Annals of Medicine and Surgery 4 (2015) 172–178

Contents lists available at ScienceDirect

Annals of Medicine and Surgery

journal homepage: www.annalsjournal.com

# Endoscopic and histological evaluations of a newly designed inguinal hernia mesh implant: *Experimental studies on porcine animal model and human cadaver*

Fabrizio Panaro [a, *], Ana Maria Matos-Azevedo [b], José Antonio Fatas [c], Juan Marin [d], Francis Navarro [a], Cristobal Zaragoza-Fernandez [e]

[a] *Department of General and Liver Transplant Surgery, University of Montpellier, Hôpital Saint Eloi, 80 Avenue Augustin Fliche, 34295, Montpellier-Cedex 5, France*
[b] *Laparoscopy Unit-Minimally Invasive Surgery, Centre Jesús Usón, Carretera N-521, 10071, Cáceres, Spain*
[c] *Department of General Surgery, Hospital Royo Villanova, Avenida San Gregorio 30, 50015, Zaragoza, Spain*
[d] *Department of General Surgery, Valme University Hospital, Crta Cádiz s/n, 41014, Sevilla, Spain*
[e] *Department of General Surgery, Hôpital Général Universitaire de Valence, Valencia, Spain*

## HIGHLIGHTS

- Feasibility-study to test a new-3D tension-free prosthesis in an experimental model.
- All animals showed good mesh tolerance and the followup period was uneventful.
- Endoscopic and histologic analysis were reported.

## ARTICLE INFO

*Article history:*
Received 21 January 2015
Received in revised form
5 April 2015
Accepted 15 April 2015

*Keywords:*
Inguinal hernia
Dynamic design
3D mesh
Experimental feasibility-study

## ABSTRACT

*Purpose:* Conventional prostheses used for inguinal hernia repair are static and passive. This feasibility-study shows the features of a new 3D tension-free prosthesis in an experimental model.
*Methods:* This study was divided into two-phases: 1) aimed to test the physics intrinsic features and the anatomical adaptability of a new 3D designed mesh, and 2) aimed to evaluate the inflammatory reaction associated with different materials used. On phase-1 implantations were performed in pigs. During the first trial phase, the prostheses were also implanted on human cadavers. On phase-2, implantation was carried out on large swine. Follow-up was of 60-days, after which the animals were anaesthetized for laparoscopic assessment, and for sample collection of mesh implantation site for histological analysis.
*Results:* All animals showed good 3D mesh tolerance, and the follow-up period was uneventful. The laparoscopy showed no inflammatory lesions on the internal surface of the peritoneum. Macroscopic observation of implantation site revealed some local fibrosis and reorganization of tissue, no signs of infection, and no changes on original implant positioning. Histological analysis on phase-1 showed in most sample segments the deferent duct maintaining its central position and surrounded by vascular and nervous structures. On phase-2 differences in inflammatory lesion score could be found between subjects.
*Conclusions:* This new 3D mesh can be placed appropriately and from this preliminary animal study no untoward complications were noted over a 60 day period.


* Corresponding author. Department of Surgery, Montpellier University Hospital, School of Medicine, 80, Avenue Augustin Fliche, 34295, Montpellier-Cedex 5, France. Tel.: +33 04 67 33 67 33; fax: +33 04 67 33 76 23.
*E-mail address:* f-panaro@chu-montpellier.fr (F. Panaro).

http://dx.doi.org/10.1016/j.amsu.2015.04.007

## 1. Introduction

Inguinal hernia repair is one of the most frequently performed surgical procedures. In the USA alone, over 800.000 hernia repairs are performed every year [1–6]. By examining the literature, and drawing upon over 30 years of surgical experience, we began to question three key problems in inguinal hernia repair: 1) the complications consequent to invasive fixation, 2) the poor quality of tissue ingrowth induced by the mesh, and 3) the early mesh dislocation after implantation [7–9]. Working closely with a team of French-Spanish biomechanical engineers, we designed an implant that would translate outward visceral forces to cause a dynamic implant deformation that would induce greater gripping forces of the inguinal area. The main purpose of this preliminary experimental porcine and human cadaver study is to demonstrate the feasibility of implantation and the inflammation response of this new 3D mesh.

### 1.1. Material and methods

All surgical procedures were carried out at certified animal experimental facilities in Spain, after previous official approval by the internal Ethics and Animal Welfare Committee. All animals used in these experiments received humane care in accordance with the requirements of the European Parliament Directive 2010/63/UE, of 22nd September 2010, and the national Royal Decree 1201/2005 of 10th October, on protection of animals used for scientific research. This experimental study was divided in two phases, carried out 5 months apart. On the first phase (phase1) we aimed at testing a new 3D design of a mesh prosthesis intended for direct and indirect inguinal hernia repair by anterior open surgical approach. On the later phase (phase 2) the purposed was to determine if the mesh material of the prosthesis could modify the tissue inflammatory and foreign body reaction.

#### 1.1.1. Study subjects

On phase 1 implantation was performed on 3 Large White intact male pigs, weighing an average of 74 ± 1,8 kg. During the first trial phase, 3D mesh prostheses were also implanted on two human cadavers, for evaluation of pliability and material intrinsic memory, as well as design adaptation to the human anatomy.

On phase 2, implantation was carried out on 5 intact Large White male swine, with an average weight of 102 ± 8,6 kg.

#### 1.1.2. Anaesthesia and analgesia

Animals were firstly sedated by intramuscular injection of ketamine (20 mg/kg) in association with diazepam (0.5 mg/kg). Peripheral venous access was established through the insertion of a 20G catheter in the marginal vein of the ear. Anaesthetic induction was then achieved with propofol (3 mg/kg) administered intravenously (IV). Tracheal intubation and anaesthetic maintenance with sevoflurane (0,5 L/min, MAC 2,6) was possible with the use of a mechanical ventilator connected to the anaesthetic station [10,11].

Preoperative intravenous analgesia was accomplished with IV injection of ketorolac (1 mg/kg) in association with tramadol hydrochloride (1,5 mg/kg). During the entire procedure animals were infused with saline solution at a rate of 5 ml/kg/h. Before starting the surgical procedure and at sacrifice on both study phases, blood was drawn from the jugular vein, and blood analysis was conducted, in order to verify the animals' adequate general health condition.

Before initiating the procedure an intramuscular injection of amoxicillin-clavulanic acid (Synulox® – 1 ml/20 kg) was administered to each animal. At the end of the implantation and after closing both bilateral skin incisions, a slow release fentanyl patch (Duragesic®, Janssen Pharmaceuticals) was applied to the clean skin of the inner thigh. After recovery, buprenorphine (Buprex® – 1 ml/30 kg) was injected intramuscularly approximately 8 h after the beginning of implantation, in order to provide sufficient analgesia until initial release from the applied patch. All animals received additional anti-inflammatory therapy with meloxicam (Metacam® – 0.025 ml/kg) once a day for three consecutive days, and adjuvant antibiotics therapy with an oral formula of amoxicillin-clavulanic acid at a dose of 20 mg/kg every 12 h for five consecutive days.

With the conclusion of the surgical procedure, spontaneous ventilation was promoted by switching off the anaesthetic inflow of gas and maintaining mechanical inflow of $O_2$. This inflow was interrupted when patients showed spontaneous respiratory efforts.

#### 1.1.3. Implanted mesh prostheses

All 3D mesh prosthesis implanted on the first phase were Surgimesh™ Xlight™ (knitted polypropylene, 28 g/m$^2$ Aspide Médical®, Lyon, France), and three mesh sizes were used (Fig. 1).

On phase 2 different mesh materials were implanted (Table 1). According to the animals' own anatomy, the extent of mesh was sometimes shortened in its longitudinal axis. On each animal, a different mesh material was used, and fixation was achieved on the right side by three polypropylene sutures, applied to ventral, lateral and medial sides (Surgipro™ 2/0, 26 mm, partially absorbable material). As for the left groin no fixation was performed. The objective of this fixation (stitches) was to compare in the same animal the influence of various materials (mesh plus polypropylene stitches) on the inflammation response. Infact, in pigs, the inflammatory reaction is variables, therefore, in this way we decreased the variability of the results. In this study, we performed 3 stitches as maximum type of fixation. With the new 3D mesh the fixation is unnecessary, however, in this experimental model we tried adding polypropylene suture to achieve the maximal inflammatory reaction.

#### 1.1.4. Surgical procedure

All subjects were placed in dorsal recumbency, and skin as well as subcutaneous incision was performed on the left groin. Muscle layers and external inguinal ring were later incised. Dissection at this point was performed respecting inguinal and genitofemoral nerves. Procedure was then carried on with the dissection of the spermatic cord and enlargement of the pre peritoneal space so that the mesh could be correctly spread against the peritoneum. A constrained 3D prosthesis was then inserted and its small ring was placed in the pre peritoneal area, surrounding the spermatic cord. Superior aspect of the mesh (elliptical portion) stayed unfolded above inguinal floor and below the spermatic cord (Fig. 1). After implantation, suture of surgical planes was completed in standard fashion [5]. Any stitches was applied to fix the prosthesis.

All pre and intra operative aspects of phase 2 implantation were similar to the first phase of the study, and post-operative treatment followed as previously described.

#### 1.1.5. Follow-up

Follow up for both study phases lasted for 60 days, after which the animals were anaesthetized for laparoscopic assessment of intra abdominal lesions and macroscopic analysis. Sample collection at implantation site was completed and samples sent for posterior histological analysis. Macroscopic examination at implantation site was carried out after incision of the previously operated area and before removal of spermatic cord and surrounding tissue. Observation of signs of inflammation, infection or mesh displacement was considered at explantation. Animals were sacrificed by an intravenous injection of potassium chloride, after sample collection, and while still under anaesthesia. Histological