Chapter 170

Stent and triple stent accommodation in aorta anomaly and length change. Case study

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1 INTRODUCTION

To improve public health, multidisciplinary teams of engineers and physicians work in various medical [1-3] and materials sectors in the development of new biomedical materials such as prostheses [4-5], as well as medical instruments [6] and development of technologies to improve the level of lives of patients who need these devices and solutions for different diseases.

For example, aortic aneurysms are a disease that can generally endanger the lives of patients, hence the importance of improving materials and endovascular treatment techniques through the successful repair of aortic aneurysms using stents, which is an endoprosthesis, implanted in the aorta, which allows the exclusion of the aneurysm and the revascularization of the arteries [7]. Visceral artery aneurysms and visceral artery aneurysms can be defined as aneurysms that affect the celiac, superior or inferior mesenteric arteries and their branches and are relatively rare. The arteries most commonly involved with aneurysms are the splenic and hepatic artery and can be life-threatening conditions with a high incidence of rupture and hemorrhage [8].

It is known that the aorta is considered the main artery of the human body and has the function of taking blood from the heart to the organs [9]. Aneurysm is when an artery wall dilation occurs, manifesting a permanent variation of at least 50% more than the normal diameter caused by various causes[10]. Vascular problem that is the cause of higher mortality and is repeated more in male patients than in females, more frequently after 50 years of age. Results of research and studies report that in Brazil, about 4% of the population suffers from the problem and, in people over 60 years old, the percentage increases to 6%.

Serious disease, more easily detectable, which when treated at the right time and correctly, presents good results, with very low post-surgery complications. [9]

Most patients are asymptomatic, and the presence of an aneurysm is common, with the potential for significant morbidity and mortality., It can be diagnosed by abdominal imaging studies for another purpose, or through ultrasound screening programs for abdominal aortic aneurysm (AAA) [10]. Usually when symptoms do occur, patients present with back pain, abdominal pain, or thromboembolism may occur, leading to symptoms of limb ischemia. Aneurysms that produce symptoms are at increased risk of rupture, which is associated with high mortality rates.

The correction of more than 80% of aortic aneurysms is with the use of stent implantation by endovascular route as an advance in vascular surgery [11]. The stent is a kind of metallic structure, which can be covered with an expanded polytetrafluoroethylene (ePTFE) film, composed of rings that can be either individually assembled or sequentially accumulated in a repeating pattern, rings that can simply be coupled to each other. , similarly to the Gianturco stent (Cook). The main stents can be manufactured in stainless steel 304 SS, 316 L SS, tantalum, elgiloy (SS), platinum, cobalt alloy and the most used, nitinol[8]. Dyet&Schurmann[9], cite the stainless steel stents of the series 316 L. Nitinol is defined as a nickel and titanium alloy with thermal memory properties, this property allows it to be tightly compressed within a delivery system, to expand after release from its delivery system into the bloodstream. Nitinol is the acronym of Nickel-Titanium Naval Ordinance Laboratories, developed for military purposes [9], which was used for the first time in 1985 in a prototype endoprosthesis consisting of continuous mesh expandable by a stainless steel balloon [11].

Modifications to the original design of these devices have resulted in a subsequent generation of endoprostheses under constant clinical evaluation. Endoprosthetic works were described by Rosseau (1987) [12]. who described the endovascular device as made of stainless mesh, with an adjustable guide inside.

Abdominal aortic aneurysm can be considered as the third cause of sudden death, mainly in elderly men. Science shows that the presence of symptoms increases the risk of a ruptured aneurysm. For most patients with symptomatic aneurysm, repair should be performed as the most viable alternative. Studies show that in the United States, for example, rupture of an abdominal aortic aneurysm (AAA) occurs in approximately 4,000 patients per year. [11].

Endovascular aneurysm repair (EVAR) is an advance in the treatment of abdominal aortic aneurysm that is performed by inserting a prosthesis or stent through the lumen of an access vessel, usually the common femoral artery, after implantation in the area of the aneurysm is released. and expands, coming into contact with the aortic wall and iliac vessels to exclude the aortic aneurysmal sac from aortic blood flow and pressure. The increased use of EVAR favors a decrease in the incidence of ruptured AAA and associated morbidity and mortality, probably due to the ability to offer EVAR to patients who otherwise would not be candidates for open surgical repair [13,14].

Abdominal aortic aneurysm, is common with potential for significant morbidity and mortality for most patients with this disease, diagnosed through ultrasound screening programs for AAA [15]. Of the majority of patients with a ruptured aneurysm who come to the hospital for treatment, between 30 and 50 percent die in the hospital [16,17].

Since the approval of graft devices for use in the United States, there has been a significant increase in the annual number of EVAR procedures performed, with EVAR accounting for nearly half of AAA repairs. [18,19]

In EVAR, the surgeon first inserts a catheter into an artery in the groin (upper thigh) and threads it into the aneurysm. Then, using an X-ray to see the artery, the surgeon threads the stent into the aorta as far as the aneurysm. The stent is then expanded within the aorta and secured in place to form a stable channel for blood flow. This endoprosthesis reinforces the weakened section of the aorta to prevent aneurysm rupture. The incidence of long-term complications and the need for reinterventions after EVAR remain a concern. State-of-the-art endoprostheses show encouraging results in the short and medium term, but a complete analysis of their long-term performance is needed [20,21].

The robustness of the area of overlap between the aortic wall and the stent is a determining factor for the long-term durability of the aortic endovascular repair [22,23]. Stent graft migration has a reported prevalence ranging from 1.1 to 28% [24 ,25]. It is responsible for most late complications after EVAR, including late endoleaks related to the stent, resulting in enlargement of the aneurysmal sac and even rupture [26,27]. Different mechanisms, such as radial forces of self-expanding stents due to oversizing and pulsatile blood flow forces, have been suggested to be associated with continuous changes in stent position and decreased stent surface apposition, consequently causing migration to the stent. over time. Furthermore, disease progression can trigger and accelerate both mechanisms [28,29]. The dynamics of the endoprosthesis over time is complex and three-dimensional.

Clinical outcomes have improved significantly over the past 20 years. Differences in outcomes, as well as overall costs tied to lifetime monitoring and late complications and reinterventions, still require ongoing comparison with prior devices and the historically proven open surgical repair. [30] [31]. An overview of stent technology in the treatment of aneurysms, has trends of new developments in its fabrication technologies [32].

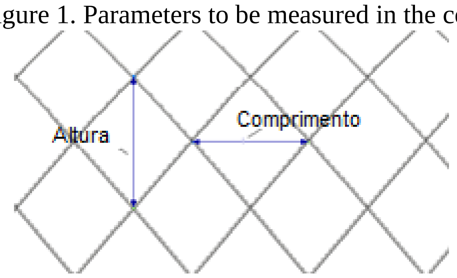
New studies of the possibilities of obtaining results that facilitate more viable solutions for patients who wait in long queues to have this medical alternative to face this type of disease. In the state of Amazonas, for example, the presence of aneurysms is common, with the potential for significant morbidity and mortality and manifests itself as a cause of sudden death, mainly in men over 65 years of age, associated with the lack of availability and possibilities of implantation of the stent for all patients who need this solution as an alternative and in relation to the technological and manufacturing specificities and that on average the cost of the endoprosthesis is still much higher compared to open surgery.

In the present work, a tool is sought in order to assist the medical procedure by predicting the change in the length of the stent determined by the aneurysm and its spatial behavior, whose idea arises as part of a field research related to the implementation of the Triple Stent technique where one of the important variants is the determination of the final length of the stent that are used and that will depend on the deformation of the aneurysm in each patient. Necessary information for physicians to have a response prior to the implantation of the result in relation to covering the entire anomaly of the artery.

2 DETERMINATION OF THE MATHEMATICAL EQUATION

In the study carried out, the parameters for the experimental analysis are determined from the selection of the cells of the stent where the variables of length and height are defined according to the spatial orientation of the cells, and thus the relationship between the variation in the length and height of each cell is obtained determined by the length and diameter of the stent. For the study, two different diameters were selected and several measurements were performed on the cells with changes in the radial and longitudinal directions (Figure 1), and the relationship between height and length was evaluated in establishing the mean values.

Figure 1. Parameters to be measured in the cell



To study the changes in length in relation to the variation in diameter, using a tube with a diameter of 10 mm in diameter and 30 mm in length, and the stent is introduced to measure the parameters in the cell according to the variation and deformation of the cells. transition zone with the aid of a profile projector for reading the measurements of each cell in 10 repetitions (Figure 2).

Figure 2. set-up of the experimente

With the results of the measurements and the variables of length and height, the average value for the parameter is established and is considered as a fixed value for that cell for the averages (Table # 1), and establish the parameters. the variables Nx and Ny.

Nx: number of cells in a row on the X axis (longitudinal to the 3D model).

Ny: number of cells in a column on the Y axis (axial to the 3D model).

Considering that the cross-section is the result of multiplying this average height by the number of cells distributed in diameter in a plane that crosses the circumference.

For the case in question, the values of Nx= 27.5 and Ny= 18,

Table 1. Values in mm for the height and length variables of cells at rest

CELL (AT REST)	
X	Y
5,6090	6,4800
5,5665	6,4930
5,6800	6,5300
5,5485	6,2920
5,2635	6,4370
5,4525	6,7055
5,4730	6,5710
5,3865	6,8490
5,2390	6,6895
5,3190	6,5555
MÉDIA X (Ẋ)	MÉDIA Y (Ẏ)
5,4538	6,5603

Table 1 shows the relationship between height and length of the cell without deformation in the recovery stage of the stent's physical memory and the value of Ẏ is 6.56 mm.

The data is processed in Excel and the graphic behavior is defined considering that the function was obtained by linear regression, a 3rd degree polynomial type that presents more precision than a linear function and thus opts for the deformation formula for each cell to establish the relationship with the total deformation of the stent. (Equation 1)

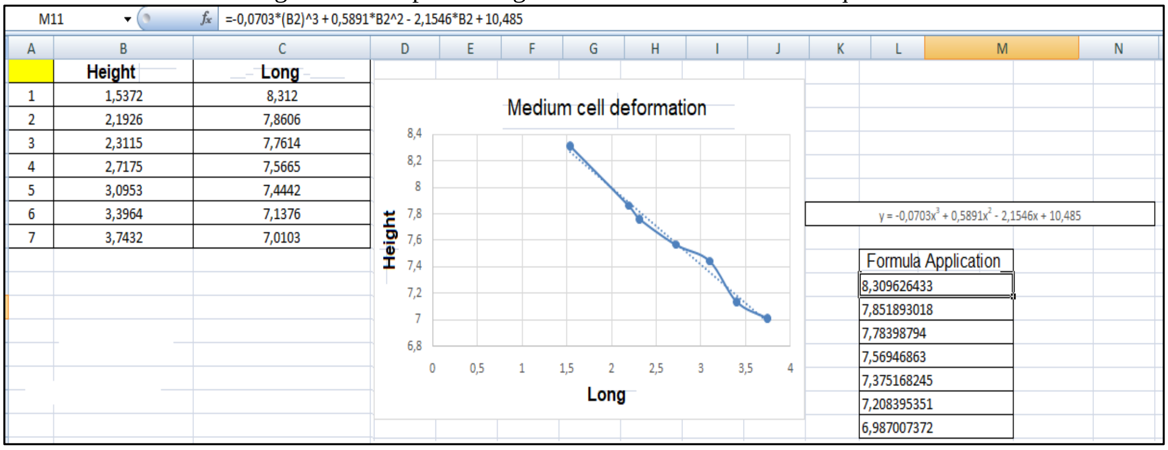
$$\textit{Equation 1}:\ \boldsymbol{d = \frac{N_{y*}\dot{Y}}{\pi} = \frac{18*6{,}56}{3{,}14} = 37{,}58mm}$$

The value of 37.58 mm is the value that corresponds to the real diameter of the stent in the nitinol memory recovery state after recovering from the deformation to be inserted in the 10 mm tube.

The range of stent length for an insertion diameter depends on the data in Table 3.

As a criterion for evaluating the adherence of the formula, it is applied as a test, equation 1 with the data obtained and the calculated values are very similar to the averages of the measured values.Figure 2.

Figure 3. Data processing to obtain the mathematical equation



	Height	Long
1	1,5372	8,312
2	2,1926	7,8606
3	2,3115	7,7614
4	2,7175	7,5665
5	3,0953	7,4442
6	3,3964	7,1376
7	3,7432	7,0103

Formula Application
8,309626433
7,851893018
7,78398794
7,56946863
7,375168245
7,208395351
6,987007372

Equation 2: L=-0,0703(B2)^3 + 0,5891*B2^2 - 2,1546*B2 + 10,485*

With the results and the definition of the mathematical equation, it is possible to estimate the change in the linear length of the stent as a result of the variation in the insertion diameter that depends on the aneurysm.

Considering (B2), our variation ratio of the deformed cells on the axial axis, substituting in equation 1, is defined:

$$\text{Equation 3: } \boldsymbol{d} = \frac{N_{y*}B_2}{\pi}$$

Isolating B_2

$$\text{Equation 4 : } \boldsymbol{B_2} = \frac{d*\pi}{N_y}$$

$$B_2 = \frac{10mm * 3{,}14}{18} = 1{,}75mm$$

When applying this value in equation 2

L=-0,0703(B2)^3 + 0,5891*B2^2 - 2,1546*B2 + 10,485*

L= 5,14mm

Then, with the value of L, the total length of the stent can be predetermined, for example for a diameter of 10 mm the result will be:

Equation 5: Lf= L Nx*

$$Lf = 5{,}67*27{,}5$$

$$Lf=156mm$$

3 CASE STUDY

To analyze the results of the previous study stage, the research is complemented with a case study of a patient who would undergo the triple stent implantation procedure. Aneurysms are lesions that are evaluated using different types of imaging tests. In this case by tomography

Selection of the abdominal aorta artery, with two and three lateral branches - patient tomography using Osirix Lite software.

Figure 4. Tomography in a patient, case study

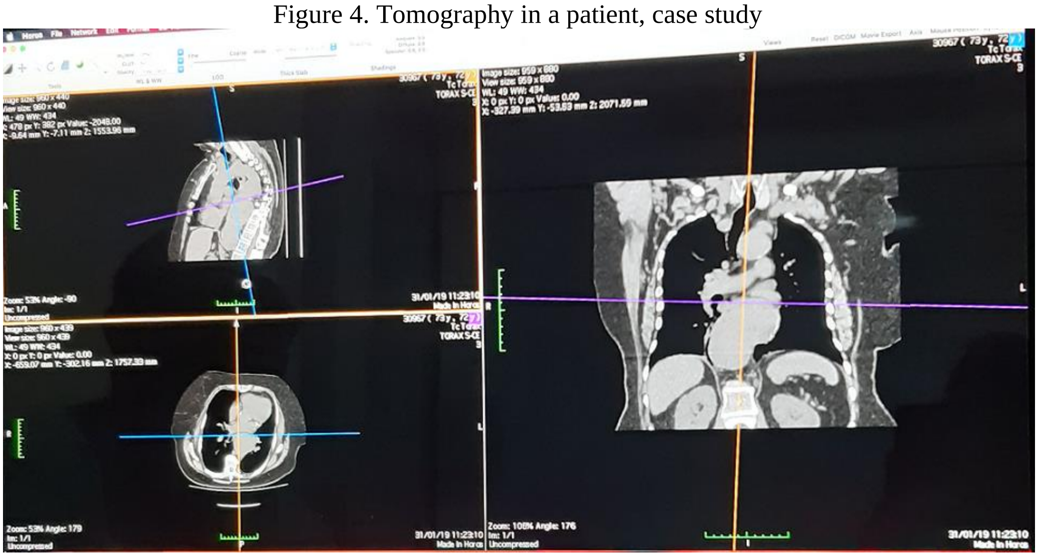


Figure 5. Image of the aneurysm in the patient

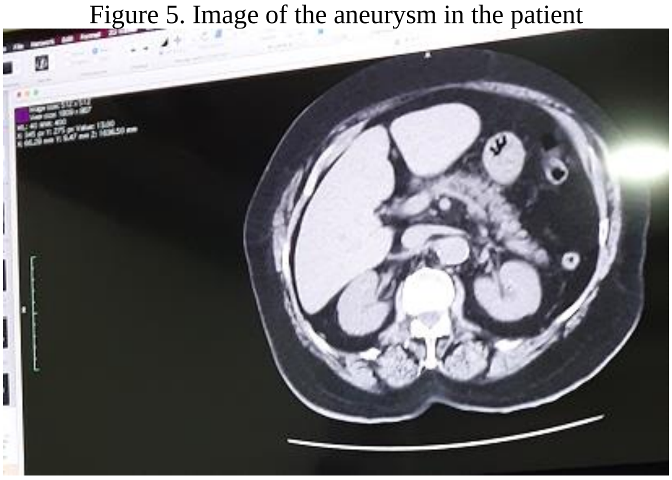


Figure 6. Definition of measurement planes in the arteries seen in the exam

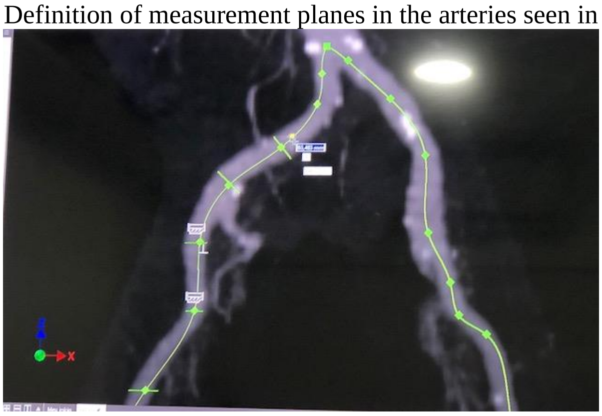


Figure 7. Measured proportional diameter of the aneurysm in the plane

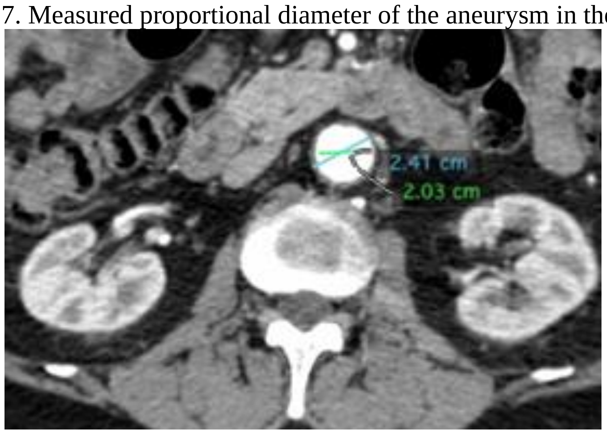
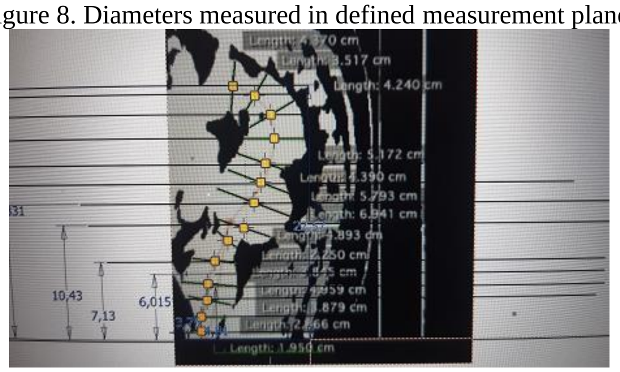


Figure 8. Diameters measured in defined measurement planes



The work makes it possible to create hypotheses that are possible with the data processing in relation to the height and length variables of the deformed cells and to be able to consider the behavior of the relationship of the parameters from the insertion point to the rest zone of the stent that allows to generate a curve in order to be able to deduce a mathematical equation that gives the possibility of relating the variation in height and the length of the cells that allows predetermining the change in length for the stent in the axial axis, with the ease of being applicable for different diameters, as long as the stent responds to this type of geometry. With the processing of images of the aneurysm and the dimensioning for the different planes of cut, it gives the possibility of being able to determine the variation of the length of the stent with the application of the formula resulting from the study.

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