Electrical Potentials between Stent-grafts Made from Different Metals Induce Negligible Corrosion

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WHAT THIS PAPER ADDS

Galvanic corrosion might, hypothetically, result in deterioration of a stent-graft. If this were the case, this would be disastrous for a patient after implantation of stent-grafts made from different metal alloys. Additionally, direct proof of whether electrical potential has any influence on damage to stent-graft frames has not yet been shown in previous studies. In our study, we detected that there was electric potential between the different stent-graft frames. However, negligible corrosion was found after 2 years of incubation. This fact makes the simultaneous deployment of stent-grafts with unmatched metal frames more acceptable.

Objective: Evaluation of the risk of galvanic corrosion in various stent-grafts in current practice, when devices with unmatched alloy compositions are deployed together.

Method: Five nitinol (NT) and two steel (SS) stent-grafts produced by different companies were used in different combinations to create 21 samples (NT:NT, $n = 10$; NT:SS, $n = 10$; SS:SS, $n = 1$). Electric potential was measured between the metal couplings after immersion in 0.9% NaCl at a temperature of 37 °C. Subsequently, the same samples were incubated for 24 months in 0.9% NaCl at 37—39 °C under hermetic conditions and examined under a scanning electron microscope in order to search for any evidence of corrosion.

Results: Electric potentials between different metals alloys were found (means: NT:SS, 181 μV; NT:NT, 101 μV; SS:SS, 160 μV). The mean electrical potential between stainless steel and nitinol samples was significantly higher than between NT:NT couplings ($p < .001$). During the final scanning electron microscope examination, only one spot of pitting corrosion (>10 μm) on a nitinol surface was found (associated with previous mechanical damage) in an NT:SS sample after 24 months of incubation in vitro and no sign of mechanical failure of the wires was found.

Conclusion: Direct contact between the stainless steel and the nitinol alloys does indeed create electrical potential but with a minimal risk of galvanic corrosion. No evidence was found for significant galvanic corrosion when two endovascular implants (stent-grafts) made from different metal composition were used in the same procedure.

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INTRODUCTION

Corrosion of nitinol and stainless steel is believed to be the reason behind damage to stent-graft frames while in the human body.[1–4] Corrosion of nitinol alloy has been observed close to a platinum marker.[1] Theoretically, electrical potential might appear between different metal alloys, thus causing corrosion.[4,5] If this were true, the possibility for future mechanical failure would be dangerous for a patient with stent-grafts implanted with unmatched alloy frames. Direct contact between different metals after implantation of one stent-graft is not very common. This is because most of the stent-graft has an external nitinol frame and thus the fabric works as an electrical isolator. Nevertheless, different metals may accidentally make contact under the following circumstances. For example, if an additional stent or stent-graft is implanted into the proximal free flow of the first stent-graft to treat type I endoleak, or if a stent-graft iliac extension comes into contact with a stainless steel stent that has been implanted previously into the orifice of a common iliac artery. Such a situation has been observed while treating thoraco-abdominal aneurysms (by the chimney or branched techniques). Additionally, different types of metal might come into contact with each other if the fabric of the stent graft has become damaged. This situation might be especially common

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after implanting a bare stent into an iliac extension in cases of restenosis or bending of the stent-graft leg. Accidental unmatched alloy contact is observed after the simultaneous deployment of an XL stent to an aortic arch together with a stent-graft to the descending aorta in the case of its dissection. All the above-mentioned situations have occurred in our practice. Furthermore, no direct proof of electric potential and the presence of galvanic corrosion between different stent-grafts has yet to be confirmed, either in vitro or in vivo. Our study is therefore an attempt to bridge this gap in understanding. There were two basic aims: first, the measurement of electric potential between different metal alloys from different stents and stent-grafts after immersion in electrolyte solution; second, measurement of the corrosion on the surface of the samples after 24 months of in vitro incubation using a scanning electron microscope.

MATERIAL AND METHODS

We made use of seven samples from stent grafts and stents of five types: one sample from a Cordis stent (stainless steel, SS) (Cordis Corp., Hialeah, FL, USA), three from Gore (Gore 1, Gore 2, Gore 3) stent-grafts (nitinol, NT) (W. L. Gore & Associates, Flagstaff, AZ, USA), one from a Jotec stent-graft (NT) (JOTEC AG, Muri, Switzerland), one from a Medtronic (Minneapolis, MN, USA) (NT) stent-graft, and one from a Cook (Bloomington, IN, USA) stent-graft (SS). In order to create the samples for the experiment we took the rings from each stent-graft. Any fabric was removed completely. From these samples 21 couplings (test group) were created: NT:NT, 10 couplings; NT:SS, 10 couplings; SS:SS, one coupling. Additionally, seven couplings consisted of samples taken from the same stent-grafts creating the control group (Table 1). All of these were incubated under the same conditions (immersion in 0.9% NaCl solution at 37 °C). Electrical potential was measured between a metal coupling after 10 minutes of complete immersion, to achieve a stable and constant temperature at any part of the apparatus. In order to measure the voltage a Data-Logging System (DLS; Universal Data Login System BS85x version 5.1.0.4 Copyright© BTC 2002) was connected to a voltmeter (Brymen BM857a, BIALL, Gdansk, Poland). Characteristics of the measurement system were impedance/capacitance, 10 MΩ/30 pF; accuracy of voltage measurement, 1 µV. Gold electrodes, which allowed improved contact, were used to connect the measurement system to the metal couple, but were not immersed into the electrolyte (Fig. 1). A 1-mm-wide ebonite isolation spacer was utilized in order to maintain a small and constant space between the examined metals. Every measurement lasted 12 seconds and was repeated every 10 minutes initially up to a maximum of five times. (In the control group only one measurement was performed to confirm the lack of any potential differences.) If the five results differed by more than 10% more measurements were made until five results were obtained differing by less than 10%. The two most extreme values were then removed before calculation of the mean from all remaining values.

In the second part of the experiment incubation and further scanning electron microscopy was carried out on samples prepared from the stent-grafts which had been used for the voltage measurements. These samples were prepared by cutting out metal wires from both stent-graft frames (Fig. 2). The area to be examined by scanning electron microscope was 1 mm in length and was located in the middle of the sample. The margin of the examined area was marked mechanically using pliers with an impression. The average length of the wires in the sample varied between 7 and 10 mm.

The initial scanning electron microscope (20 kV, magnification 1,000× and 1,300×) was conducted using the marked areas of every wire. Afterwards the pieces of wire were connected with the use of a 5-0 Polypropylene surgical suture, using five throws to fix the sample (Fig. 2). All samples were immersed in 0.9% NaCl, making sure there was no air inside

Table 1. Electric potentials between different metal couplings.

Alloy		NT					SS	
	Stent-graft manufactureer	Jotec	Medtronic	Gore 1	Gore 2	Gore 3	COOK	Cordis
NT	Jotec	0 µV n=1	30 µV 2.9 SD n= 5	73.8 µV 7.04 SD n= 5	120 µV 10.0 SD n= 3	80 µV 7.75 SD n= 5	200 µV 19.03 SD n= 5	212.67 µV 23.08 SD n= 6
	Medtronic		0 µV n=1	187 µV 18.39 SD n= 5	171,2 µV 15.0 SD n= 5	180 µV 5.0 SD n= 3	128 µV 10.37 SD n= 5	125.3 µV 12.19 SD n= 6
	Gore 1			0 µV n=1	100 µV 9.58 SD n= 5	19.8 µV 2.0 SD n= 5	150 µV 6.0 SD n= 3	210 µV 13.59 SD n= 5
	Gore 2				0 µV n=1	80 µV 7.0 SD n= 3	163 µV 10.41 SD n= 3	176.8 µV 16.31 SD n= 5
	Gore 3					0 µV n=1	250 µV 18.46 SD n= 5	179.8 µV 14.35 SD n= 5
SS	COOK						0 µV n=1	160 µV 0.0 SD n= 3
	Cordis							0 µV n=1

Note. Green = control group (metal coupling from the same stent-graft); yellow = NT:NT, coupling with nitinol and nitinol; orange = NT:SS, coupling with nitinol and stainless steel; dark yellow = SS:SS, coupling with stainless steel and stainless steel; n = number of voltage measurements; NT = nitinol; SS = stainless steel; SD = standard deviation.