Nitinol Self-Expanding Stents for the Superficial Femoral Artery

Ashwin Nathan, MD[a,b,1], Taisei Kobayashi, MD[a,b,1], Jay Giri, MD, MPH[a,b,*]

KEYWORDS

• Nitinol • Self-expanding stents • Superficial femoral artery • Peripheral arterial disease

KEY POINTS

- Atherosclerotic vascular disease in the superficial femoral artery is difficult to treat given the biomechanical loading environment of the artery as it courses through the leg.
- Nitinol has material properties that allow it be uniquely suited to withstanding the stresses of stents placed in the superficial femoral artery.
- Novel iterations of self-expanding stents using nitinol have targeted reductions in restenosis and stent fracture.

INTRODUCTION

The superficial femoral artery (SFA) poses unique challenges for endovascular stenting. It is a long, muscular artery that is fixed between the hip and the knee; as a result of the complex motions of the hip joint, the SFA is subject to unique forces, including flexion, extension, and torsion (Fig. 1). The SFA is further exposed to longitudinal and lateral compressional forces and even extrinsic muscular compression as the artery dives through the Hunter canal between the muscular bodies of the anterior and medial compartments of the thigh.[1] Because of the magnitude of mechanical stressors that it is exposed to, the SFA has a particularly prominent smooth muscle layer that allows it to withstand these forces.

Angioplasty alone for atherosclerotic SFA disease is unsuccessful in 30% or more of cases because of the elastic recoil, vascular dissection, and high-grade residual stenosis (Fig. 2).[1] Balloon-expandable stents were designed to improve patency after SFA angioplasty through the deployment of a metallic lattice that could resist extrinsic forces; although they did decrease failure rates immediately after the procedure, early iterations of these stents were plagued by restenosis and crush damage over time.[2–4]

As a result, alloys were developed that could withstand the stresses of the SFA and were incorporated into self-expanding stents that constantly applied an outward radial force. Early self-expanding stents used Elgiloy, an alloy consisting mainly of cobalt, chromium, and nickel. Initial experiences with self-expanding Elgiloy stents were marked by excessively high rates of stent fracture and low long-term patency. The introduction of a novel material, nitinol, revolutionized treatment of the SFA via improvement in radial strength and incorporation of shape-memory characteristics that promoted crush recovery.[5,6]

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[a] Cardiovascular Medicine Division, Perelman Center, Hospital of the University of Pennsylvania, South Tower, 11th Floor, 3400 Civic Center Boulevard, Philadelphia, PA 19104, USA; [b] Penn Cardiovascular Quality, Outcomes, and Evaluative Research Center, University of Pennsylvania, Philadelphia, PA, USA

[1]These authors are equally contributed.

* Corresponding author. Cardiovascular Medicine Division, Perelman Center, Hospital of the University of Pennsylvania, South Tower, 11th Floor, 3400 Civic Center Boulevard, Philadelphia, PA 19104.

E-mail address: Jay.Giri@uphs.upenn.edu

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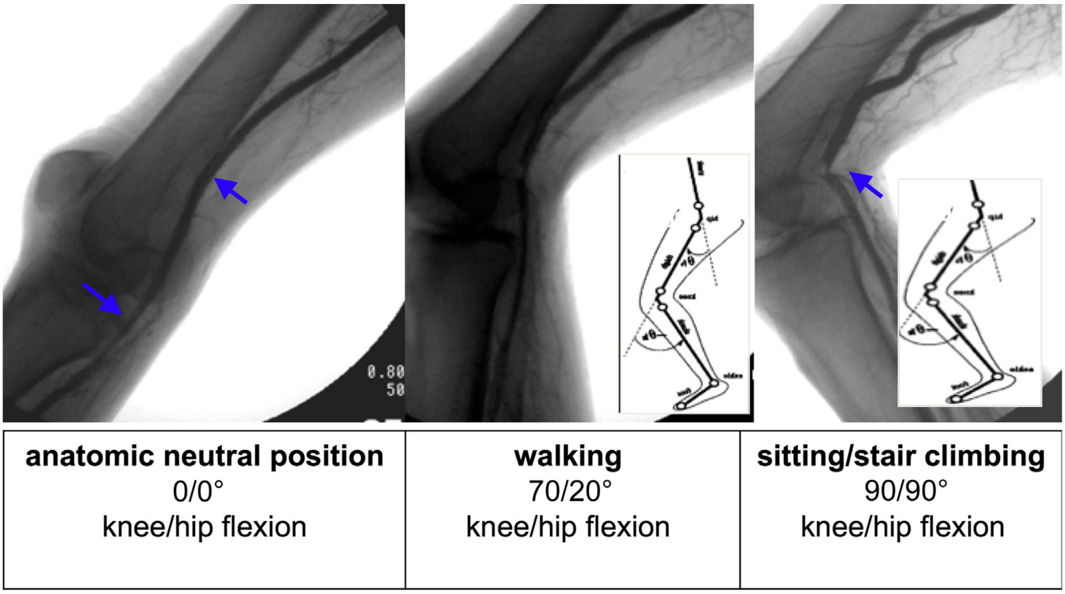

Fig. 1. Biomechanical loading conditions that the SFA is exposed to during activities of daily living with corresponding angiograms. Blue arrows identify areas of the distal SFA and popliteal artery that are vulnerable to flexion stress.

TECHNICAL CHARACTERISTICS OF NITINOL STENTS

Conventional metal alloys, such as stainless steel or cobalt alloys, provide poor elasticity (1% deformation capability) in comparison with nitinol, which can tolerate 10% strain forces and still retain its original shape.[7] Most elasticity of other metals is reliant on stretching of atomic bonds, but deformational changes to nitinol result in alteration of its crystalline structure. This crystal structure reverts back to its normal shape after the stresses are released. Another key trait of nitinol is that it is temperature sensitive. At low temperatures the frame is easily manipulated, but at body temperature the frame will expand to its original shape and size. This property allows the nitinol stent to be crimped at room temperature and to revert back to its cylindrical shape when deployed in the body.

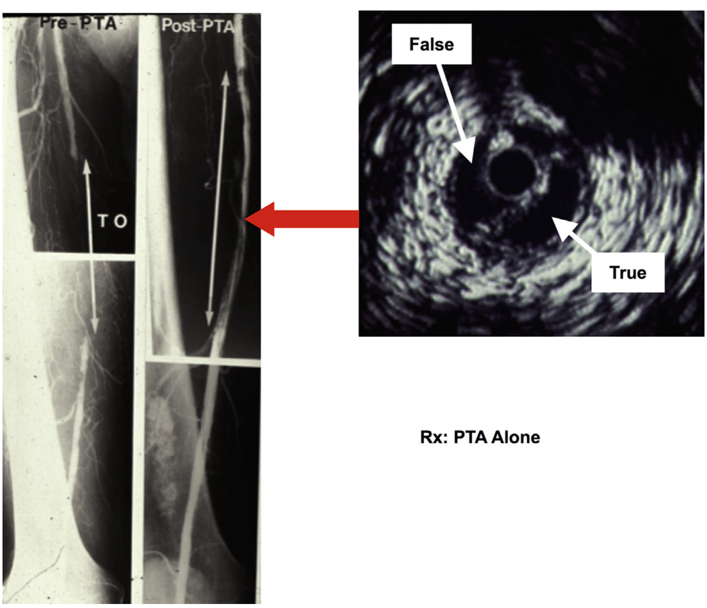

Fig. 2. Intravascular ultrasound of SFA after balloon angioplasty alone. The true lumen and false lumen are clearly seen with intravascular imaging. The *arrow* identifies the angiographic area shown in the IVUS image. PTA, percutaneous transluminal angioplasty; Rx, prescription.