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Influence of elevated intra-abdominal pressure on suture tension dynamics in a porcine model

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ABSTRACT

Background: Inadequate suture tension is a risk factor for the failure of laparotomy closure. Suture tension dynamics in the abdominal wall are still obscure due to the lack of measuring devices. To answer the questions if intra-abdominal hypertension (IAH) influences suture tension in midline laparotomies and if IAH leads to a permanent loss of suture tension, microsensors were applied in a porcine model of IAH.

Material and methods: Microsensors measuring suture tension "on the thread" with a frequency of 1/s were developed and implanted in the suture lines of midline laparotomies in four pigs. During a 23-h experiment under general anesthesia, two intervals of IAH (30 mm Hg) were applied, interrupted by a 3-h interval without elevated intra-abdominal pressure.

Results: All sensors showed an immediate and reproducible response to changes of intra-abdominal pressure. The two 9-h periods of IAH resulted in a significant elevation of suture tension ($P = 0.003$ and $P = 0.0009$, respectively). Reducing the IAH lead to a significant loss of suture tension ($P = 0.0005$ and $P = 0.0001$, respectively). After the second interval with IAH, a complete loss of mean suture tension was observed. A statistically significant "recovery" of suture tension in the interval between the two phases with IAH was not observed.

Conclusions: Intervals with elevated intra-abdominal pressure have a direct influence on suture tension in midline laparotomy wounds. Intervals with IAH lead to a significant loss of suture tension in the suture line and to a complete loss of mean suture tension at the end of this experiment. A subsequent gaping of the fascia might contribute to either acute or chronic failure of laparotomy closure.

Introduction

There are clear hints that the failure of primary abdominal closure at an early stage after surgery with the development of a "burst abdomen" can—to a large percentage—be attributed to effects of the suture itself. Van Ramshorst *et al.*[1] demonstrated in 363 cases of abdominal wound dehiscence over a period of 10 y that 35 % occurred due to sutures tearing out of the fascia or due to fascial necrosis.

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Regarding the chronic failure of laparotomy closure with formation of an incisional hernia, inadequate suture tension has at least to be regarded as a significant cofactor.[2]

At the same time, intra-abdominal hypertension (IAH) and the abdominal compartment syndrome (ACS) have been recognized as frequent medical conditions. The prevalence of IAH on intensive care units in a multicenter study was found to be 32.1%, and the prevalence of ACS to be 4.2 %.[3]

Still surgeons are reluctant to primarily leave the abdomen open to prevent the development of IAH or ACS or to open it secondarily once the condition has developed, thus putting their patients at risk.[4,5] Although we know that forced abdominal closure with high suture tension is a risk factor for IAH, ACS, "burst abdomen," and incisional hernia, efforts to get close to a definition of "adequate suture tension for fascial closure" have not been consequently undertaken. Reliable sensors for longer term *in vivo* measurements do not exist.[6-8]

As a consequence, an implantable sensor and data logger were developed and tested. The results of this feasibility study in a porcine model focusing on suture tension dynamics during a 23-h narcosis with normal intra-abdominal pressure revealed a loss of almost 50 % of the initial suture tension after 23 h with a significant reduction occurring already 30 min after laparotomy closure. The experimental setting and results have been published elsewhere.[9]

In this study, the dynamics of suture tension were evaluated in the same setting; this time applying an intermittently elevated intra-abdominal pressure (grade IV IAH).

Hypothesis

Primary hypothesis

IAH has a direct influence on suture tension dynamics in the abdominal wall after closure of a midline laparotomy.

Secondary hypothesis

Periods of elevated intra-abdominal pressure lead to a persistent loss of suture tension in a sutured midline laparotomy incision after the intra-abdominal pressure has returned to normal.

Material and methods

In collaboration between the Fraunhofer Institute for Production Technology in Aachen, Germany, and the Department of Surgery, Technical University (RWTH) Aachen, Germany, an implantable sensor device capable of measuring suture tension "on the fascial thread" as well as an implantable data logger and an external connect board to read out the data were developed (Fig. 1). Animal housing, experiments, sensor device requirement specifications, sensor realization, and sensor/data logger function have been described in another publication.[9]

The research protocol of the underlying investigation was approved by the regional animal welfare committee and the district government (file Number 50.203.2-AC18, 53/02). Experiments were carried out under the supervision of a veterinarian at the Institute of Laboratory Animal Science, Technical University (RWTH) Aachen, Germany.

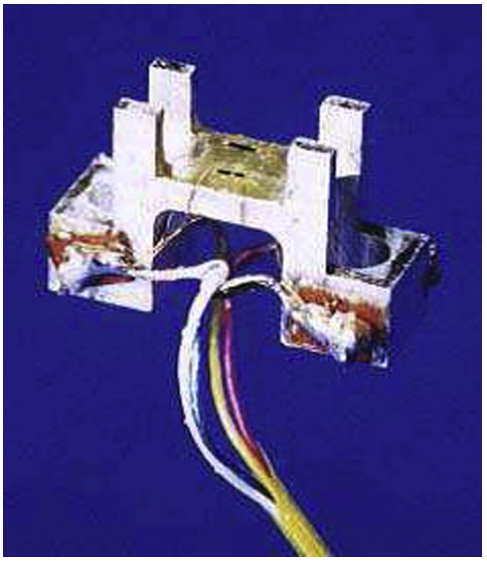

Fig. 1 – "Naked" sensor device measuring 6 × 3 × 1 mm. (Color version of figure is available online.)

The experimental setting and monitoring of the animals described in this article (further called "study group") was identical to the collective described in.[9]

In all animals, 12 cm median fascial laparotomies were closed by running size 1 Vicryl sutures (Ethicon, Norderstedt, Germany) with a suture length to wound length ratio of 4:1. Two sensors were positioned on the thread, the first at the transition of the upper to the middle third of the incision and the second at the transition of the middle to the lower third. During sensor development, *in vitro* tests were performed using different suture materials [braided polyglactin 910 (Vicryl), monofilament polypropylene (Prolene), and monofilament polydioxanone (PDS) (all materials from Ethicon, Norderstedt, Germany)]. With use of Vicryl, the sensors provided the best results concerning reliability and reproducibility of suture tension measurements.

The study group consisted of four domestic male pigs with a mean body weight of 52 ± 4.9 kg being kept under general anesthesia during the entire experiment.

After sensor implantation and an equilibration period of 1 h, the registration of suture tension was started with measurement intervals of 1/s. After 1 h, a capnoperitoneum maintained and controlled by a commercially available CO_2-insufflator (Electronic-pneu, Storz, Germany) with an intra-abdominal pressure of 30 mm Hg (grade IV IAH) was established and maintained over 9 h. The IAH was then reduced by depressurizing the abdominal cavity. After three more hours without artificial elevation of intra-abdominal pressure, another 9-h capnoperitoneum (30 mm Hg) was established and maintained. One hour after renewed depressurizing of the abdominal cavity, the animals were sacrificed.

For analysis, suture tension values measured in *n* were registered at the beginning of the measurement (time point 0), immediately before establishing the IAH (time point 1), immediately after establishing the capnoperitoneum (CP) (time point 2), immediately before depressurizing of the CP