2 Historical background

The concept of endovascular grafting is almost one hundred years old and based on the idea of replacing the arterial wall by an internal tube reducing the lumen in case of an aneurysm or widening it in the presence of a stenosis. The first endovascular graft placement was performed by Alexis Carrel in a canine experiment in 1912 [1]. He entitled the study the ‘permanent intubation of the thoracic aorta’. Rigid glass and aluminium tubes were inserted into the descending thoracic aorta through a direct small aortotomy following proximal and distal clamping. He proposed this technique for the repair of thoracic aneurysms. Carrel was, however, aware of the Achilles’ heel of aneurysm repair by inlaid tubes, namely reliable fixation. Nevertheless, he considered this technique to be simple and superior to aortic resection and graft replacement. He was familiar with both implantation of inlaid tubes and aortic replacement by vein graft interposition, yet he considered the latter to be a dangerous procedure.

For the next forty years surgical attempts to treat abdominal aortic aneurysms met with little success. They consisted of electrothermically-induced thrombosis by placement of intraluminal wires, ligation of the aneurysm or endo-aneurysmorrhaphy. The surgical principles, namely excision of the diseased segment and restoration of the continuity were performed in a patient for the first time in 1951 by Dubost who interposed an aortic homograft following resection of an infrarenal aortic aneurysm [2]. This technique was used successfully in seven patients by DeBakey and Cooley who then standardized the treatment [3]. In 1952, Voorhees observed excellent biological compatibility of Vinyon-N, but it was not until 1957 when DeBakey introduced knitted Dacron tubes that were successfully used thereafter by every surgeon till these days [4]. An important technical modification was established in 1966 by Creech who proposed an intra-saccular anastomosis to reduce operating time and avoid damage to adjacent structures [5]. In 1974 Orr and Davies developed the graft inclusion technique into a straightforward procedure using exclusively tube grafts which were sewn to the aorta from inside and wrapped by the aneurysm sac without any attempts at resection [6]. Thereby a marked reduction in mortality was achieved particularly in ruptured aneurysms. Soon this technique became the golden standard for open aneurysm repair.

The idea of replacing the arterial wall by a tubular substitute from inside the artery remained an attractive idea throughout the century. In 1969 Dot-
ter inserted plastic tubes into the femoral canine arteries over a guide wire using a remote access [7]. The high thrombogenicity of the material and the small diameter of the tubes resulted, however, in occlusion prompting him to use open springs with better patency rates. Thereupon the potential of this technique using a remote access for catheter-based manipulations within the arterial system was recognized.

Tubular substitutes at the level of the aorta were less subjected to thrombosis owing to their large diameter and the high aortic flow. Yet direct access to the aorta for device insertion was still required to insert these tubes. In 1974 Dureau inserted Dacron tubes with a rigid Velour-covered Teflon ring directly into the ascending aorta in two patients with an acute dissection [8]. The prostheses were secured by tightening an external tape around the aorta at the level of the rings. However, this type of sutureless fixation carried an impending risk of tissue necrosis and did not gain widespread application.

It was not until the beginning of the eighties, when the concept of a transluminally inserted device was further developed. In 1982 Maass invented a self-expandable double helix spiral of stainless steel with a maximum expansion factor of five to one [9, 10]. For the first time remote access through a small peripheral artery with device deployment at the level of the large aorta was realized. The spirals were preloaded in a state of maximal tension on a small, 7 mm diameter introducer and inserted via iliac arteries. They were deployed by a remote torque release on the handle in the thoracic aorta using fluoroscopy. Maass demonstrated precise device deployment with circumferential alignment with the aortic wall, neointimal covering and absence of stenosis, thrombosis or perforation. He calculated the pressure transmitted to the aortic wall by the spirals in order to know its amount for reliable fixation without causing perforation. He recognized the significance of the spirals in aortic dissection by obliteration of the false lumen. At that time, Nitinol was discovered and considered the ideal material in these applications. The striking characteristic of Nitinol, a nickel titanium alloy, is thermal recovery. The spirals were designed by heating the wire over 525°C. Following cooling, the spirals were modified and constrained on a catheter. In body temperature, they transformed again into the original spiral shape. In 1983 Dotter implanted spirals into the femoral canine artery by use of a catheter and accomplished complete expansion by flushing the catheter with hot saline solution [11]. The same year, Cragg envisaged the application of a long spiral in the nonsurgical treatment of inoperable aortic aneurysms based on the observation of an excluded pseudoaneurysm [12, 13]. Maass was less enthusiastic because in his experiments he noted high-grade stenoses in tightly wound spirals. However, these experiments proved neointimal covering and patency of a metallic scaffold within the arterial system provided that its interstices were wide. Two problems remained to be addressed: First, the potential of the devices to expand, and second their equipment with sealing characteristics. In 1984 Lemole treated fifty-five patients with aortic aneurysms and dissections