The Effect of Hypercarbia on Healing of Colonic Anastomosis During Pneumoperitoneum

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ÖZET

Pnömoperitona bağli hiperkarbinin kolon anastomuzuna etkileri

Amaç: Bu çalışmanın amacı pnömoperitonun neden olduğu hiperkarbi, asidoz ve hipoksinin kolon anastomuzuna etkisini değerlendirmektir.

Gereç ve Yöntem: Ağırlığı 500-550 gr olan Gine domuzları onarlı dört gruba ayrıldı. Grup 1: Laparotomi + kolon anastomozu, Grup 2: 30 dakika 12 mmHg CO2 pnömoperiton+kolon anastomozu, Grup 3: 60 dakika 12 mmHg CO2 pnömoperiton+kolon anastomozu, Grup 4: 30 dakika 12 mmHg CO2 pnömoperiton+subkutan amfizem+kolon anastomozu. Pnömoperiton sonrası gruplara uygulanan işlemlerden sonra femoral arter kanüle edilerek kan gazı için arteryel kan alındı. Sol kolon rezeksiyonu ve uç uca anastomoz yapıldıktan sonra tüm hayvanlardan kan örnekleri alındı. Postoperatif 4. günde tüm hayvanlar sakrifiye edilerek anastomozda patlama basıncı ölçüldü.

Bulgular: Pnömoperitonium oluşturulan gruplarda hiperkarbi, asidozis ve hipoksi düzeyleri kontrol grubuna göre istatistiksel olarak anlamlı farklıydı. Hiperkarbi, asidoz ve hipoksinin derecesi subkutan amfizem varlığı ve pnömoperitonium süresine bağlı absorbe edilen CO2 miktarı ile uyumluydu. En yüksek hiperkarbi, asidozis ve hipoksi düzeyi Grup 4'te bulundu. Anastomoz için en düşük patlama basıncı Grup 4'te diğer gruplardan istatistiksel olarak anlamlı farklı bulundu ($p<0.05$).

Sonuç: Kritik seviyelere kadar hiperkarbi, asidoz ve hipoksinin anastomoz iyileşmesine etkisi olmadığı görüldü. Bu çalışmada tek başına pnömoperitonun kritik seviyeye etkili olmadığı, bununla beraber artmış CO2 absorpsiyonuna neden olan subkutan amfizemin anastomoz iyileşmesine etkisi olduğu görüldü.

Anahtar kelimeler: Pnömoperiton, hiperkarbi, asidozis, hipoksi, anastomoz iyileşmesi

ABSTRACT

The effect of hypercarbia on healing of colonic anastomosis during pneumoperitoneum

Objective: The aim of this study was to evaluate the effects of hypercarbia, asidosis and hypoxia due to pneumoperitoneum on healing of colonic anastomoses.

Material and Methods: Forty Guinea pigs weighting 500-550 gr, were divided into four groups, each consisting of 10 Guinea pigs. Group 1: laparotomy plus colon anastomosis (control group), Group 2: 12 mmHg CO2 pneumoperitoneum for 30 minutes plus colon anastomosis, Group 3: 12 mmHg CO2 pneumoperitoneum for 60 minutes plus colon anastomosis, Group 4: 12 mmHg CO2 pneumoperitoneum for 30 minutes plus subcutaneous emphysema plus colon anastomosis. After pneumoperitoneum was induced as described above, arterial blood samples were withdrawn from the femoral artery for arterial blood gase analysis. Left colon resection and end-to-end anstomosis was performed on all animals after blood samples were withdrawn. All animals were killed on the postoperative day 4 and anastomosis bursting pressures were measured.

Results: Hypercarbia, acidosis and hypoxia were all present in the pneumoperitoneum groups and these levels were statistically different compared to the control group. The degree of hypercarbia, acidosis and hypoxia correlated with the volume of CO2 absorbed which was dependent on the lenght of pneumoperitoneum and presence of subcutaneous emphysema. The highest levels of hypercarbia, acidosis and hypoxia were found in Group 4. The lowest anastomotic bursting pressure occurred in Group 4 and the difference was statistically significant when compared with control group ($p<0.05$).

Conclusion: Anastomotic healing is not impaired until a critical level of hypercarbia, acidosis and hypoxia is reached. In this study pneumoperitoneum alone was not sufficient to achieve this treshold, however subcutaneous emphysema likely futher increased CO2 absorbtion which impairs anastomosis healing.

Key words: Pneumoperitoneum, hypercarbia, acidosis, hypoxia, anastomotic healing

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INTRODUCTION

As more experience gained with various laparoscopic procedures, surgery for various colonic lesions (tumors, diverticular disease, intestinal endometrioma, inflammatory bowel disease, volvulus, etc) are now being done laparoscopically (1,2).

Laparoscopic bowel surgery has demonstrated the benefits of decreased duration of hospital stay and time of return to full activity, smaller incisions, lower risk of cardiopulmonary complications, reduced risk of small-bowel obstruction, limited postoperative narcotic requirements and reduced intraperitoneal adhesion formation (3,4).

The learning curve for laparoscopic bowel surgery is

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steeper than routinely performed simple procedures such as, laparoscopic cholecystectomy and appendectomy. The long duration of operating time and the occasional need for high pneumoperitoneum pressures are the the disadvantages of laparoscopic bowel surgery (5,6,7). Preoperative and postoperative hypercarbia and acidosis resulting from prolonged and high intraabdominal pressure during laparoscopic bowel surgery has been documented (8).

In this study, we aimed to investigate the effects of hypercarbia and acidosis from CO2 pneumoperitoneum on the healing of colonic anastomosis. During the study, it was noted that hypoxia was also present additional to hypercarbia and acidosis and therefore the effects of different levels of hypercarbia, acidosis and hypoxia on the anastomosis healing were evaluated.

MATERIAL AND METHODS

This study was done at the Istanbul University, Cerrahpasa Medical School, Animal Production and Experimental Research Center. Forty Guinea pigs, each weighing between 500 and 550 gram, were divided into 4 equal groups. The animals were kept in the same physical and environmental conditions and were fed with a standard laboratory diet and water ad libitum. The groups were as follows (Table 1):

Table 1: Groups

Group 1	laparotomy plus colon anastomosis (control group)
Group 2	12 mmHg CO2 pneumoperitoneum for 30 minutes+colon anastomosis
Group 3	12 mmHg CO2 pneumoperitoneum for 60 minutes+colon anastomosis
Group 4	subcutaneous emphysema plus 12 mmHg CO2 pneumoperitoneum for 30 minutes+ colon anastomosis

laparotomy plus colon anastomosis (Group 1), 12 mmHg CO2 pneumoperitoneum for 30 minutes plus colon anastomosis (Group 2), 12 mmHg CO2 pneumoperitoneum for 60 minutes plus colon anastomosis (Group 3), 12 mmHg CO2 pneumoperitoneum for 30 minutes plus subcutaneous emphysema plus colon anastomosis. Fifteen cc CO2 was injected subcutaneously to create subcutaneous emphysema in Group 4.

Animals were anesthetized by intraperitoneal injection of 50 mg/kg ketamine hydrochloride (Ketalar, Eczacibasi/Istanbul, Turkey). In Group 1, after arterial blood samples were withdrawn from femoral artery for arterial blood gase analysis, a midline laparotomy was performed and descending colon was transected 3 cm proximal to the peritoneal reflection. End-to-end anastomosis was performed with interrupted 5-0 polypropylene sutures by an inverted single layer technique. The fascia and skin were closed separately with continuous 3-0 silk sutures. The animals were allowed to feed on postoperative day 1. In the other groups, the abdomen was insufflated with CO2 via a 16 gauge Braun cannula under 12 mmHg constant pressure for 30 minutes (Group 2), under 12 mmHg constant pressure for 60 minutes (Group 3), and under 12 mmHg constant pressure for 30 minutes (Group 4). In addition to the pneumoperitoneum, 15 cc CO2 was injected subcutaneously to create subcutaneous emphysema in Group 4. Arterial blood gas samples were then withdrawn and colon anastomosis was performed with the same technique as described for Group 1.

On postoperative day 4, all animals were killed with a high dose of ether anesthesia. The abdomen was opened from the incision scar. Anastomotic line determined gently from the sutures and bursting pressure was measured in situ. The colon was transected 2 cm proximal to the anastomosis and fecal content was gently cleaned. After the colon was ligated 2 cm distal to the anastomosis a feeding tube was inserted in to the proximal stump and tied with suture to prevent air leaks. The entire animal was then submerged in a saline filled aquarium, and feeding tube was connected to manometer and infusion pump with a 3-way stopcock. The colon was insufflated with air via the tube at a constant rate of 6 ml/min. The bursting pressure was recorded when the first air bubbles were observed.

Statistical Analysis:

Anova -Tukey HSD test was used for statistical analysis. P values less than 0.05 were considered to be significant and less than 0.001 were considered to be highly significant.

RESULTS

There was no mortality in the groups. Bursts occurred along the anastomotic lines in all groups. The arterial blood gas values and anastomotic bursting pressure values are given in Table 2. pCO2 levels were significant different

Table 2: Arterial Blood Gases Values and Anastomotic Bursting Pressures (mmHg)

	Group 1	Group 2	Group 3	Group 4
pH	7.41±0.018	7.3±0.044	7.19±0.035	7.18±0.02
pCO2	38.7±1.64	59.6±9.38	63.7±9.31	66.7±6.68
Lactic asid	0.79±0.35	2.01±0.42	3.63±1.04	3.91±0.67
pO2	96.4±1.34	70.5±7.14	62.4±11.14	57.7±8.96
Bursting pressures	105.4±13.85	97.2±10.88	97±8.17	89.2±12.26

between all pneumoperitoneum groups vs. control group (group 2, 3 and 4 vs. group 1; ($p<0.001$)). No difference was seen between the pneumoperitoneum groups ($p>0.05$). Acidosis occurred in all pneumoperitoneum groups. pH in the pneumoperitoneum groups were significant different compared to the control group (group 2, 3 and 4 vs. group 1; ($p<0.001$)). In addition, statistically significant difference was encountered between groups 3 and 4 vs group 2 ($p<0.001$). When lactate levels were compared; difference was observed for all pneumoperitoneum groups vs control group (group 2, 3 and 4 vs group 1; ($p<0.001$)). In addition, difference was found for group 2 vs 3 and for group 2 vs 4, ($p<0.001$). Hypoxia occurred in all pneumoperitoneum groups and the difference was statistically significant for all pneumoperitoneum groups vs. control group (group 2, 3 and 4 vs. group 1; ($p<0.001$)). In addition, statistically significant difference was encountered for group 2 vs group 4, ($p<0.001$). These findings suggest that the severity of the hypercarbia, acidosis and hypoxia is directly correlated to the volume of CO2 absorbed. Group 4 had the lowest anastomotic bursting pressures, and the difference was significant vs. control group, ($p<0.05$). There was no statistically significant difference between the other pneumoperitoneum groups or between any of the pneumoperitoneum only groups and control.

DISCUSSION

Although hypercarbia and acidosis are well known entities occurring during prolonged laparoscopic procedures, the effect of these unwanted events on wound healing, especially on intestinal anastomosis healing is still unclear (8).

In this study, the effect of different levels of acidosis and hypercarbia due to carbon dioxide pneumoperitoneum on colon anastomoses healing was studied. Furthermore; hypoxia was found in addition to these findings remains controversial in clinical literature.

Length of pneumoperitoneum was correlated with severity of acidosis, hypercarbia, hypoxia, as well as inversely correlated with anastomosis bursting pressures. Further impairment of anastomotic healing was encountered in the animals (Group 4) who had subcutaneous emphysema in addition to the carbon dioxide pneumoperitoneum.

Many factors slow anastomosis healing and are directly related to anastomotic complications (9,10). Blood loss, hypovolemia and hypoxia are among the important causes of failure of wound healing (11,12).

Adequate oxygenation is necessary for wound healing. Wound healing is adversely affected by hypoxia, and this causes early and late wound complications (9,10). It has been suggested that healing can be improved by increasing inspired oxygen tension. Uhl et al. (13) suggested that hyperbaric oxygen therapy improves reepithelialization in normal and ischemic skin tissue. Hamzaoglu et al. (14) demonstrated that hyperbaric oxygen improves anastomotic healing of both normal and ischemic colonic anastomosis and hyperbaric oxygen reverses ischemic damage.

In this study, hypoxia accompanied hypercarbia in all pneumoperitoneum groups. This is in contradiction to clinical studies in which mechanical ventilation is used. The severity of the hypercarbia and hypoxia is directly correlated with the length of pneumoperitoneum and the volume of CO2 absorbed. Most significant hypercarbia and hypoxia occurred in the pneumoperitoneum plus subcutaneous emphysema group. Although the length of pneumoperitoneum was the same in Group 2 and 4, the presence of subcutaneous emphysema likely caused more absorption of CO2 and therefore the development of hypoxia. Similar to our results, hypercarbia has been reported in patients who had subcutaneous emphysema during pneumoperitoneum, but in contrast to hypoxia development in this study, hypoxia was prevented by mechanical ventilation (15).

Hypercarbia and acidosis resulting from carbon

dioxide insufflations during laparoscopy has been well documented. Following a long laparoscopic procedure, several hours are needed to eliminate the accumulated carbon dioxide and restore acid-base balance (16). Taura et al. (8) demonstrated that plasma lactate levels significantly increased 90 min after insufflations and reached the highest value 1 h after deflation of 15±1 mmHg CO2 pneumoperitoneum. Simultaneously, arterial pH was significantly lower at 1 h after surgery.

In this study acidosis developed in the all pneumoperitoneum groups. Similar to hypercarbia and hypoxia, the degree of acidosis was directly correlated with the length of pneumoperitoneum. The deepest acidosis occurred in the subcutaneous emphysema group. The large absorption surface area in the subcutaneous tissue and the large difference in the partial pressure likely cause the extensive gase interchange of CO2 between subcutaneous tissue and surrounding capillaries (15).

A transient level of hypercarbia, acidosis and hypoxia from CO2 pneumoperitoneum likely doesn't affect anastomosis healing but conditions in which the hypercarbia, acidosis and hypoxia persist after the desufflation, such as subcutaneous emphysema, may affect the anastomoses healing adversely. More studies are required to better determine the threshold.

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