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Research Paper

Operative procedures in warm humidified air: Can it reduce adhesion formation? A randomized experimental rat model

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ABSTRACT

Background: Postoperative peritoneal adhesions form in 63–97% of patients, give rise to subsequent adhesion related problems and create a considerable socioeconomic burden. In the present study, a local artificial atmosphere was created around the abdominal cavity during a surgical procedure in an effort to reduce postoperative adhesion formation.
Methods: Forty-eight Wistar male rats (Clr:WI) were randomized into two groups and weighed about 280 grams each. The abdominal cavities of the rats of the study group were exposed to warm and humidified air (21% O_2, 37 °C, 95–100% relative humidity (RH)) during an open surgical procedure, while the rats of the control group were exposed to the air from the operating theatre (21% O_2, 21 °C, 40–47% RH). The surgical procedure consisted of a midline laparotomy, four cuts and ischaemic knots in the anterior abdominal wall and blood from the tail vein dripped into the abdominal cavity. The abdominal cavity was assessed for adhesion formation and the bacterial load (CFU/ml) was measured.
Results: Significant differences in mean total adhesion, severity, tenacity scores and in the mean rank of the extent scores were found ($p < 0.001$). Also, significant differences in the median numbers of CFU/ml on chocolate agar and blood agar were found ($p < 0.001$).
Conclusions: Rats in the study group had higher total adhesion, extent, severity and tenacity scores postoperatively compared to rats in the control group. A possible reason could be the observed higher bacterial load amongst the rats of the study group compared to the rats of the control group.

1. Introduction

Peritoneal adhesions are defined as abnormal fibrous connections between peritoneal surfaces that can form postoperatively during the healing process [1–3]. The peritoneal surface is composed of a mesothelial monolayer supported by a basement membrane and underlying connective tissue, and damage to this monolayer seems to be the trigger for adhesion formation [1,2,4,5]. Potential damaging factors to the peritoneal surface are many, such as surgical trauma like ischaemia from sutures, chemical irritation, abrasions, foreign materials, overheating, cauterization, infections and dessication [1,6–8]. Adhesions form postoperatively after both laparoscopic and laparotomic procedures [1,2]. However, adhesion formation appears to be reduced after laparoscopic procedures [1,8–10]. In theory, this is due to laparoscopic procedures inducing less mesothelial damage than laparotomic procedures [1,5].

Earlier studies found incidences of peritoneal adhesion formation to range from 63 to 97 % after surgery [1,11–13]. A study from 2001 found that approximately a third of the patients who underwent lower intraabdominal surgery had to be readmitted, due to possible adhesion related problems during the subsequent 10 years after surgery [14]. Examples of such adhesion related problems are intestinal obstruction, pelvic pain, decreased fertility and impaired organ functioning, but also increased risk of inadvertent enterotomy and operating time needed due to adhesiolysis during subsequent reoperations [2,8,11,13,15–20]. Also, the annual adhesion-related expenditures in 1994 were estimated to be 1,3 billion dollars in the USA [21]. In summary, postoperative adhesion formation should be reduced as much as possible and reducing mesothelial damage during surgery seems like a good place to start [1].

One possible way of reducing mesothelial damage during surgery is to control the environment the peritoneum is exposed to during surgery. The reason for this being that the peritoneum does not adjust well to conditions differing from its physiological environment [1].

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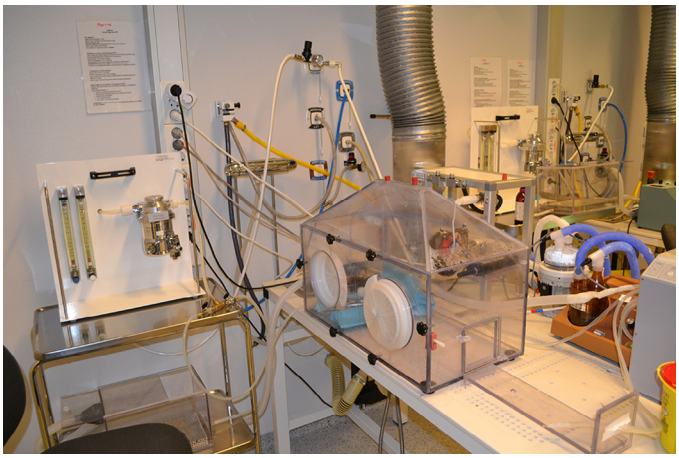

Fig. 1. Perspex box.

Dry and cold insufflation gas, to which the peritoneum is exposed during laparoscopic procedures, can cause dessication of the peritoneum [1]. Therefore humidifying and warming the insufflation gas could be a logical step towards a pneumoperitoneum with conditions more close to physiological conditions and towards the idea of minimizing trauma [1,22,23]. More physiological-like conditions during surgery could prevent or reduce postoperative pain, hypothermia and adhesions, which are some of the morbidities associated with laparoscopic surgery and peritoneal desiccation [1,22,23]. Extending this line of thinking to open surgical procedures seems logical, since tissue dessication is of equal consequence during open surgery [1,24–28].

Intraoperative field flooding with insufflation of CO_2 in the pericardial cavity is routinely used during cardiac surgery in order to displace intra-cardiac air [24,29]. A diffuser is used to insufflate CO_2 into the wound cavity, thereby de-airing it and establishing a local atmosphere within the wound cavity consisting of a high CO_2 concentration [24,29]. A medical hypothesis published in 2009 hypothesized that intra-operative field flooding of the abdominal cavity during open surgical procedures with warm and humidified CO_2 could reduce postoperative adhesion formation, reduce surgical site infection and prevent oxidative stress [1,24,30].

The idea of establishing a local artificial atmosphere within and around the intraabdominal cavity during open surgery in order to reduce mesothelial damage and thereby postoperative adhesion formation is interesting. Which properties such an atmosphere should have in order to maximize reduction of postoperative adhesion formation requires more research [31]. In an earlier study and in the present study a perspex box, in which a local artificial atmosphere could be created and rats could be operated upon through airtight holes for the surgeon's arms (see Fig. 1), was used [31].

The aim of the present study was to establish a warmed and humidified local artificial atmosphere consisting of air within and around the abdominal cavity during an open surgical procedure and assess the effect on postoperative adhesion formation and bacterial load in a rat model. It is hypothesized that exposure of the peritoneum to warm and humidified air instead of the cold and dry air from the operating theatre during an open surgical procedure will reduce desiccation of the peritoneum and thereby postoperative adhesion formation [1].

2. Materials and methods

In the present block randomized experimental study, postoperative adhesion formation and bacterial load were assessed, measured and compared between two groups after an open surgical procedure was performed on 48 Wistar male rats (Clr:WI) from 'Charles River Laboratories'. The rats weighed about 280 grams each, were fed standard rat chow with tap water ad libitum and kept under standard laboratory conditions. Each rat lacked outward identifying characteristics and received an identifying chip subcutaneously, thereby enabling blinding of the investigator at the time of adhesion assessment.

During the open surgical procedure the abdominal cavities of the control group rats were exposed to the cold and dry air from the operating theatre. The abdominal cavities of the study group rats on the other hand were exposed to the warmed and humidified local artificial atmosphere consisting of air. The local artificial atmosphere was created within a perspex box that had several access points for intubation equipment, gas and the surgeon's arms (see Fig. 1) [31].

Air from a wall outtake was warmed and humidified by several heaters and humidifiers (Ultra-Neb 99, DeVilbiss, Dietzenbach, Germany, and Auto-Fill Humidification Chamber and Heated Humidifier, Fisher and Paykel Healthcare, New Zealand) up to 37 °C and a relative humidity (RH) of 95–100% before it entered the perspex box. The humidity and temperature conditions, measured with 'Testo 625' (Testo LTD., Alton, UK), within the perspex box were kept as stable as possible. Adjustments, if necessary, were made at intervals during the procedure.

All rats received atropine 20 minutes before receiving anaesthesia. The initial dose of anaesthesia consisted of 5% isoflurane, and was delivered through a vaporizer and inhaled inside a closed chamber. Subsequently the study group rats were intubated and connected to a rodent ventilator (Harvard Starling 'Ideal' Ventilator, Sydney, Australia) with a stroke volume of 1.5 ml/min and respiration rate of 80 breaths/min, while the control group rats were connected to gas masks. A plane of anaesthesia, consisting of approximately 1.5% isoflurane delivered through a vaporizer, 40% O_2 and 60% N_2O, was maintained during surgery in both groups.

After being connected to a ventilator or gas mask, the rats received 12 ml isotone saline subcutaneously. The abdomen was shaved and the skin was sterilized with chlorhexidine before a 3.5 cm long midline laparotomy was performed. Afterwards, four ischaemic knots and four cuts of about 1 cm in length were applied in four different quadrants of the anterior abdominal wall [31,32]. 'Self-retaining retractors' were used to keep the abdominal cavity open and exposed to the surrounding atmosphere for 1 hour and 15 minutes, after which the surgical cavity was filled with 5 ml 37 °C warm isotone saline. A fluid sample was then taken after 2 minutes, which was later used for a quantitative bacteriologic cultivation on chocolate and blood agar. After an intubation period of 3 days, the number of colony forming (CFU) was counted and the bacterial load (number of CFU/ml) was calculated.

Just prior to closing the abdominal cavity with PDS sutures, but after taking a fluid sample, nine drops of blood from the tip of the tail vein were administered inside the abdominal cavity [33]. After closure, the rats received buprenorphine (0.05 mg/kg s.c., Temgesic, Reckitt and Coleman, Hull, UK) subcutaneously before waking in order to reduce acute postoperative pain. Additional pain medication was administered depending on the rats' general behaviour, alertness and posture during the following weeks. Also, the control group rats were kept warm with warming blankets during surgery.

As advised in previously published literature [34,35], postoperative adhesion formation was assessed after 3 weeks. The rats were fed standard rat chow and tap water ad libitum during these weeks. The rats were put under anaesthesia and the anterior abdominal wall was cut open from the pubis along the hip bone, the left flank and left subcostal bow until the os xiphoideum was reached. While opening the abdominal cavity, any adhesions attached to the anterior abdominal wall were assessed. After adhesion assessment, euthanization of the animals was performed by removal of the heart.