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Dynamic intermittent strain can rapidly impair ventral hernia repair

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ABSTRACT

Ventral hernia repair fails frequently despite advanced mesh inserting surgery. A model for dynamic intermittent straining (DIS) of ventral hernia repairs was developed. The influence of phospholipids, position, overlap, fixation and tissue quality of various meshes on the durability of hernia repair was studied.

DIS comprises the repetition of submaximal impacts delivered via a hydraulically driven plastic containment. Pig tissues simulate a ventral hernia with a standardized 5 cm defect. Commercially available meshes strengthened with tacks, glue and sutures were used to bridge this defect in an underlay (IPOM) or sublay (retromuscular) position starting with a 5 cm overlap in all directions. We tested 35 different ways of ventral hernia repair with up to 425 submaximal intermittent dynamic impacts until mesh dislocation occurred 10 times or a maximum of 4000 impacts each were withstood.

The likelihood of a failing repair was related to the mesh, the lubricants, the position, the overlap, the fixation and the tissue quality. Most meshes dislocated easily and required fixation. One of the meshes tested was stable without fixation with a 5 cm overlap and failed after reducing the overlap. Phospholipids exerted a strong influence on the biomaterial tested. The sublay position was about 10% more durable in comparison to the IPOM position. DIS revealed distinct degrees of stability with primarily stable, intermediate and primarily unstable repairs.

Based on the DIS results available, the currently used ventral hernia repair options can be classified. In the future, DIS investigations can improve the durability of hernia repair.

1. Introduction

The repair of ventral or incisional hernias is one of the most frequent operations in abdominal surgery (Albino et al., 2013). Mesh repair is considered superior to primary suture (Nguyen et al., 2014). Despite advanced mesh augmentation techniques, recurrences still occur in six to 23% within the first year (den Hartog et al., 2008; Novitzky and Orenstein, 2013; Köckerling et al., 2015). Newly developed biomechanical abdominal wall models permit a new kind of bench testing of commercially available meshes and fixation devices (Binnebösel et al., 2007; Guerin and Turquier, 2013; Tomaszewska et al., 2013; Lyons et al., 2015). Most tests use gradually increasing pressure, as occurring during bending or slow movements (Lyons et al., 2015). On mechanical grounds, intraabdominal pressure up to 150 mmHg should be withstood by most mesh repairs using an overlap of 5 cm (Lyons et al., 2015). Pressures above 150 mmHg occur during coughing or postoperative vomiting and might occur up to 400 times in the first few hours after surgery (Cobb et al., 2005; Turner and Bothamley, 2014). A new model permits the assessment of dynamic intermittent strain on ventral hernia repair imitating coughing bursts (Siassi et al., 2014). In the first report, plain and bulging repairs were examined with 200 repetitions revealing pronounced instability with bulged bridging. In the work presented here, up to 425 dynamic impacts were used to assess the durability of 35 different hernia repairs. The influence of phospholipids as a physiologically occurring lubricant was examined. The underlay and the sublay position were compared. Bridging with recommended and reduced overlap was investigated (Lyons et al., 2015). The influence of different mesh fixations and of textile and tissue properties was analyzed. As a conclusion, a classification of ventral hernia repair options is proposed with potential for clinical application.

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Table 1
Descriptive statistical parameters of the 35 series conducted on 6 different meshes.

Condition	Mesh	Fixation	Lubricants	Mean	Standard error	Minimum	1st quartile	Median	3rd quartile	Maximum
Phospholipids (Fig. 1)										
Underlay flat	Ultrapro®	None	Vaseline®	23	15.17	7	12	20.5	28	54
Underlay flat	Ultrapro®	None	Lecistar 100®	39	35.31	5	17	26.5	54.75	123
Underlay flat	DynaMesh IPOM®	None	Vaseline®	88.5	112.18	17	29.25	39.5	57.25	372
Underlay flat	DynaMesh IPOM®	None	Lecistar 100®	72.5	86.01	4	19	55	85.75	379
Underlay flat	TiMesh light®	None	Vaseline®	11.91	11.46	5	7.5	8	10.5	46
Underlay flat	TiMesh light®	None	Lecistar 100®	13.2	15.27	1	4.5	10	15	54
Underlay flat	PhysioMesh®	None	Vaseline®	2.6	1.35	1	2	2	3	6
Underlay flat	PhysioMesh®	None	Lecistar 100®	3.4	1.07	2	3	3	4	5
Underlay flat	Permacol®	None	Vaseline®	18.7	3.3	13	17	18.5	20.5	24
Underlay flat	Permacol®	None	Lecistar 100®	2	.94	1	1.25	2	2	4
Mesh position (Fig. 2)										
Underlay flat	TiMesh light®	None	Vaseline®	11.91	11.46	5	7.5	8	10.5	46
Sublay flat	TiMesh light®	None	Vaseline®	86	123.5	5	10.75	33.5	114.25	400
Underlay flat	Dynamesh IPOM®	None	Vaseline®	5.3	2.16	2	4	5	7	8
Sublay flat	Dynamesh IPOM®	None	Vaseline®	32.8	21.48	15	20	24	33	73
Sublay flat	Dynamesh CICAT®	None	Vaseline®	400	0	400	400	400	400	400
Reduced overlap (Fig. 3)										
Sublay flat Overlap 5 cm	Dynamesh CICAT®	None	Vaseline®	425	0	425	425	425	425	425
Sublay flat Overlap 3.75 cm	Dynamesh CICAT®	None	Vaseline®	226.4	176.06	13	106	146.5	425	425
Sublay flat Overlap 2.5 cm	Dynamesh CICAT®	None	Vaseline®	16.4	8.86	8	8	14	23	29
Sublay flat Overlap 1.25 cm	Dynamesh CICAT®	None	Vaseline®	3.4	3.84	1	1	1	5	11
Rotation (Fig. 4)										
Underlay flat longitudinal	Dynamesh IPOM®	None	Vaseline®	398.57	98.89	55	425	425	425	425
Underlay flat transverse	Dynamesh IPOM®	None	Vaseline®	183.67	180.66	2	48.25	82.5	425	425
Fixation (Figs. 5 and 6)										
Underlay flat	TiMesh light®	None	Vaseline®	12.3	12	5	7.25	9	10.75	46
Underlay flat	TiMesh light®	8 points AbsorbaTack®	Vaseline®	364.08	73.77	167	390	400	400	401
Underlay bulged	TiMesh light®	8 points AbsorbaTack®	Vaseline®	295.86	154.69	10	230.5	400	400	400
Underlay flat	TiMesh light®	8 points Glubran®	Vaseline®	74.2	116.76	15	22	38	46.25	400
Sublay flat	TiMesh light®	none	Vaseline®	86	123	5	10.75	33.5	114.25	400
Sublay flat	TiMesh light®	8 points Glubran®	Vaseline®	162.6	164.63	24	55.25	73	324.75	400
Underlay flat	Dynamesh IPOM®	None	Vaseline®	100.6	149.42	2	7	31.5	83.75	425
Underlay flat	Dynamesh IPOM®	8 points Glubran®	Vaseline®	98.5	150.17	2	21.75	48	72	400
Underlay flat	Dynamesh IPOM®	4 sutures	Vaseline®	355.5	125.87	44	400	400	400	400
Underlay flat	Dynamesh IPOM®	4 sutures & 8 pts Glubran®	Vaseline®	400	0	400	400	400	400	400
Tissue quality (Fig. 7)										
Pigs belly: adipose, much muscle	Dynamesh IPOM®	None	Vaseline®	227.73	192.18	5	63	143	425	425
Pigs belly: adipose, little muscle	Dynamesh IPOM®	None	Vaseline®	168.4	182.89	2	38.5	75.5	360	425
Pigs belly: slim, much muscle	Dynamesh IPOM®	None	Vaseline®	88.5	112.18	17	29.25	39.5	57.25	425
Pigs belly: slim, little muscle	Dynamesh IPOM®	None	Vaseline®	32.8	21.48	15	20	24	33	73