorbable locking suture (Ti-Cron; Medtronic) **(Figure 3).**

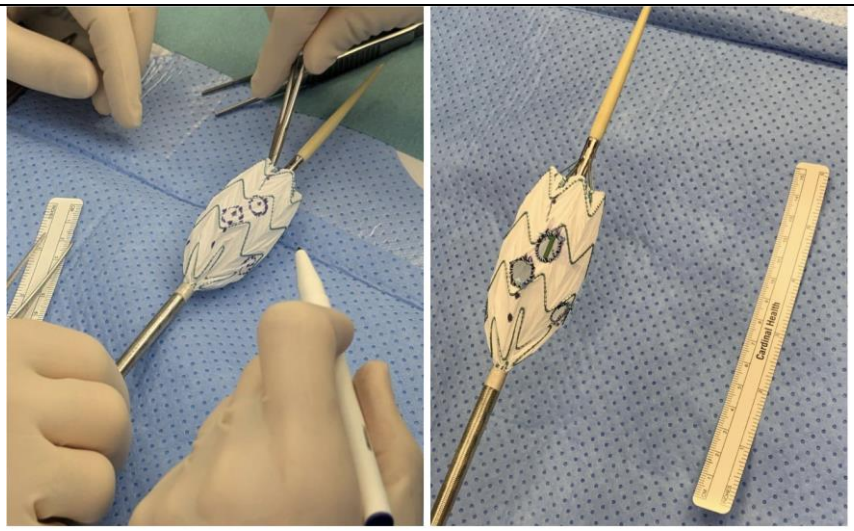

Figure 3: Anterior view of the Physician-Modified Endograft (PMEG) after completion of the modification and before graft resheathing.

A posterior diameter-reducing mechanism is constructed using a 5-0 Prolene suture passed beneath the stent struts, reducing graft diameter by 20% to 30% without fabric perforation **(Figure 4).**

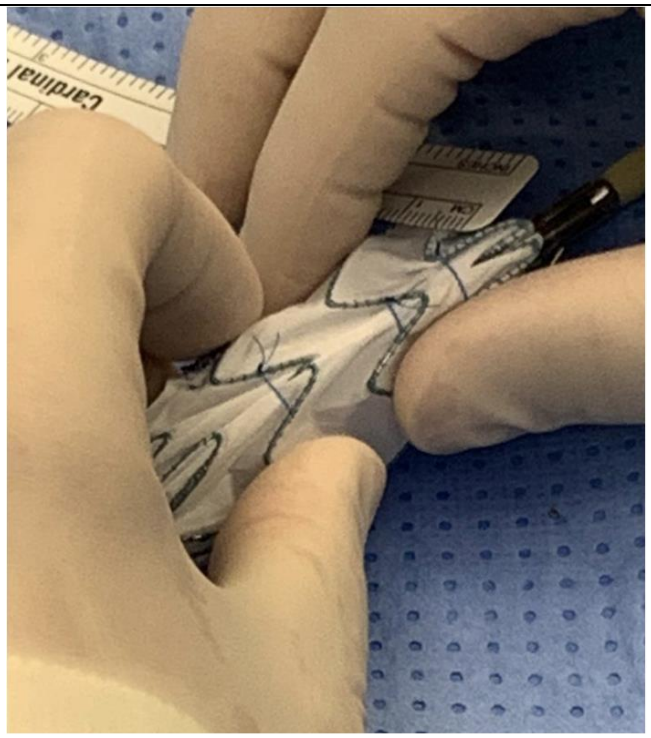

Figure 4: Posterior view of the PMEG after completion of the modification and before graft resheathing. Note the diameter-constraining wire.

The graft is then resheathed using Rummel tourniquets and a spiral vessel loop **(Figure 5).**

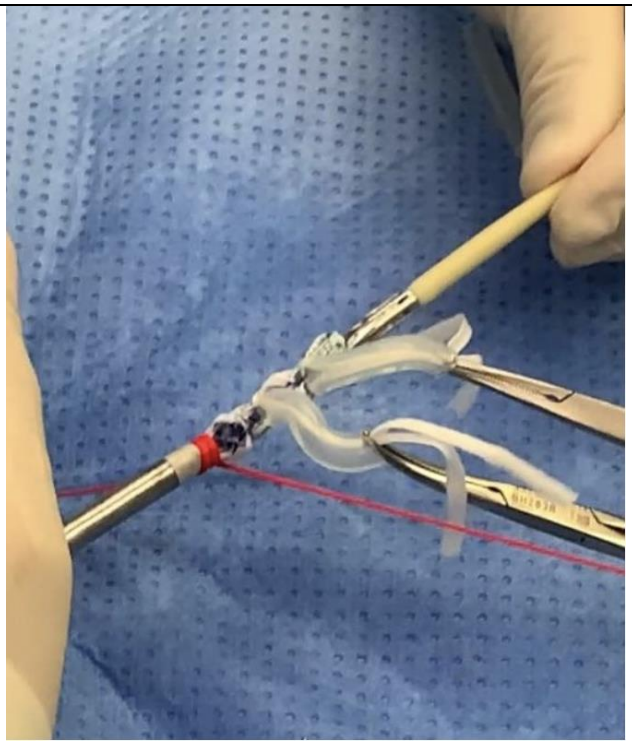

Figure 5: Endograft being resheathed by Rummel tourniquets and a spiral vessel loop positioning.

Implantation technique

Following preparation, the graft is oriented fluoroscopically outside the patient and then introduced via femoral access under fusion imaging guidance. Deployment proceeds to the level of the flow divider, allowing controlled expansion and rotational adjustment via the diameter-reducing tie. Two target vessels—typically the superior mesenteric artery and one renal artery—are cannulated via axillary or brachial access. After confirming correct positioning, the contralateral gate is fully deployed, and a third vessel is catheterized via femoral access **(Figure 6).** The constraining ties are then released using a compliant balloon, permitting full graft expansion. The final target vessel is subsequently cannulated, and bridging stents are deployed and flared. Iliac extensions are placed according to standard technique.

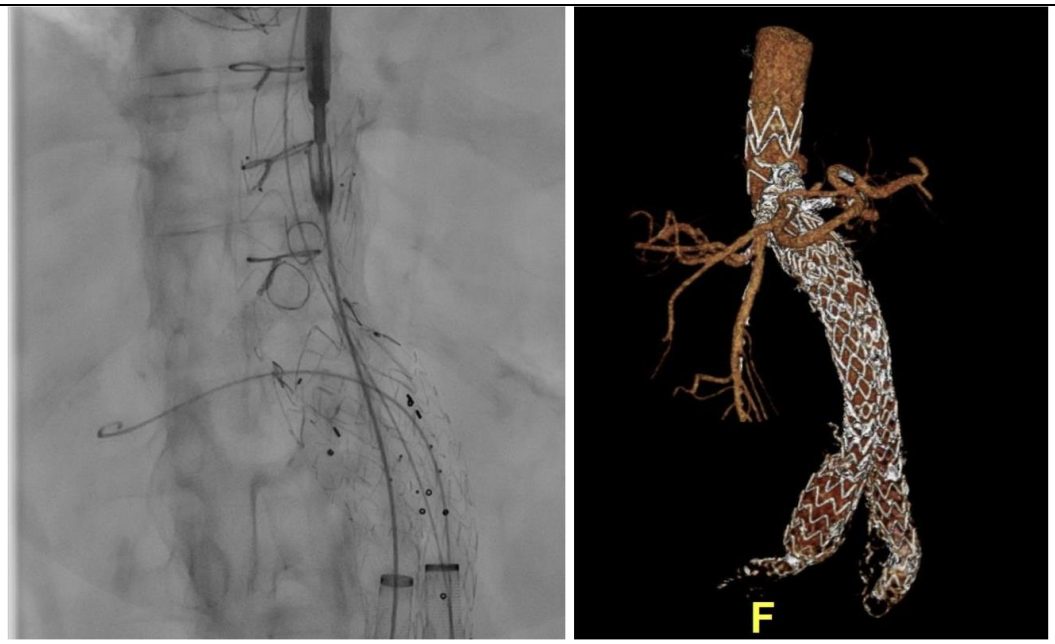

Figure 6: Intraoperative image showing Physician-Modified Endograft (PMEG) and three-dimensional image of the postoperative computed tomography angiogram.

Completion angiography and cone-beam CT are performed to assess graft positioning, vessel perfusion, and the presence of endoleaks. Postoperative CT angiography is obtained immediately **(Figure 6)** and at 3 months to evaluate device integrity and early outcomes.

Ethics statement

Written informed consent was obtained from the patient for publication of clinical data and images. The study was approved by the Ethics Committee of the Autonomous province of Bolzano (protocol No. 48-2026).

Results

The reported patient met all anatomical criteria and underwent urgent repair within 24 hours of admission. The procedure involved incorporation of four visceral vessels via fenestrations. The patient had a history of urgent infrarenal EVAR with a Medtronic Endurant II graft performed 5 years earlier for a ruptured infrarenal AAA, and had been lost to follow-up for 4 years. At presentation, imaging revealed a type IA endoleak with aneurysm sac enlargement to 9 cm, compared with 5.5 cm at the initial procedure **[8]**. Graft modification required approximately 70 minutes, and no stent strut manipulation was necessary.

Procedure duration, fluoroscopy time, and contrast volume were within our institutional standards for a standard fEVAR procedure (mean procedure time: 180 minutes; mean fluoroscopy time: 33 minutes; mean contrast volume: 90 mL). During deployment, an adjustment of approximately 10° rotation was performed. Final intraoperative imaging demonstrated optimal fenestration alignment, with a technical success rate of 100%. Hospital stay was 6 days, including 1 day in intensive care for monitoring. No perioperative complications or reinterventions occurred within 30 days. Early postoperative imaging confirmed precise vertical alignment and minor (<15°) horizontal misalignment in two fenestrations. At 3-month follow-up, no endoleaks (types I–V), structural failures, or adverse clinical events were observed [9].

Discussion

This report describes a structured approach to PMEG creation using the Terumo Aortic Treo platform in an urgent clinical setting [2,10]. The principal objective of this technique is to reduce variability in planning and graft modification through standardized measurement and templating. An original, relevant and reproducible aspect of this standardized approach is the use of a transparent polybond peel pouch as a template for fenestration planning and transfer. While the use of generic transparent sterile plastic sheets has been briefly suggested as a possible templating option [11], our standardized approach using a sterilized polybond peel pouch combined with a graph-based blueprint provides a reproducible, cost-effective and readily available solution specifically designed for urgent four-fenestration PMEG with the Terumo Aortic Treo platform. This method represents a highly cost-effective solution, relying on materials that are universally available in operating rooms worldwide, thereby eliminating the dependency on advanced resources such as three-dimensional or laser-printed models [12,13]. In contrast to these technologies—which, although well described in the literature, may require specialized equipment, increased production time, and dedicated sterilization workflows—the polybond peel pouch can be rapidly prepared and processed using standard steam sterilization protocols that are readily accessible in virtually any hospital setting. This significantly reduces both preparation time and logistical complexity, which is particularly advantageous in urgent scenarios. Despite its simplicity, the technique provides a high degree of accuracy in fenestration positioning, ensuring reliable alignment with target vessels while remaining procedurally feasible and technically achievable in a controlled setting.

Alternative strategies in urgent settings include parallel grafting and off-the-shelf thoracoabdominal devices. Comparative analyses have shown that PMEGs are associated with fewer complications and a reduced incidence of gutter endoleaks relative to parallel graft techniques [1]. While off-the-shelf devices are effective, their design often necessitates extensive proximal coverage, which may increase the risk of spinal cord ischemia compared with the limited supraceliac coverage achievable with PMEGs [5]. A major limitation of PMEG use is the heterogeneity in technique and indications reported in the literature [6,7]. In this protocol, we aim to minimize variability through strict patient selection, standardized measurement, and a consistent modification protocol. The use of limited supraceliac coverage (<5 cm), in line with SVS recommendations, may further reduce the risk of paraplegia. However, the technique remains technically demanding and highly operator-dependent. Regarding device selection, although

Cook Medical and Medtronic platforms are most frequently reported, the Terumo Aortic Treo system offers several advantages, including wide spacing between stent struts, facilitating fenestration placement without structural compromise [10]. Comparative analyses have also shown favorable results of physician-modified grafts compared with company-manufactured fenestrated devices [14]. Additional benefits include ease of resheathing, the ability to implement diameter-reducing ties without fabric perforation, low-profile delivery (18–19F), and improved conformability in challenging access anatomies.

Unlike other platforms, the Treo design permits construction of the constraining mechanism without multiple fabric punctures, potentially reducing the risk of type IV endoleaks. A torsion technique during endograft deployment has been described in the literature to obviate the need for constraining wires to reduce graft diameter; however, this approach is highly operator-dependent. We therefore elected to incorporate a constraining step to enhance reproducibility. The use of guidewire-reinforced fenestrations enhances visualization and alignment during deployment, facilitating precise rotational control relative to the contralateral gate marker, which serves as the anteroposterior orientation reference. Preloaded wires were not utilized in this series, as their benefit is more pronounced in branched configurations or highly complex anatomies. The availability of steerable sheaths further reduces the need for such adjuncts. Overall, a step-by-step method supports the feasibility, safety, and reproducibility of this standardized PMEG protocol [6,15,16].

Limitations

This report is limited by the single-case presentation and short 3-month follow-up. Although the technique proved technically feasible and safe in this urgent setting with type IA endoleak after prior EVAR, larger series with longer follow-up are required to confirm reproducibility, long-term durability, and broader applicability of the standardized protocol.

Conclusions

A structured approach to PMEG creation using the Terumo Aortic Treo platform appears to be a practical and reproducible solution for managing complex AAAs in urgent settings. The integration of strict anatomical criteria, standardized planning, and a consistent modification technique may improve procedural reliability and reduce variability. Our proposal to use a transparent polybond peel pouch as a template facilitates accurate fenestration design while remaining cost-effective and compatible with standard sterilization methods. This approach enables rapid intraoperative customization without reliance on advanced manufacturing technologies.

The structural characteristics of the Treo device, particularly its favorable stent geometry and fabric availability, make it well suited for fenestrated modification. The described templating and modification strategy may facilitate procedural planning and execution, enabling meaningful comparisons and helping to define the role of this technique in both urgent and elective complex aortic repair, in line with the favorable long-term outcomes reported by Starnes et al. [17,18].

Conflict of interest: The authors declare no conflicts of interest.

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