

Nonwoven polypropylene prosthesis in large abdominal wall defects in rats¹

Tela de polipropileno sem tecelagem na correção de grandes defeitos da parede abdominal em ratos

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ABSTRACT

PURPOSE: To evaluate, in large abdominal wall defects surgically shaped in rats, if a synthetic polypropylene nonwoven prosthesis could be used as a therapeutic option to conventional polypropylene mesh.

METHODS: Twenty four (24) Wistar rats were enrolled into three groups. Group 1 (Simulation group) with an abdominal wall defect of 3 X 3 left untreated and Groups 2 and 3, respectively treated with a conventional polypropylene mesh and a polypropylene nonwoven (NWV) prosthesis to cover the breach. At the 45th postoperatively day, adhesion (area and strength) and vascularization of Groups 2 and 3 were evaluated. The histological preparations with Hematoxylin-Eosin, Tricromium of Masson, Picrosirius red and polarization with birefringence, and also the structural analysis of the prostheses carried on by Thermogravimetry and Differential Scanning Calorimetry were also assessed.

RESULTS: There were no significant differences between the Groups 2 and 3.

CONCLUSION: In rats, the polypropylene nonwoven prosthesis showed to be safe and has to be considered as an alternative to conventional mesh manufactured by weaving in the treatment of great defects of the abdominal wall.

Key words: Hernia, Abdominal. Surgical Mesh. Polypropylenes. Tissue, Adhesions. Rats.

RESUMO

OBJETIVO: Avaliar, em grandes defeitos da parede abdominal produzidos cirurgicamente em ratos, se uma prótese sintética de polipropileno sem tecelagem poderia ser utilizada como alternativa terapêutica às telas convencionais de polipropileno.

MÉTODOS: Vinte e quatro ratos foram distribuídos em três grupos numericamente iguais. Grupo 1 (Simulação), no qual um defeito de 3 x 3 cm foi constituído na parede abdominal sem tratamento. Uma tela convencional de polipropileno e uma tela de polipropileno sem tecelagem foram colocadas para cobrir o defeito, nos grupos 2 e 3, respectivamente. No 45º dia de pós-operatório foram avaliadas a área e a força das aderências, além da vascularização. Também foram analisados os preparados histológicos com Hematoxilina-eosina, Tricrômio de Masson e Picrosirius com polarização e birrefringência, além de efetuada análise estrutural da prótese mediante Termogavimetria e Colorimetria Exploratória Diferencial.

RESULTADOS: Não houve diferença significativa entre os grupos 2 e 3.

CONCLUSÃO: Em ratos, a tela de polipropileno sem tecelagem mostrou ser segura e deve ser considerada como uma alternativa à tela convencional manufaturada por tecelagem, no tratamento dos grandes defeitos da parede abdominal.

Descritores: Hérnia Abdominal. Telas Cirúrgicas. Polipropilenos. Aderências Teciduais. Ratos.

Introduction

Surgical repair of major congenital or acquired defects of the abdominal wall such as the incisional hernias and certain congenital diseases represents a major challenge for surgeons. Significantly, the clinical condition of the patient is often adverse and there exists no comparative studies with high clinical and epidemiological evidence to validate one surgical procedure as a golden standard. Often, the biological tissue from the individual patient is used. Alternatively, synthetic material is used with several options available, all based upon evolving scientific and technological advancement.

Reconstruction with pedicle flaps of aponeurosis or muscles like latissimus dorsi, rectus femoris and fascia lata can avoid complications encountered with synthetic material, especially the reaction of foreign body or rejection of the material^{1,2}. However such management often requires the presence of a plastic surgeon in addition to the general surgeon in the operating room. Moreover, biological materials placed as graft or pedicle flaps may generate new defects in the wall of donor sites. It is estimated that approximately one million implants per year are placed globally for abdominal wall defects correction³. Polypropylene monofilament is the most common, yet it must be emphasized that in developing countries such as Brazil, a mesh of 30x30cm costs from US\$ 145 (Marlex[®]) to US\$ 380 (Prolene[®]). The need to fix major wall defects with prostheses creates a common problem in developing countries and most third world nations. In these countries, and especially in rural areas of such countries where health care infrastructure is not integrated into major population centers, health care systems have budget constraints for the purchase and distribution of imported material. Nevertheless, this problem is not restricted to less privileged population. In Brazil, for instance, the insurance plans and health care systems in general do not allow for reimbursement of prostheses and, therefore, patients must acquire it with their own resources. Thus, whether in public or private health care, patients who cannot afford prostheses purchase usually have their surgeries postponed, with a higher risk of complications and an associated increase of hospital expenses.

The polypropylene used in this study, known as nonwoven, or tecido não tecido (Portuguese), tejido notejido (Spanish), tessuto nontessudo (Italian), tissé nontissé (French), vliesstoffe (German), represents a cheaper alternative with a price level around one dollar and a half (USD), for a size of 60 x 60 cm. The structure of the polypropylene is flat, flexible, continuous, autoclavable, without pores or weft filamentary and with the innovation in the union of the filaments by thermal polymerization

process, without weaving. This material has been produced for decades on an industrial scale, and has multiple applications, such as the production of: sheet, soap packaging, inner packaging of shoes (20g/m²) aprons for patients, hats, masks, shoes, protective head seats for airplanes, pillow cases, operative field (30g/m²), pants, mask type duck-billed filters (40g/m²), amongst other applications with greater weight.

This study therefore aimed to evaluate, in large abdominal wall defects in rats, the viability of placement of a synthetic polypropylene nonwoven prosthesis which has a low cost and is easily affordable as an alternative to conventional polypropylene mesh that is widely used as first choice but much more expensive, especially for public health care.

Methods

This study was approved by the Ethics Committee for Use of Laboratory Animals in Research, Education and Extension of Federal University of Rio de Janeiro (UFRJ), registered under number 75/08, according to Brazilian law for animal research and the international standards and guidelines.

The study used 24 female Wistar SPF (free pathogenic species), rats (*Rattus norvegicus albinus*, *Rodentia mammalia*), three months old and weighing approximately 200g. The animals came from the Center for Experimental Surgery, Faculty of Medicine Federal University of Rio de Janeiro, where they were housed in environmentally controlled conditions. The animals had free access to food (trade pattern), and water.

The anesthetic protocol consisted of ketamine (90mg/kg), xylazine (10mg/kg), both intraperitoneal associated with atropine (0.05mg/kg) intramuscularly, without fasting.

The animals were randomly divided into three groups of eight rats each. Group 1 was the Simulation group and went without prosthesis. In Group 1, after a midline abdominal incision 5 cm long, starting 2 cm from the xiphoid process, compromising the skin and subcutaneous tissue, a traumatic defect of the anterior musculoaponeurotic wall and the peritoneum was introduced, covering an area with 3 x 3 cm. The surgical intervention was finished with the synthesis of the skin over the parietal failure with a monofilament nylon 2.0 suture with separate stitches in "x" shape. In Group 2, a synthetic industrial and conventional woven mesh of polypropylene monofilament, macro-heavy, (originally 15 centimeters long by 15 centimeters wide) was used. A traumatic defect in the anterior wall of the abdomen was introduced, similar to Group 1, and a 3 x 3 cm prosthesis was attached to the abdominal wall by a running suture with monofilament polypropylene 3.0,

making sure to cover around the entire abdominal defect. Skin synthesis completed the surgical procedure at the same manner described for group 1. In Group 3, a synthetic polypropylene nonwoven prosthesis (NWV), weighting 40g/m², with white color was implanted. The material was first cut in the standard size (3 x 3 cm), packed in paper Kraft® and then sterilized by autoclaving at a temperature of 134°C for 12 minutes at one atmosphere (ATM). The same surgical abdominal close procedure seen at Group 2 was followed.

Postoperative analgesia with dipyrone (50mg/kg/day), diluted in water was applied for a period of five days. Monitoring consisted of daily inspection of the appearance of the wound searching for hematoma, seroma, local infection, skin dehiscence, evisceration, enventration, incisional hernia, strangulation or death.

At the 45th postoperatively day, the animals were induced to death by sodium thiopental administered intraperitoneally in order to remove fragments of the musculoaponeurotic anterolateral wall of the abdomen, including the prostheses areas (Groups 2 and 3) or surgical scar (Group 1/Simulation). At this time, the presence of any adhesions or other gross intra-abdominal changes such as abscess, volvulus, stenosis, ischemia or necrosis and peritoneal surface vascularization was recorded.

Adhesions (strength and size) or presence of vascularity were classified according to an adaptation of the semiquantitative scoring systems used by Jenkins⁴, Kiudelis and collaborators⁵ (Table 1).

Samples were photographed after cover the abdominal surface with a transparent plastic with square millimetric lines. The results were analyzed with the software Image Pro-Plus[□], version 4.5 in order to estimate the total area of the implant covered by adhesions.

For each group the sum of individual scores was performed. Statistical comparisons between group averages were made by Student t test considering the distribution of the samples with standard Gaussian graph, according to the Kolmogorov-Smirnov test. The scores of adhesion strength and vascularity were analyzed by the Mann-Whitney and the results considered significant for p<0.05.

The samples were fixed in 10% formalin and the prepared sections stained with hematoxylin-eosin (HE), Picrosirius red and Tricromium of Masson for the general evaluation of the inflammatory response, vascular fibrosis, adapted from Soiederer *et al.*¹ (Table 2), and characteristics of the granuloma with a grade score from 0 to 3 (absent, exsudative, with predominance of macrophages and epithelioid cells and fibrotic)⁶.

TABLE 1 - Semi-quantitative scoring system of adhesion and vascularization.

SCORE	STRENGHT OF THE ADHESION	SIZE OF THE ADHESION	VASCULARIZATION
0	No adhesion	No adhesion	No vascularization
1	Loose adhesions released spontaneously	1 - 25% of the prosthesis area covered by the adhesion	With vascularization
2	Adhesions released by moderate traction	26 - 50% of the prosthesis area covered by the adhesion	-----
3	Adhesions firm released by dissection	51 - 75% of the prosthesis area covered by the adhesion	-----
4	Impenetrable like a block of adherences containing solid organ, peritoneum and omentum	76 - 100% of the prosthesis area covered by the adhesion	-----

TABLE 2 - Histopathological semiquantitative grading scale.

GRADE	INFLAMMATION (INFLAMMATORY CELLS)	VASCULARITY	FIBROSIS
0	Absent	Absent	Absent
1 - minimum	Hard to see	Ocasional	Discontinuous in the subcutaneous or in the conjunctive tissue between the fibers
2 - slight	Small aggregates	Light proliferation on the edge of the prosthesis	Discontinuous in the subcutaneous tissue with a little conjunctive tissue between the fibers
3 - moderate	Large aggregates and numerous cells in the prosthesis	Half of the thickness of the prosthesis	Continuous in the subcutaneous tissue with little tissue between the conjunctive fibers
4 - massive	Pronounced inflammatory infiltrate	More than half of the thickness of the prosthesis	Continuous in the subcutaneous tissue with abundance of connective tissue between the conjunctive fibers

Histopathological examination was accomplished with the study of five to 20 cells per field with 100 or 160 times magnification. For photomicrography, a Nikon microscope was used (LABOPHOT-Pol of the Service of Clinical Pathology, University Hospital Clementino Fraga Filho – UFRJ).

The polymers of the two prostheses were compared using the tests of Thermogravimetry (TG) and Differential Scanning Calorimetry (DSC), respectively, using TGA-DSC Q 500 and Q-1000 (dp UNION, BRA). Furthermore, a Transform Infrared Fourier, with the device Varian 3100 FT-IR Excalibur Series was used. These tests were performed in the laboratory at LAPIN-IN, Institute of Macromolecules, COPPE – UFRJ.

The scores were analyzed by the Mann-Whitney and the results considered significant for $p < 0.05$.

Results

In the first 24 hours surgical wounds were intact in all groups but there was one death in Group 1 (Simulation). Seven animals of Group 1 developed ventral hernia after the surgical procedure over the abdominal wall (Figure 1) however, at 48 hours of postoperative period, there was one wound dehiscence. At 72 hours three other dehiscences were noted, one in Group 3 (nonwoven prosthesis) and two in Group 2 (conventional mesh of polypropylene) with infection associated in one of them. These five rats were excluded from the study. No hematoma, seroma, intracavitary abscess, volvulus, ischemia or necrosis was observed.



FIGURE 1 - The iatrogenic ventral hernia is easily seen as a protrusion in the abdomen of the rat.

In Group 1 (Simulation), with respect to the total area of adhesion, all rats had the median score of 1.

Table 3 shows the measurement of the areas of adhesion between intraabdominal structures and the peritoneal surface of the abdominal wall (Figure 2). Significant differences were observed when both group 2 and 3 data were compared with group 1 and with each other ($p < 0.05$). Scores obtained for each animal seen in Table 3 were summarized in Figure 3.

TABLE 3 - Statistical data of area of adhesion (cm²).

Groups	N	Min	Median	Max	Mean	SD	SE
1- Simulation	6	0.40	1.01	1.54	0.96	0.43	0.19
2- Conventional mesh	6	4.43	7.29	9.00	7.04	1.47	0.60
3- NWV prosthesis	7	3.87	6.79	9.00	6.56	1.92	0.72

N- Number of animals of each group, **Min**- Minimum area of adhesion, **Max**- Maximum area of adhesion, **SD**- Standard deviation, **SE**- Standard error

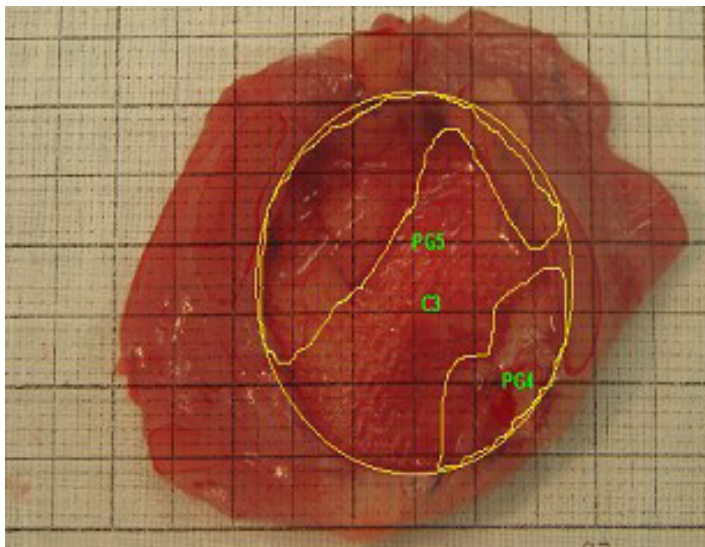


FIGURE 2 - The irregular area inside the circle delineates a peritoneal surface covered by adhesions.

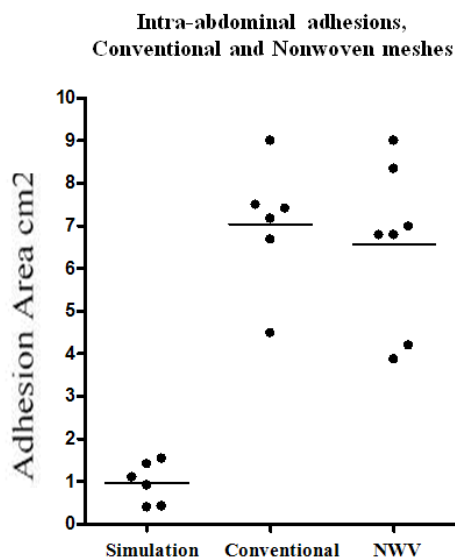


FIGURE 3 - Significant differences ($p < 0.05$) can be observed comparing Groups 2 (Conventional) and 3 (Nonwoven - NWV) with Group 1.

All animals of both Groups 2 and 3 showed inflammatory reaction such as a strange body with giant cells, granuloma formation, without significant differences (Figures 4 and 5). In the Simulation Group (Group 1) all were scored as 1. In Group 3 the connective tissue proliferation with fibrosis was the same observed in group 2 (Figure 6).

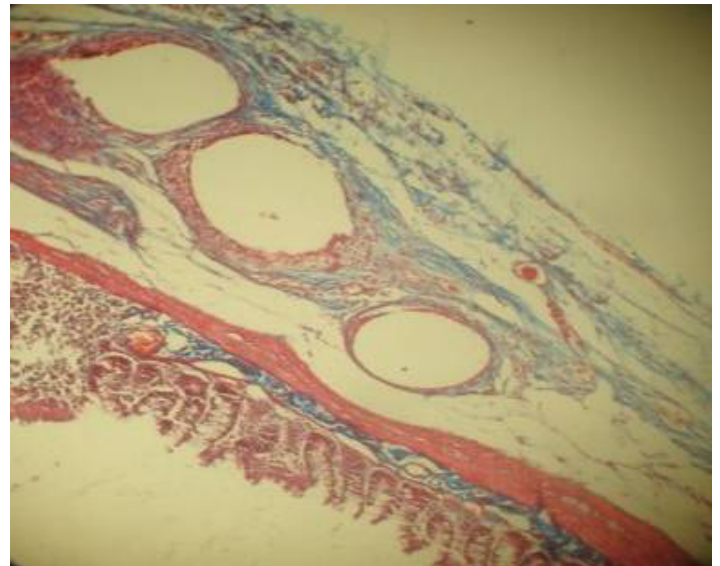


FIGURE 4 - Granulomatous reaction in Group 2, comprising the fibers of the mesh (A), associated with moderate fibrosis (B) and adherence to the intestinal wall (C). Tricromium of Masson 160x.

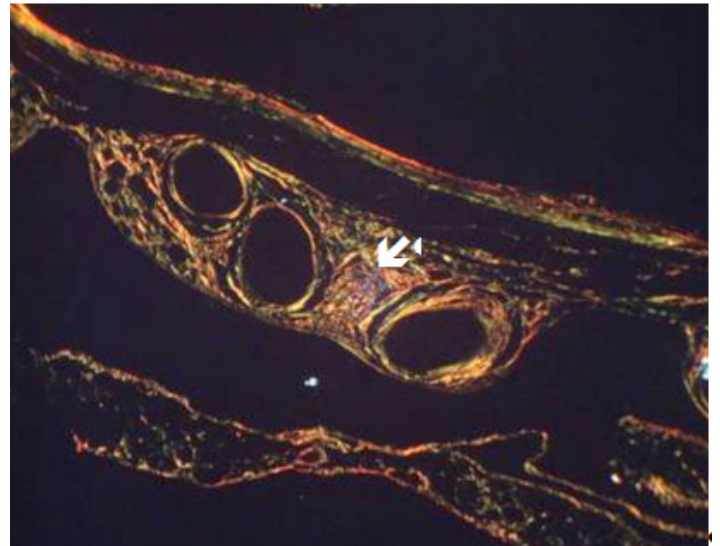


FIGURE 5 - Note numerous collagen fibers (arrow) birefringent with the polarized light amongst the fibers of the mesh (Group 2), featuring moderate fibrosis. Picrosirius red 160x.

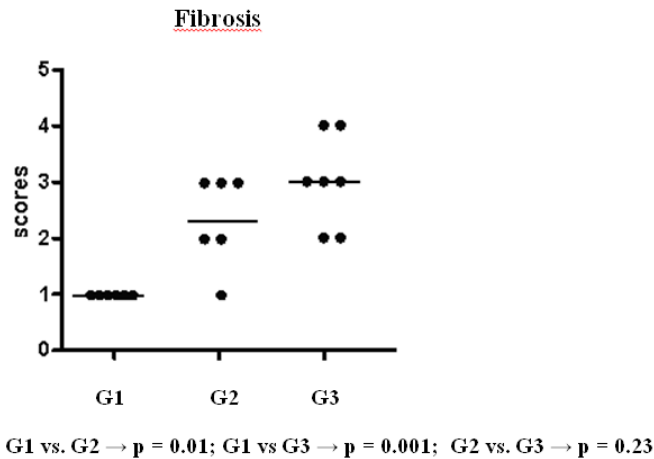


FIGURE 6 - The presence of fibrosis analyzed in all groups by the Mann-Whitney with 95% of confidence interval. There were no statistical differences comparing Group 2 with 3.

At thermogravimetry the polymer of Group 2 showed a beginning of decomposition at 439°C and peaked at 457°C with residual difference of 0.05% (Figure 7). The Group 3 polymer (before autoclaving) procedure revealed the start of decomposition at 435°C and reached a maximum value at 456°C, with residual difference of 2%. After autoclaving (Group 3), the results were respectively at 339°C for the beginning of the decomposition with a peak at 390°C and a decrease of residual decomposition to 1.5% (Figure 8).

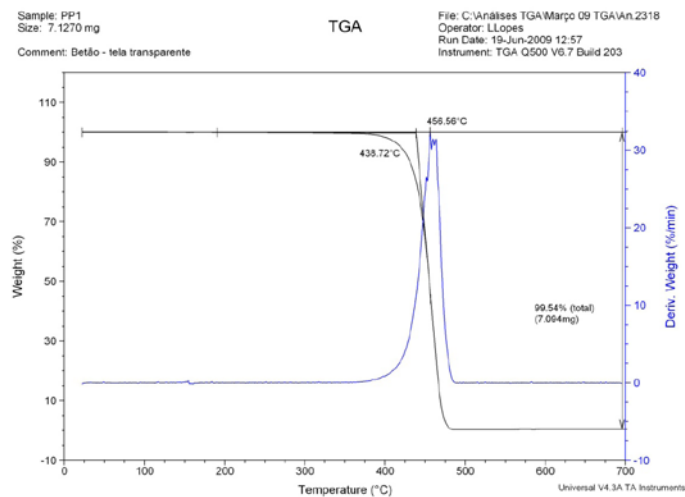


FIGURE 7 - Thermogravimetry of Group 2 showing the beginning of decomposition and the peak value.

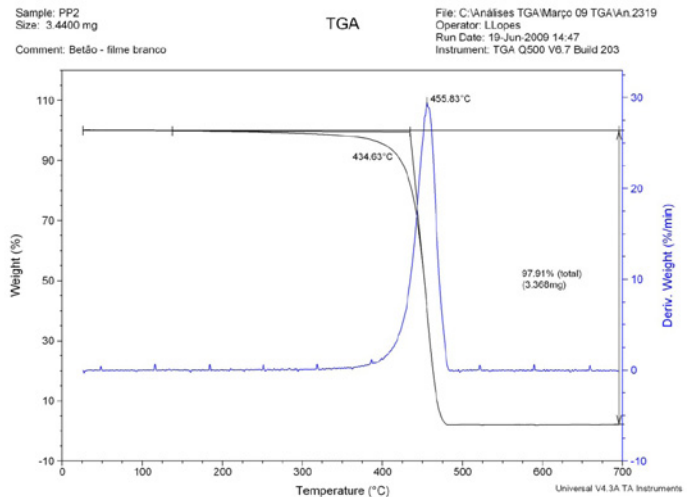


FIGURE 8 - Thermogravimetry of Group 3 also showing the beginning of decomposition and the peak value.

In Group 2, the first curve of Differential Scanning Calorimetry (DSC) showed the first warming of the fusion curve with two coalescent peaks. The second curve expressed the crystallization or freezing which began at 119°C with a peak at 115°C and crystallization heat at 138.4 J/g. The third curve represented the second heating with only one peak of fusion at 161°C, beginning at 156°C and heat fusion at 132.4 J/g (Figure 9). The third group polymer presented in the first heating curve one shoulder and two coalescent peaks. The third group freezing curve was started at 119°C with a peak at 115°C and heating of crystallization at 101.1J/g. The second heating showed one peak and one shoulder (conversion of the second peak) with a major peak at 157°C with fusion heat at 92.66 J/g (Figure 10).

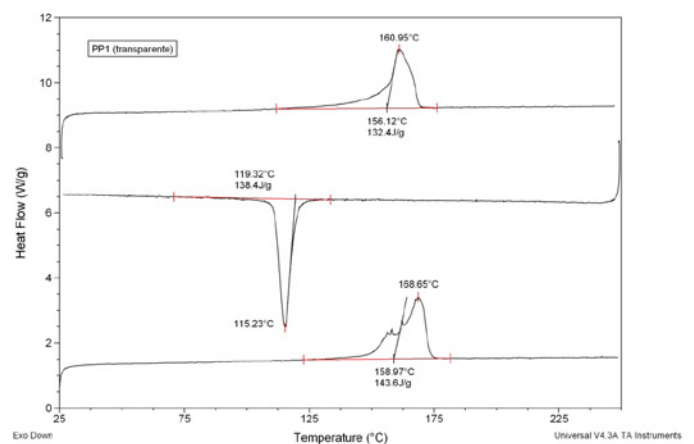


FIGURE 9 - Differential Scanning Calorimetry of Group 2 (Conventional mesh). The bottom curve represents the fusion curve. In the middle the crystallization point and peak. At the top of the graph is the second heating with a peak of fusion.

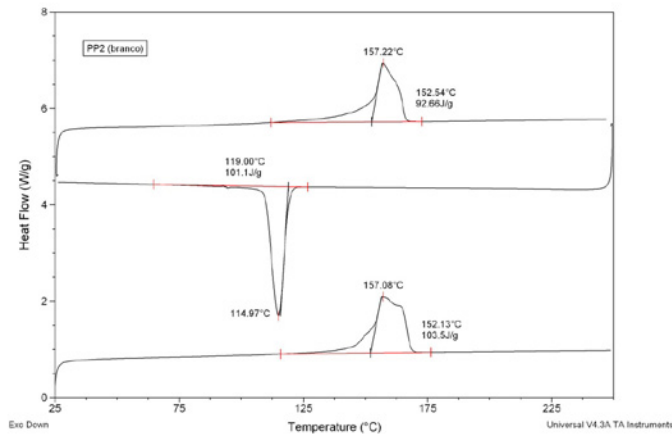


FIGURE 10- Differential Scanning Calorimetry of Group 3 (Nonwoven prosthesis). The bottom curve represents the first heating curve. In the middle the crystallization point and peak. At the top of the graph is the second heating. It was observed no significant differences to Group 2.

Discussion

Treatment of abdominal wall hernias is the most common surgical procedure performed. The physiopathological mechanism consists of weakness of the aponeurosis which creates a local muscular dystrophy or dysmorphisms. Surgical approach is the main cause of large hernias but there exist several others predisposing factors⁷. Congenital anomalies such as gastroschisis and omphalocele are two other relevant wall defects.

Dubay *et al.*⁸ mentioned more than 400.000 cases of incisional hernia diagnosed per year in the United States. These hernias are more common in the first two years after surgery with an incidence of 11 to 20% and risk of incarceration of 25% and strangulation of 8% to 10%⁹. When diagnosed, surgical correction with closure of the parietal defect by reducing the hernial content is recommended, but the reoccurrence of these defects is noted in up to 40% of cases. The repair of large abdominal ventral hernia is still a challenge and in most cases, effective treatment demands a preoperative preparation and the use of prostheses.

Whereas there are many synthetic materials available to fix parietal hernias, there exist few attractive options, especially in the public hospitals. The authors of this experimental research studied a kind of prosthesis similar to a synthetic mesh, cheaper and easily available in the market and even in hospital stock room, that could both be used safely and offer a viable alternative to the treatment of large abdominal wall defects.

The rat was selected as experimental model because it has muscular and aponeurotic parietal layers very similar to human beings. Furthermore, because the animal species used are quadrupeds, their movement increases the pressure placed

on prosthesis or mesh in a way much more active than in animal.

The anesthetic protocol applied consisted of the use of ketamine, xylazine and atropine, similar to other experiments. The anesthetic protocol applied provided good analgesia and adequate time to perform the procedure^{3,5,10,11}. Euthanasia was induced with a sodium thiopental by intraperitoneal, similar to the method used by Cobb *et al.*¹².

Chatzimavroudis *et al.*¹¹, instead of cutting and removing part of muscle and aponeurosis of the abdominal wall, have opted for a large incision in the linea alba with posterior fixation of the mesh. However, this approach does not create a major gap capable of simulating a clinical context of a large incisional hernia with parietal weakening, muscle atrophy or displacement of the aponeurosis. Therefore, the applicability of this model is limited especially concerning to an early formation of ventral hernias.

The synthesis of the skin over the muscularaponeurotic failure in a square shape was effective to create a model of ventral hernia. The Simulation Group (Group 1) showed herniation early in all animals which confirmed the effectiveness of the model.

The treatment of major defect in the ventrolateral abdominal wall usually requires the use of prostheses. Many techniques have been described to minimize the wall tension and to prevent ischemia, disruption of the sutures with recurrence of hernia, eventration or evisceration¹³. Therefore, the decision to place a prosthesis over the large iatrogenic defect in the ventral abdominal wall of rats aimed to mimic a clinical situation. Significantly, the implant needs to be attached to surrounding tissues with sutures. In the absence of such a procedure, the edges of the implant could bend and the prosthesis may well suffer shrinkage or detachment, leading to a predictable recurrence.

It was observed, as a result of the quadruped posture in animals with short distance between body and paws, that there was constant friction of the abdomen of the rats with the bottom of the cage where they were housed. It causes ischemia and consequently wound dehiscence and exposure of the prostheses as seen in four animals from all groups. Furthermore the rodents usually attempt trying to remove, with their teeth or feet, the foreign bodies (wires and knots). Obviously, these conditions predisposed the wound to infection, seen in one animal of Group 2, but without systemic complications. It should be noted that the NWV prosthesis was previously sterilized in an autoclave and its manipulation took place under aseptic conditions. The one death seen just after the first 24 hours was not associated with the infection but occurred as a consequence of respiratory distress due to the anesthesia procedure.

Ansaloni *et al.*¹³ reported that the infection accelerates the degradation of certain prostheses which could lead to failure of the treatment. Abscesses, enteric fistulas, and eventually elimination of the material with formation of incisional hernias discourage the use of certain meshes in the presence of infection¹⁴. Even taking into consideration that the absence of pores in the fabric of NWV prosthesis made of monofilament fibers (unlike multi-filament or pored materials), is less likely to harbor bacteria, no significant differences between the three groups was noticed regarding infected wound dehiscence.

Considering that some parameters evaluated (adhesion and vascularization) may suffer from interpretation bias in the presence of parietal dehiscence or infection with prosthesis exposure or not, all animals with such findings were taken aside from the research.

The conventional polypropylene mesh (Marlex[®]) placed in Group 2, is the most widely prosthesis used for correction of abdominal wall defects. This material has excellent biocompatibility, mechanical stability and elasticity, low tendency to degradation, good integration to the surrounding tissue with the formation of a strong scar tissue and a low susceptibility to infections^{15,16}. The NWV prosthesis is composed of the same polymer of Marlex[®] mesh but it is not manufactured by a weaving process. Instead, the fibers are joined by heat, which produces a nonwoven fabric. The prosthesis is smooth, has white color, does not fade, has a similar thickness of a sheet of paper and is highly flexible and resilient. It has been used increasingly, with various weights and with amazing applicability. The choice of NWV prosthesis with a weight of 40g/m² was done to demonstrate the application of using a material that was easy to access and handle, extremely flexible and cost effective. This material is the same used in hospital masks and surgical aprons. It is suitable to be shaped in different sizes without difficulty and may be cut with common scissors. Cobb *et al.*¹² and O'Dwyers *et al.*¹⁷ stated the advantages of such lightweight fabrics which are well adapted to the host site with minimal traction and less restriction of abdominal movements. They also reduce pain in the postoperative evaluation. The effectiveness, however, is still controversial because of an observed rate of hernia recurrence similar to conventional mesh¹⁸.

The polypropylene is not indicated to be in contact with the peritoneum considering the formation of firm adhesions^{5,11}. It is noteworthy that development of adhesions is inevitable and independent of the material used¹⁴. This is due to foreign body reaction but may be exacerbated by the access route, the method for setting the mesh, the visceral or parietal peritoneum desperitonization^{5,15} and the presence of infection. Intra-

abdominal adhesions can be classified in terms of area, expressed as percentage of the prosthesis covered by the adhesion and the force of adhesion, and the presence or absence of vascularization as described in table 1^{2,5,9,14}.

In our study, one animal from the Simulation Group (Group 1) had a score of 4 for area and of 3 for strength but we postulate the cause may well be due to some desperitonization during visceral manipulation. Subjects in Groups 2 and 3 presented some adhesion and vascular growth over the adherent tissue but, considering the area and the adhesion force, differences were not statistically significant between the two Groups ($p < 0.05$). The presence of vascularization indicates the existence of a healing wound in progress, and provides a substrate for deposition of fibroblasts and collagen. Kiudelis *et al.*⁵ reported data similar to our results.

It is known that mesh with micropores or without pores causes fewer adhesions than those with macropores. Our results showed that the absence of pores in the NWV prosthesis did not contribute to the reduction of adhesions.

Amongst the structures that most often adhere to the mesh/prosthesis are the greater omentum and the small intestine as observed in Groups 2 and 3. In an attempt to minimize these problems, some surgeons choose to avoid placing the mesh directly in contact with the viscera and interpose part of the hernial sac, peritoneum or omentum^{5,14,15}.

The presence of a synthetic prosthesis increases the risk of complications in the host site such as stiffness, hematoma, seroma, pain, adhesions, abscess or wound infection, mesh shrinkage, intestinal obstruction, fistulas visceral, dehiscence of skin suture, rejection, among others^{10,14,18-21}. A prosthesis not incorporated or rejected is usually involved in a foreign body reaction. Encysted fluid collections may be manifested under the surgical scar as a benign tumor. Some authors report that mesh without pores reduces the dead space between the tissue and is associated with a lower risk of seroma formation^{10,18}. Over time, these serous collections initially aseptic drains to the skin, through a "sinus", and may become infected and purulent contributing to dehiscence of the overlying tissue with partial or full exposure of the prosthesis²¹. The accumulation of serous or blood collections around the prosthesis is frequently observed, especially when the implants are large and associated with extensive areas of detachment. These liquids hinder integration and prevent the arrival of the polymorphonuclear neutrophils, which results in a culture medium. The prophylactic use of antibiotics in reoperations on a prosthesis site is indicated to reduce the risk of local infection. In such cases, the partial or total withdrawal of sequestered prosthesis

is often required and it demands laborious surgery with risk of other and perhaps more severe complications²¹. In our experiment, no animal showed seroma and the complications seen were the presence of dehiscence and infection in animals excluded from the sample group and the planned incisional hernia in the Simulation Group.

Other studies show that inflammatory response following implantation of light prostheses are significantly smaller than in conventional or heavy meshes, except when the prostheses are lightweight and nonwoven. In such cases, the inflammation is more intense than in the application heavy prostheses^{10,18,19}. There exists a lack of studies comparing heavy with light prostheses structures, woven with nonwoven and macro with micropores. Weyhe *et al.*¹⁰ and Dubova *et al.*¹⁹ studied the inflammatory response of rats subjected to abdominal wall reconstruction with polypropylene mesh at different intervals of postoperative days. One group received a woven polypropylene heavy mesh with macropores, and the other received a nonwoven fabric, light, with micropores. Although Dubova *et al.*¹⁹ agree with Weyhe *et al.*¹⁰ about the more severe inflammatory reaction which occurred in the group of nonwoven fabrics, but they disagree with regard to fibrosis. Dubova *et al.*¹⁹, at the end of the experiment (28 days), reported a less intense fibrosis in nonwoven fabric and attribute this to the fact that the fabric does not have a net, allowing a tissue growth upon a uniform surface. Weyhe *et al.*¹⁰ found that the differences between the two groups began to decline over time, but until 21 days after surgery they were not statistically significant. However, after 21 days, the concentration of inflammatory cells began to decline in both groups. At 90 days after surgery a decrease in the group of heavy mesh was observed as more significant than in the light ones. In our results the inflammatory reaction in both Groups 2 and 3 was similar ($p=0.10$). Fibrous tissue covered both kinds of prostheses after 45 days but such scarring process was a little bit intense in Group 3 than Group 2 in comparison with Group 1 of animals. This may be related to the greater collagen proliferation but no statistical differences was found between Groups 2 and 3 ($p=0.23$).

We emphasize that interpretation of the results has to be considered with caution because of the small sample size.

Klinge *et al.*³ and Cobb *et al.*¹² argue that the higher the weight of the prosthesis, the greater the amount of synthetic material and, therefore, the greater likelihood of the presence of inflammatory foreign body. The formation of giant cells and proliferation of connective tissue between the pores are common finding in the microscopic implants of polypropylene^{1,3,11}, but no differences were observed between groups 2 and 3, respectively,

with heavy or light screen.

Thermogravimetry is one of the tools used to determine whether sterilization in the autoclave would alter the physical properties of polypropylene or melt the synthetic material. Marlex mesh was sterilized by ethylene oxide. There were no relevant differences between the temperatures at the beginning of decomposition of Group 2 (439°C) and Group 3, post-autoclaving (339°C). The temperature of any autoclaving process never goes above 132°C and therefore there is no risk of overlap the prosthesis melting point which can be easily sterilized.

Differential Scanning Calorimetry (DSC) is a technique of thermal analysis of differences in materials or tissues under linear variations of temperature, in a controlled environment. It allows checking the structural stability under isothermal exposure. Polymer of Group 2 was more crystalline than that of Group 3 but this feature does not interfere with the resistance of the non woven fabric because fibrosis itself is sufficient to give parietal protection and to substitute the function of the original tissue.

The amount spent on getting the NWV prosthesis was half a dollar/m², while the polypropylene conventional costs an average of US\$ 140/m² (almost 300 times greater). It should be noted that the industry offers to purchase meshes of woven polypropylene, 30cm x 30cm, at a cost of approximately US\$ 900. This is roughly a hundred times the amount spent on acquisition of the prosthesis used in Group 3 of our study. NWV prosthesis is a material of everyday use in hospitals, found in a series of disposable items and, as already mentioned, autoclaving NWV prosthesis does not alter its composition or structure.

Further studies in anima nobile must be done before its surgical indication but this experimental research endorses its alternative use, especially in remote locations where there are no facilities or resources available to purchase or import conventional woven meshes, such as public hospitals. This is an unprecedented proposal to using a substitute material for conventional meshes in surgical repairs of ventral incisional hernias.

Conclusion

The polypropylene type of nonwoven prosthesis showed a satisfactory cost-effectiveness in the treatment of large abdominal wall defects in rats.

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