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COMPARISON OF THE MECHANICAL PROPERTIES OF THE STEEL GUIDES CARDIOLOG

M. Andryszczyk[*], A. Andrzejewska[**], T. Topoliński[***]

Abstract: *This article demonstrates results of the tests of mechanical properties of steel guidewires used in cardiac surgical procedures. The established research methodology embracing specimen geometry and simulated operating environment allowed determining the maximum strength of a guidewire during surgeries. The results of the tests were subjected to statistical analysis, on the basis of which the differences in mechanical strength of material were determined. Results indicate differences in the strength of cardiac guidewires which are in the same group characteristics and end uses. This study considered on three types of steel guidewire strength: Amplatz Ultra Stiff; Lunderquist Extra Stiff; Back – Up Meier Steerable. The AMPLATZ guidewire showed the lowest tensile strength, stiffness and the highest torsion with Young's modulus. The BACK – UP MEIER guidewire has very similar properties to the LUNDERQUIST guidewire.*

Keywords: Guides, Cardiolog, Mechanical properties, Medical applications

1. Introduction

Technological development and the changing lifestyle in highly developed countries result in the occurrence and higher incidence of the so-called civilisation diseases. One of such diseases is sclerosis, which can result in ischaemic heart disease, cardiac infarction and at worst in death. Progressing atherosclerotic plaque is a long-term process that begins as early as in childhood. That is why, introducing preventive actions from as early as possible is very important.

When it comes to the already advanced arteriosclerotic vascular disease, the constantly developing vascular surgery is applied. The most commonly used is angioplasty, which is a procedure that makes a blood vessel passable, using a balloon or a stent. In the first case, after inserting a balloon, it is inflated in order to widen the blood vessel diameter, and then it is removed. The second method, which uses a stent, involves decompressing a balloon with a small metal spring (stent) attached to it, which, after being extended, permanently expands blood vessel diameter.

Requirements concerning medical equipment specified in international standards provide strict conditions that the equipment must meet in order to be applied in treatment. When it comes to guidewires, the most significant factors are the precision in reaching to the location of stenosis (which depends on its rigidity), torque, bend strength, and proper durability (so that the guidewire does not break during a surgery). Furthermore, it is also extremely important to select proper material of the guidewires to meet the expectations of medical professionals (Murray, 2006, Sarkissian, 2012).

There are many kinds of angiographic guidewires, which differ in terms of material, type of guidewire tip and coating. These aspects affect not only the appearance of guidewires, but, above all, their mechanical properties. During a surgery, it is very important to match the equipment to a given clinical case (Murray, 2006, Sarkissian, 2012).

[*] M.Sc. Eng. Marek Andryszczyk: Faculty of Mechanical Engineering, UTP University of Sciences and Technology in Bydgoszcz, Al. Prof. S. Kaliskiego 7; 85- 796, Bydgoszcz; PL, Marek.Andryszczyk@utp.edu.pl

[**] M.Sc. (Eng.) Angela Andrzejewska: Faculty of Mechanical Engineering, UTP University of Sciences and Technology in Bydgoszcz, Al. Prof. S. Kaliskiego 7; 85- 796, Bydgoszcz; PL, Marek.Andryszczyk@utp.edu.pl

[***] Prof. Tomasz Topoliński: Faculty of Mechanical Engineering, UTP University of Sciences and Technology in Bydgoszcz, Al. Prof. S. Kaliskiego 7; 85- 796, Bydgoszcz; PL, Tomasz.Topolinski@utp.edu.pl

The analysed aspects make it necessary to define common possibilities and expectations for the materials used in medical guidewires. In order to implement new and to improve the existing treatment methods, the equipment we use must be improved.

Guidewires used in coronary angioplasty should be flexible due to difficult access to the location of stenosis and small artery sizes. When it comes to introducing stents/stent grafts to larger blood vessels, guidewires with more rigid body will be used. This is because peripheral arteries have larger lumen and require larger catheters which will carry heavier elements, such as stent grafts (Murray, 2006, Sigwart 2015).

Also, when there are large calcified atherosclerotic deposits, it is necessary to use rigid guidwires, as excessively flexible ones would not be able get through the narrowings, which would make it impossible to introduce a stent or decompress a balloon.

We should also remember that a guidewire should not damage vascular walls and atherosclerotic plaque. It may lead to the risk of tearing off a part of the plaque or forming clots which may cause sudden closure of vascular lumen in other location. Therefore, guidewire tip has been designed to be more flexible than guidewire shaft. Another characteristic element is the shape of tip, which can be curved (J-shaped) to facilitate passing through vascular branching points. However, it can also be straightened by applying force in order not to damage the vessel.

The knowledge of properties and mechanical strength of guidewires may considerably facilitate the work of doctors. The results obtained will help a doctor to select an optimum guidewire suitable for a given clinical case.

It happens quite often that stenosis is so advanced that a flexible guidewire is not sufficient to pass through the narrowed vessel diameters. Knowing the mechanical properties of guidewires may prevent a wrong choice of equipment and lower the cost and duration of a surgery.

2. Purpose

This paper is aimed at comparing physical and mechanical properties of angiographic guidewires used in artery angioplasty procedures.

3. Materials and Methods

3.1. Material characterisation

This paper describes a study on steel guidewire strength. Three types of guidewires were used: Amplatz Ultra Stiff; Lunderquist Extra Stiff; Back – Up Meier Steerable.

The table below describes feathers of the guidewires used in the study.

Tab 1. Guidewire parameter

Name:	Coating	Length [mm] / diameter [mm]	Type and length of tip
Amplatz	PTFE	2600 / 0.89	J-type tip, 70mm, radius 3 mm
Lunderquist	TFE	2600 / 0.89	Straight tip, 40mm
Back – Up Meier	PTFE	3000 / 0.89	C-type tip, 110mm

Tests were carried out on specimens which were fragments of core wires of the above listed guidewires. Distal parts (tips) were not used in the study because of too little number of specimens. Appropriate lengths of specimens were established based on standards that govern the tests. Lengths of specimens were: 220 mm for tensile test, 67 mm for torsion test.

3.2. Figures and tables

Material characterisation results were processed with the STATISTICA 12.5 software. Consistency of distribution of the tested parameters with normal distribution was determined with the Shapiro-Wilk test. For further analysis, parametric and non-parametric tests were employed. Statistical significance of differences among the obtained results was determined with one-way analysis of variance (ANOVA) and by way of the Tukey multiple comparison test. Correlation analysis was performed with the Pearson test. Level of significance $p<0.05$ was assumed as statistically significant.

4. Results and Discussion

Studies aimed at acquiring detailed knowledge on the properties of angioplasty guidewires are carried out worldwide. Most of them are concerned with the same properties as these analysed in this paper.

Guidewires of the same group and intended purpose should be characterised by very similar or even identical strength parameters. Differences may depend on a manufacturing method, coating or addition of trace amounts of other elements to the alloys in order to improve their qualitative parameters (Sarkissian, 2012).

This paper is focused on steel guidewires only, which belong to rigid guidewires. The obtained results show differences between guidewires which should have very similar strength characteristics. The analysis of the data demonstrates that the three guidewires concerned considerably differ from one another, which translates into their practical application during surgeries (Maguire, 2005).

The above test results have been obtained during strength tests and demonstrate differences among the selected guidewires. Tests were carried out in identical conditions. It should be noted that the coating of the AMPLATZ guidewire were removed due to its spring-like structure.

The statistical tensile test showed that elongation of all the guidwires reached similar levels. However, significant differences were observed when it comes to breaking force, Young's modulus and rigidity.

Breaking force indicates which guidewire has the highest tensile strength, which may be a key feature if a guidewire becomes wedged in a vessel. The LUNDERQUIST guidewire showed the highest tensile strength and the AMPLATZ guidewire – the lowest.

The highest Young's modulus, was demonstrated by the AMPLATZ guidewire, and the lowest by the BACK – UP MEIER guidewire. The situation is opposite when it comes to rigidity. AMPLATZ is characterised by the lowest rigidity.

During the torsion test carried out until the point of breaking of guidewire, the highest angle of torsion (almost two times higher) was also observed in the AMPLATZ guidewire, with means its torque is two times lower than in the LUNDERQUIST and BACK – UP MEIER guidewires.

Availability of different types of material for manufacturing guidewires may be both very practical (possibility to match a guidewire to a given clinical case) and problematic (too many possibilities make the selection process more difficult and longer). Therefore, the optimum solution would be to make a guidewire, using material which is universal and which would be suitable for both large stenoses and those difficult to reach. This will lead to reduced costs and complications of the procedure due to the use of only one guidewires during surgery, instead of several as at present.

Tab 2. Aggregated results medium parameters obtained from research

Nazwa	AMPLATZ	LUNDERQUIST	BACK - UP MEIER
ΔL [mm]	3.4	3.5	3.3
Fm [N]	850.4	1268.2	1130.5
Young's modulus [MPa]	2341.5	2085.1	1858.7
Stiffness [N/mm]	427.2	675.1	653.1
Torsion [°]	4871.3	2993.3	2804.4
Torque [Nm]	0.1	0.2	0.2

5. Conclusions

The highest rigidity of the tested guidewires is demonstrated by the LUNDERQUIST guidewire, and therefore it will be the optimum choice for restoring patency of vessels with a high number of stenoses.

Thanks to the best elasticity and the lowest torque, the AMPLATZ guidewire can be used for smaller stenoses which are hard to reach. The lower torque means better controllability of the guidewire.

The BACK – UP MEIER guidewire has very similar properties to the LUNDERQUIST guidewire, which leads to the conclusion that they can be used interchangeably. These guidewires have different coating, which may be a key-factor when it comes to choosing the right one.

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