

# Computed tomographic measurements of mesh shrinkage after laparoscopic ventral incisional hernia repair with an expanded polytetrafluoroethylene mesh

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Received: 8 December 2008 / Accepted: 1 April 2009 / Published online: 15 May 2009  
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## Abstract

**Background** The potential for shrinkage of intraperitoneally implanted meshes for laparoscopic repair of ventral and incisional hernia (LRVIH) remains a concern. Numerous experimental studies on this issue reported very inconsistent results. Expanded polytetrafluoroethylene (ePTFE) mesh has the unique property of being revealed by computed tomography (CT). We therefore conducted an analysis of CT findings in patients who had previously undergone LRVIH with an ePTFE mesh (DualMesh, WL Gore, Flagstaff, AZ, USA) in order to evaluate the shrinkage of implanted meshes.

**Patients and methods** Of 656 LRVIH patients with DualMesh, all patients who subsequently underwent CT scanning were identified and only those with precisely known transverse diameter of implanted mesh and with CT scans made more than 3 months postoperatively were selected ( $n = 40$ ). Two radiologists who were blinded to the size of the implanted mesh measured in consensus the maximal transverse diameter of the meshes by using the AquariusNET program (TeraRecon Inc., San Mateo, CA, USA). Mesh shrinkage was defined as the relative loss of transverse diameter as compared with the original transverse diameter of the mesh.

**Results** The mean time from LRVIH to CT scan was 17.9 months (range 3–59 months). The mean shrinkage of the mesh was 7.5% (range 0–23.7%). For 11 patients (28%)

there was no shrinkage at all. Shrinkage of 1–10% was found in 16 patients (40%), of 10–20% in 10 patients (25%), and of 20–24% in 3 patients (7.5%). No correlation was found regarding the elapsed time between LRVIH and CT, and shrinkage. There were two recurrences, one possibly related to shrinkage.

**Conclusion** Our observations indicate that shrinkage of DualMesh is remarkably lower than has been reported in experimental studies (8–51%). This study is the first to address the problem of shrinkage after intraperitoneal implantation of synthetic mesh in a clinical material.

**Keywords** Hernia · Laparoscopy · Mesh · Shrinkage · CT

Despite the increasing popularity of laparoscopic repair of ventral and incisional hernias (LRVIH), the long-term consequences of intraperitoneal implantation of synthetic mesh remain a concern. One of these concerns is the potential for shrinkage of implanted meshes, which can be responsible for recurrences and pain. A large number of experimental studies addressed this important issue but the reported results are so inconsistent that it is nearly impossible to make any reliable clinical conclusions. Among various meshes that are in common usage presently, expanded polytetrafluoroethylene (ePTFE) mesh has the unique property of being revealed by high-resolution imaging techniques such as computed tomography (CT) and magnetic resonance image due to its structure and density (Fig. 1). We therefore conducted an analysis of CT findings in patients who had previously undergone a LRVIH with an ePTFE mesh (DualMesh<sup>®</sup>, WL Gore, Flagstaff, AZ, USA) in order to evaluate the shrinkage of implanted meshes.

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**Fig. 1** CT of the abdomen shows a DualMesh prosthesis

## Patients and methods

Medical records of all 656 patients who underwent LRVIH by using DualMesh prosthesis at our hospital between 2000 and 2008 were reviewed. Patients who subsequently underwent CT scanning for various indications more than 3 months after LRVIH were identified ( $n = 64$ ). A period of 3 months was selected as the minimum for evaluation of eventual shrinkage, assuming that shrinkage would require some time. All patients who had an original mesh trimmed according to operative needs before implantation without precise specification of a new size were excluded from analysis ( $n = 4$ ). Further, all patients in whom one of the two main axis of implanted mesh was not parallel to the craniocaudal axis of the patient's body were excluded ( $n = 20$ ). The angled positioning of mesh, such as by repair of a hernia by subcostal incision will cause CT transverse slices to show diagonal diameters, rather than actual transverse diameters of the implanted mesh, if measured. Hence, only patients with a precisely known transverse diameter of implanted mesh were selected for this review and they represented the study group ( $n = 40$ ). Of these, in 23 patients the mesh was fixed both with tacks (ProTack, TycoUSS, Norwalk, CT) placed circumferentially at 1-cm intervals and with transabdominal sutures (TAS). In the remaining 17 patients, the mesh was fixed only with a double crown (two rings) of tacks.



**Fig. 2** By using the AquariusNet program, a line is traced precisely over the contour of the mesh, whose length is then measured by the computer program

Two independent radiologists, who were blinded to the size of the originally implanted mesh and had no knowledge of standard mesh sizes, measured, in consensus, the maximal transverse diameter of meshes on the CT scans by using the AquariusNet program (TeraRecon, Inc., San Mateo, CA, USA). In brief, by using this program an examiner, using a computer mouse, has to trace a line precisely over the contour of the mesh, whose length is then measured by the computer program (Fig. 2). Manual operation of the mouse can result in minor impreciseness, so the drawings were made on a monitor of larger size, thus limiting the mistakes in measurements to a few millimeters, thereby providing very reliable results. Mesh shrinkage was defined as the relative loss of transverse diameter as compared with the original transverse diameter of the mesh.

Data were collected in a database and statistical analyses were performed using Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA) for Windows. Measured mesh size and implanted mesh size were compared between DC and TAS groups using the Mann–Whitney test. Findings were correlated using the Pearson correlation coefficient and the Spearman correlation coefficient. Statistical significance was considered at  $p$ -values less than 0.05.

## Results

The mean time from LRVIH to CT scan was  $17.9 \pm 13$  months (range 3–59 months). The mean shrinkage of the

mesh was  $7.5 \pm 7.5\%$  (range 0–24%). Statistically, this was significant ( $p < 0.001$ ). For 11 patients (28%) there was no shrinkage found at all. Shrinkage of 1–10% was found in 16 patients (40%), of 10–20% in 10 patients (25%), and of 20–24% in 3 patients (7.5%). Mesh fixation method did not significantly influence shrinkage ( $p = 0.289$ ). No correlation was found between mesh size and shrinkage (correlation coefficient 0.474,  $p = 0.19$ ). No correlation was found between the elapsed time between LRVIH and CT, and shrinkage (correlation coefficient 0.124,  $p = 0.565$ ).

Two patients had a recurrence. In one of these patients there was no shrinkage at all (implanted transverse diameter 20 cm/CT measured diameter 20 cm). The probable reasons for recurrence were either technical error such as insufficient overlap or detachment of mesh that had been fixed with a double ring of tacks. The other of these two patients was found to indeed have a remarkable transverse shrinkage of the mesh by 22%. This recurrence occurred cranially above the mesh and at the site of a previously sufficient incision scar of a midline laparotomy that was not covered during LRVIH.

## Discussion

LRVIH is dependent upon the use of prosthetic biomaterials. Materials placed in the abdominal cavity have to meet some additional requirements and to approach maximal biocompatibility, presenting more physiologically functional properties than any other prosthetic material used in extraperitoneal hernia repair. Besides these qualities, they must trigger minimal or no foreign-body reaction. During the normal contraction phase of tissue healing in response to inflammatory reactions stimulated by prosthetic material there is definitely a potential for a certain degree of mesh contraction or shrinkage that might be further responsible for recurrences and pain [1]. To what extent meshes used currently for LRVIH shrink has not been accurately defined. A large number of experimental studies addressed this important issue [2–12]. However, diversity of experimental models, animals used, study times, methods used for measuring shrinkage, occasional funding by industry [9, 10] and a potential for a conflict of interest, and above all the extremely wide range of reported results even for identical meshes have resulted in difficulties in making any reliable clinical conclusions. For example, the reported shrinkage of Proceed (Ethicon, Somerville, USA) ranged between 11% [2] and 44% [3], that of Sepramesh (Genzyme Corporation, Cambridge, USA) ranged between 7% [4] and 38% [5], and that of Parietex (Sofradim, Trevoux, France) between 15% [4] and 29.5% [3].

The shrinkage of the ePTFE biomaterials has also been extensively analyzed in experimental studies [2, 4, 6–11].

A summary of these studies is presented in Table 1. Although the reported range of shrinkage from 7.6% [7] to 50.8% [11] was extremely wide, most of the studies reported shrinkage of around  $38 \pm 6\%$  [2, 4, 6, 8–10]. Such a degree of shrinkage would have worrisome effect on clinical results that is obviously not the case and the clinical interpretation of these finding remains unclear.

As far as clinical data on shrinkage are concerned, surprisingly little information is available. This study is the first to address the problem of shrinkage after intraperitoneal implantation of synthetic mesh in a clinical material. With the exception of prostheses containing ePTFE, all prostheses that are presently used for LRVIH are isoattenuating relative to surrounding tissues and are therefore not visible at CT. The specific structure and high attenuation of ePTFE biomaterials provide a unique ability to visualize these prostheses on CT scans, making this study possible. With the radiologic material that we possessed, it was possible to measure only transverse diameters of the prosthesis. A new generation of CT scanning and advanced reconstruction techniques hold a possibility for a much more complete set of information regarding shrinkage of ePTFE biomaterials by providing information on both the longitudinal diameter and the surface of implanted meshes. Such studies will definitely follow.

Our observations indicate that shrinkage of DualMesh in patients is either absent or minimal in two-thirds of patients, and on average is remarkably lower than has been reported in other experimental studies. The observation that shrinkage never exceeded 24% in this series indicates that, if the rule of minimal overlap of 3–4 cm is respected, shrinkage probably plays a minor role in the development of recurrences. In our only case of recurrence that was associated with remarkable transverse shrinkage of mesh, the longitudinal shrinkage of mesh must be considered as a possible reason for the recurrence. However, another possible reason—that the repair did not address the whole incision—cannot be excluded. The remaining patients with a significant shrinkage of mesh did not develop recurrences

**Table 1** Experimental studies on shrinkage of Gore DualMesh biomaterials: literature results

Reference	Animals	Study time	Shrinkage (%)
[7]	New Zealand white rabbits	90 days	7.6
[8]	New Zealand white rabbits	1 year	32
[2]	New Zealand white rabbits	16 weeks	34.7
[6]	New Zealand white rabbits	12 weeks	41
[4]	Male Wistar rats	30 days	44.2
[9]	Pigs	87 days	43.5
[10]	Pigs	4 weeks	37
[11]	New Zealand white rabbits	5 months	50.8

in this series. Our observations suggest that the clinical importance of mesh shrinkage in development of recurrences might be in general overestimated. However, with the knowledge that shrinkage can reach nearly 24% in a subset of patients, it seems wise to take that into calculation when selecting a size of DualMesh for LRVIH and to opt for a larger mesh than would normally be selected by using conventional criteria.

The observed wide range in shrinkage in this study is difficult to understand and explain, and reliable data on that issue are definitely missing. If we assume that meshes do not shrink by themselves but only as a consequence of scar tissue formation around them, it might well be that the observed range in mesh shrinkage in our study reflects the differences in scar tissue formation among individual patients.

Discrepancies between the results of this clinical study and findings of other experimental studies raise the question of reliability and the clinical relevance of the latter. Clinical studies on mesh shrinkage that are based on new high-resolution radiologic techniques and reoperative findings are needed for a better understanding of the problem of shrinkage and its clinical consequences.

## Conclusion

An expanded polytetrafluoroethylene (ePTFE) mesh has the unique property of being revealed by computed tomography (CT). We therefore conducted an analysis of CT findings in patients who had previously undergone a LRVIH with an ePTFE mesh (DualMesh, WL Gore, Flagstaff, AZ, USA) in order to evaluate the shrinkage of implanted meshes. Our observations indicate that shrinkage of DualMesh is remarkably lower than has been reported in experimental studies. This study is the first to address the problem of shrinkage after intraperitoneal implantation of synthetic mesh in a clinical material.

**Acknowledgements** The authors would like to thank Job van der Palen, epidemiologist, PhD, for his assistance with statistics.

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