Innominate artery reimplantation as a strategic step in lifetime aortic management: a vascular surgeon's perspective

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The management of complex aortic disease has evolved toward a "lifetime management" strategy, where the initial surgical arch repair critically influences the feasibility of future staged interventions. While the left subclavian artery has received significant attention, the strategic role of the innominate artery (IA) as a primary endovascular gateway remains underappreciated. This paper explores how IA reimplantation geometry determines the success of subsequent endovascular procedures. We analyzed the technical requirements for optimal antegrade endovascular access during complex downstream repairs, such as branched and fenestrated endovascular aortic repair (B-FEVAR). Two surgical strategies aimed at optimizing supra-aortic vessel alignment were evaluated: the "arch vessels' switch" technique using a standard trifurcated graft, and the use of the novel T-NEXT hybrid prosthesis (Terumo Aortic, Vascutek Ltd., Renfrewshire, UK). In currently available frozen elephant trunk (FET) and hybrid arch grafts, the longitudinal arrangement of supra-aortic branches often results in sequential vessel reimplantation patterns that may create acute angulations between the IA and the ascending aorta. Such configurations can impair guidewire and catheter maneuverability, reducing effective transmission of torque and forward force during antegrade navigation toward the descending thoracic and thoracoabdominal aorta. The "arch vessels' switch" technique, in which the IA is reimplanted onto the distal (3^{rd}) branch of a standard trifurcated graft, improves coaxial alignment and creates a smoother, more anteriorly directed trajectory for catheters and delivery systems intended for downstream aortic interventions. Similarly, the T-NEXT hybrid prosthesis (Terumo Aortic, Vascutek Ltd.) combines preservation of a longer native ascending aortic segment, potentially facilitating future root or ascending aortic reinterventions with a dedicated transverse 10-mm IA branch that provides a stable and pre-aligned access route. This optimized geometry minimizes abrupt directional changes at the anastomotic level, facilitates device advancement, and enhances support for guidewires, sheaths, and endovascular adjuncts. IA reimplantation should be conceptualized as a strategic maneuver rather than a purely reconstructive step. A multidisciplinary "aortic team" approach is essential to design arch reconstructions that facilitate bidirectional endovascular navigation. By optimizing IA take-off geometry, surgeons can prevent "dead-end" anatomies and ensure that the primary arch repair serves as a durable platform for the patient's entire therapeutic journey.

Keywords: Arch surgery; supra-aortic reconstruction; branched and fenestrated endovascular aortic repair (B-FEVAR); thoracoabdominal aneurysm

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Introduction

The management of complex aortic disease has undergone a profound transformation over the past two decades (1). What was historically considered a condition amenable to definitive surgical repair is now increasingly recognized as an evolving and progressive pathology, particularly in patients with chronic dissections, connective tissue disorders, or extensive aneurysmal degeneration (2). In this context, the concept of a single curative procedure has been replaced by a strategy of lifetime aortic management, in which staged interventions are frequently required (3). Despite these advances, a critical gap persists in the current treatment paradigm. The initial surgical procedure is often planned with a focus on immediate anatomical repair and perioperative outcomes, while insufficient attention is given to how this first intervention may influence the feasibility and complexity of subsequent treatments. In particular, the lack of structured integration between cardiac and vascular surgical perspectives may lead to arch reconstructions that are anatomically correct but suboptimal from an endovascular standpoint. This issue becomes particularly relevant in the setting of modern arch prostheses. Current trifurcated grafts used in total arch replacement and conventional frozen elephant trunk (FET) techniques were originally designed to restore the native anatomy of the aortic arch, with the distal anastomosis typically performed in zone 3 and sequential reimplantation of the supra-aortic branches (4). However, contemporary practice has progressively shifted toward more proximal distal anastomoses (zones 0–2) (5,6). While this approach may simplify the index procedure, it results in a more proximal positioning of the arch branches, potentially limiting surgical access to the aortic root in reoperative settings. Moreover, this configuration may create unfavorable geometric conditions for future endovascular interventions, due to acute and double angulation between the supra-aortic branches and the main graft body, making catheterization from an upper-body approach more challenging (*Figure 1*) (7).

While considerable attention has recently been directed toward management of the left subclavian artery (8), the role of the innominate artery (IA) remains comparatively underappreciated. From a vascular surgeon's perspective, the IA constitutes the critical anatomical conduit connecting the right axillary artery, the preferred antegrade access site for many complex endovascular procedures of the aortic arch and descending aorta. Consequently, its configuration during arch reconstruction may critically influence the feasibility, efficiency, and safety of subsequent endovascular interventions.

These considerations highlight the need for a truly multidisciplinary "aortic team" approach, in which cardiac and vascular surgeons collaboratively design the initial procedure with full awareness of the entire therapeutic pathway. Within this framework, the reimplantation of the supra-aortic vessels and particularly of the IA should not be regarded as a purely reconstructive step, but rather as a strategic maneuver aimed at optimizing long-term management.

This article explores the role of IA reimplantation as a key determinant of future endovascular feasibility, proposing a vascular surgeon's perspective on how standardized supra-aortic reconstruction may contribute to a more effective and durable lifetime aortic treatment strategy.

The strategic role of the IA

The IA plays a central role in endovascular navigation within the aortic arch. Compared with the left common carotid and left subclavian arteries, it provides a larger caliber, a more direct orientation relative to the ascending aorta, and a more stable platform for guidewire and catheter manipulation. However, these advantages are highly dependent on the configuration achieved during surgical reimplantation.

Suboptimal reconstruction, characterized by excessive angulation, inadequate graft length, posterior orientation, or anastomotic tension, may significantly impair catheter stability and limit the feasibility of subsequent interventions. In such cases, what was intended as a technically correct reconstruction may paradoxically become a limiting factor for future treatment.

Technical principles

To facilitate future interventions, the reimplantation of the IA should follow a set of reproducible technical principles aimed at preserving optimal access geometry.

Ultimately, the goal is to preserve a wide and accessible pathway that enables safe and efficient navigation of guidewires, sheaths, and endovascular devices. In this context, the IA should be conceptualized not only as a perfusion vessel but as a dedicated access route for future interventions.

However, in conventional arch reconstruction using

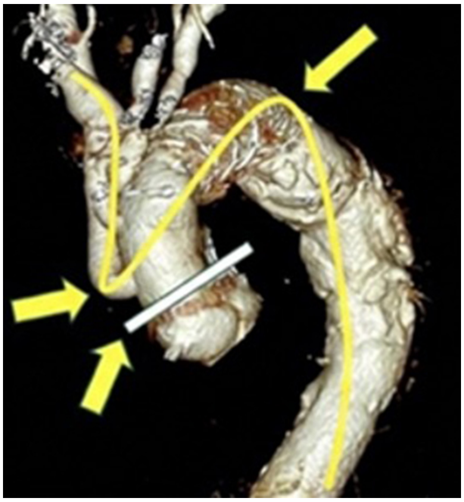

Figure 1 Unfavorable antegrade access geometry after conventional supra-aortic vessel reimplantation. The yellow line represents the anticipated antegrade guidewire pathway. The white line marks the proximal anastomosis of the aortic arch graft. The yellow arrows highlight the abrupt changes in direction and unfavorable angulations along the antegrade access pathway.

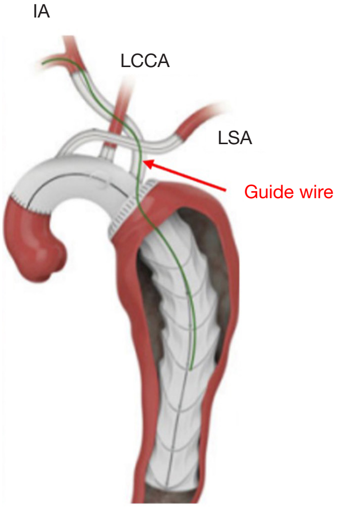

Figure 2 Arch vessels' switch configuration and antegrade guidewire pathway. IA, innominate artery; LCCA, left common carotid artery; LSA, left subclavian artery.

standard trifurcated prostheses, the branch dedicated to the IA is often positioned relatively proximally on the main graft. This configuration may result in an unfavorable take-off angle between the innominate branch and the descending aortic axis, particularly when the distal anastomosis is performed in more proximal zones [0–2].

Consequently, antegrade catheterization of the descending thoracic and thoracoabdominal aorta from the IA may become technically challenging. The presence of acute or double angulation at the junction between the branch and the main graft can reduce catheter stability, limit pushability, and increase friction during device advancement, ultimately complicating complex endovascular maneuvers such as visceral vessel cannulation during branched or fenestrated repair.

To address these limitations, we have refined our arch strategy through the adoption of the arch vessels' switch technique and the use of dedicated prosthetic designs such as the Thoraflex T-NEXT graft (Terumo Aortic, Vascutek Ltd., Renfrewshire, UK), aiming to optimize branch orientation and improve the geometric alignment between the supra-aortic vessels and the descending aorta.

Surgical technique and rationale of the arch vessels switch

Conventional FET is performed through median sternotomy with IA cannulation, bilateral antegrade selective cerebral perfusion (ASCP), and zone 2 FET implantation under moderate hypothermia. After the distal anastomosis, systemic perfusion is resumed through the graft side branch and rewarming is initiated (9).

The core of this technique, the "arch vessels' switch", involves a deliberate rearrangement of the supra-aortic reconstruction sequence using a trifurcated graft. Instead of the standard anatomical order, the distal (3^{rd}) branch of the prosthesis is anastomosed to the IA, while the proximal (1^{st}) and middle (2^{nd}) branches are used for the left subclavian and left common carotid arteries, respectively (*Figure 2*). This modified configuration optimizes the spatial orientation of the innominate branch, creating a smoother, more anteriorly directed angle relative to the main arch graft. The resulting geometry significantly enhances coaxial alignment and facilitates easier antegrade catheterization for any potential subsequent endovascular procedures (*Figure 3*) (9).

Surgical technique and rationale of the T-NEXT graft

The surgical procedure is initiated via a median sternotomy, with cardiopulmonary bypass (CPB) established through cannulation of the IA and the right atrium. During the systemic cooling phase, the left subclavian artery is

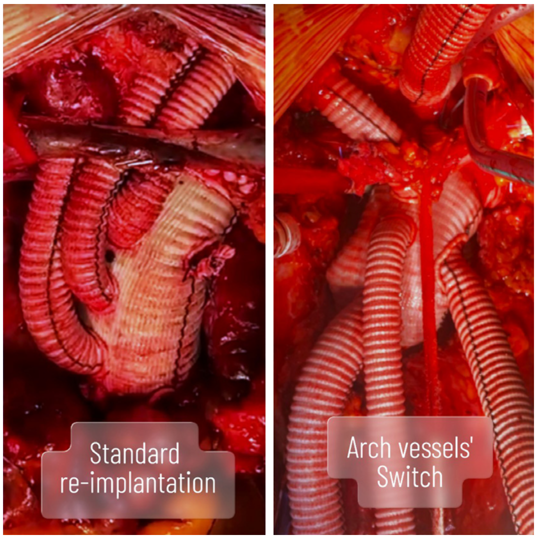

Figure 3 Intraoperative comparison of arch vessels' switch and standard supra-aortic reimplantation.

proximally ligated and distally anastomosed to an 8-mm vascular graft, which is independently perfused to enable ASCP. Following aortic clamping and cardioplegic arrest, the left common carotid artery is ligated at its origin and perfused distally for bilateral ASCP. At a nasopharyngeal temperature of 26 °C, the IA is clamped, and the ascending aorta and aortic arch are excised. A T-NEXT hybrid prosthesis (Terumo Aortic, Vascutek Ltd.) is then deployed in zone 2, and the distal anastomosis is completed. CPB is reestablished through the graft's side branch to commence rewarming. After performing the aortic valve replacement and finalizing the proximal anastomosis between the graft and the aortic root, the aortic clamp is removed to proceed with the supra-aortic vessel reconstruction (10).

The T-NEXT graft represents a customized evolution of the Thoraflex Hybrid system (Terumo Aortic, Vascutek Ltd.), specifically designed to optimize the "lifetime management" of complex aortic disease through a unique branch architecture (7). Previous experiences with single trifurcated hybrid prostheses, such as the E-vita graft, have demonstrated the advantage of providing a longer proximal graft segment free from prosthetic side branches, thereby facilitating distal aortic clamping during potential future root reoperations. However, the acute angulation created by the trifurcated branch configuration may limit the feasibility of subsequent endovascular interventions. This angulation can generate a hostile anatomical configuration that hampers antegrade navigation of guidewires and catheters within the thoracoabdominal aorta and may complicate catheterization of the visceral vessels.

To address these limitations and simplify both proximal root reoperations and distal endovascular thoracoabdominal repairs, our aortic team in Ancona recently developed and introduced a novel FET prosthesis, the T-NEXT graft (Terumo Aortic, Vascutek Ltd.). Unlike traditional prostheses with longitudinal branch arrangements, the T-NEXT features a distal and transverse branch configuration. This design offers two critical advantages: first, it preserves a significantly longer segment of the ascending aorta graft, maintaining a clear, unobstructed zone for potential future reinterventions on the aortic root or heart valves. Second, the graft incorporates a dedicated 10-mm IA branch with a predefined angulation, alongside a bifurcated branch for the left common carotid and subclavian arteries. By positioning the branches more distally and transversely, the graft ensures a more physiological take-off and a smoother, anteriorly directed trajectory for the IA (*Figure 4*). This optimized geometry preserves a direct antegrade pathway, significantly facilitating the passage of guidewires and catheters for subsequent downstream thoracoabdominal endovascular procedures or future supra-aortic interventions (*Figure 5*) (11).

Technical implications

From a vascular surgeon's perspective, the IA represents the primary endovascular gateway for complex downstream repair. The success of advanced procedures such as branched and fenestrated endovascular aortic repair (B-FEVAR) depends heavily on the ability to transmit force and torque effectively through the endovascular system.

When the IA is reimplanted with optimal geometry, it provides a stable and coaxial pathway that enhances catheter control and procedural precision. Conversely, unfavorable configurations may lead to loss of stability, increased friction, and reduced effectiveness of device delivery.

In the context of B-FEVAR, although antegrade access via the IA is not routinely the primary approach, it becomes particularly valuable in selected scenarios. A well-designed reconstruction prevents "shelfing" at the anastomosis and allows efficient transmission of force during target vessel cannulation. It also facilitates the use of adjunctive techniques, such as the buddy-wire strategy, by providing sufficient space and alignment for multiple devices.

Similarly, for device delivery and distal extensions, a smooth transition between the arch graft and the

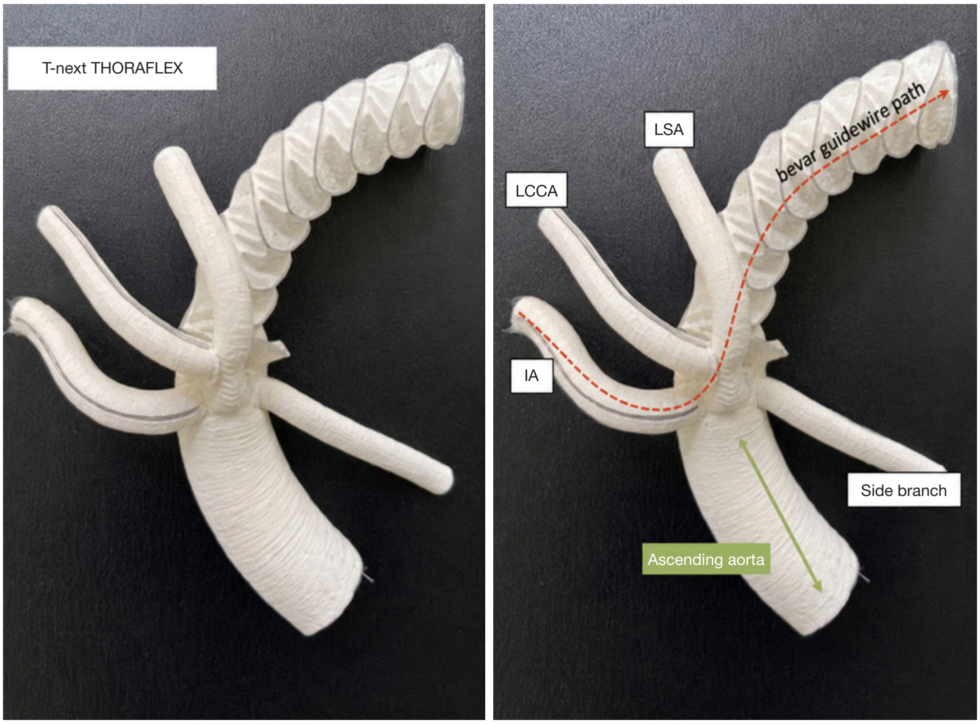

Figure 4 T-NEXT graft architecture and dedicated antegrade IA pathway. IA, innominate artery; LCCA, left common carotid artery; LSA, left subclavian artery.

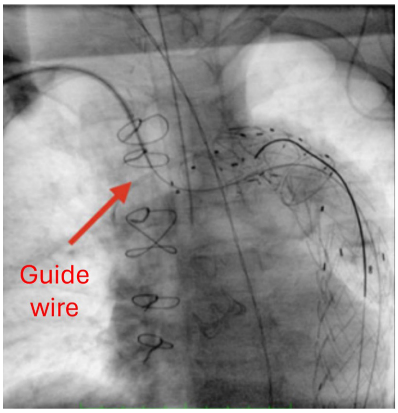

Figure 5 Fluoroscopic demonstration of antegrade guidewire passage through the reconstructed IA pathway. IA, innominate artery.

innominate branch minimizes resistance and allows accurate deployment.

Even in open surgery, this concept remains relevant. During endoclamping maneuvers, the IA may serve as a route for balloon positioning within the arch graft (12,13) (*Figure 6*). This requires a wide, non-angulated pathway to ensure safe advancement and effective proximal control.

Conversely, a non-strategic or haphazard reimplantation does not merely increase procedural difficulty; it creates a definitive mechanical barrier. Such suboptimal geometry results in a "dead-end" anatomy that significantly escalates fluoroscopy time and technical failure rates. In extreme cases, these anatomical constraints can preclude endovascular options entirely, leaving the patient with no alternative but high-risk, morbid redo open surgery, a scenario that could have been avoided through proactive "lifetime management" design at the time of the primary arch replacement.

The role of the aortic team

The increasing complexity of aortic disease and the shift toward a lifetime management strategy underscore the critical importance of a dedicated aortic team. The treatment of these patients extends beyond the boundaries of a single specialty and requires seamless integration between cardiac surgeons, vascular surgeons,

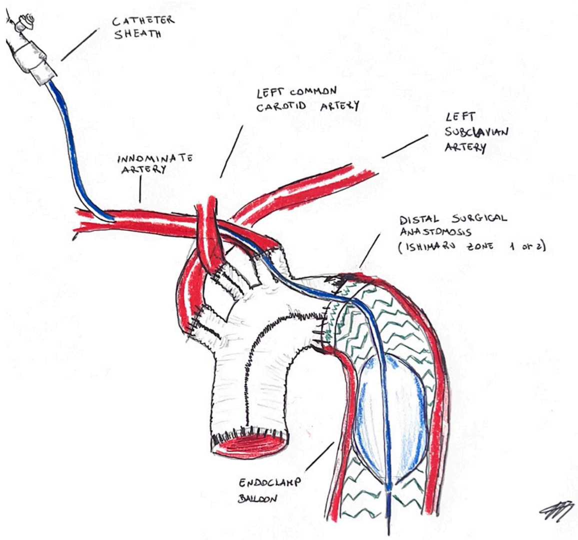

Figure 6 Arch vessels' switch configuration providing a favorable antegrade IA pathway for endoclamp balloon advancement and positioning within the aortic arch graft. IA, innominate artery.

interventionalists, and imaging specialists. In particular, the planning of the initial arch procedure should not be driven solely by immediate surgical considerations, but rather by a shared understanding of the entire therapeutic pathway (14,15). From this perspective, the configuration of the supra-aortic vessels and especially the reimplantation of the IA must be discussed within a multidisciplinary framework, taking into account its implications for future endovascular access and device delivery. The lack of such integration may result in technically successful procedures that inadvertently compromise subsequent treatment options. Conversely, a coordinated aortic team approach allows the adoption of standardized and forward-looking strategies, including optimized supra-aortic reconstruction and tailored use of modern prostheses, ultimately improving procedural efficiency and long-term outcomes.

In this evolving paradigm, the aortic team is not only a model of collaboration but a fundamental prerequisite for delivering truly patient-centered, durable, and strategically planned aortic care.

Conclusions

The transition toward a lifetime management strategy in aortic disease requires a fundamental shift in surgical thinking. The initial arch procedure should no longer be considered an isolated intervention, but rather the first step in a complex and evolving therapeutic pathway.

Within this framework, IA reimplantation emerges as a key determinant of future treatment feasibility. A standardized approach characterized by appropriate graft length, optimal orientation, and preservation of access geometry can significantly simplify subsequent interventions and expand therapeutic options.

From a vascular perspective, the reconstruction of the supra-aortic vessels represents a unique opportunity to influence long-term outcomes. For this reason, it should be planned within a multidisciplinary aortic team strategy, integrating both surgical and endovascular considerations from the outset.

Ultimately, the IA should not be regarded simply as a branch of the arch, but as a strategic gateway to the future of aortic repair.

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Footnote

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