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The Effects of Carbon Dioxide Pneumoperitoneum on Peritoneal Structure

Karbondioksit ile Oluşturulan Pnömoperitoneumun Periton Yapısı Üzerine Etkileri

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Abstract

To create pneumoperitoneum at the beginning of laparoscopic surgery, several gases have been trialled. The most commonly used of these gases is carbon dioxide. Although pneumoperitoneum created with carbon dioxide provides an appropriate area for surgeons to perform laparoscopic operations, it can also cause several unwanted changes to the peritoneal structure. Some of these side-effects are inevitable but some exhibit changes depending on the method of application. This review was prepared taking into consideration the previous experimental and clinical studies in literature related to the effects on the peritoneal structure of pneumoperitoneum created with carbon dioxide. The creation of pneumoperitoneum affects the peritoneal environment and thereby the organism. This effect is caused by increased intra-abdominal pressure, the local peritoneal destructive effect, carbon dioxide absorption and chemical metabolic changes. It is important to be aware of the effects created by pneumoperitoneum, especially in obese patients or those with concomitant diseases. With this awareness, it will be possible to reduce the effects of the undesired changes wrought by pneumoperitoneum.

Keywords: Carbon Dioxide Pneumoperitoneum, Laparoscopy, Carbon Dioxide Insufflation

Özet

Laparoskopik ameliyatların uygulanmaya başlamasıyla beraber pnömoperiton oluşturmak için birçok gaz denenmiştir. Bunlar arasında halen en yaygın kullanımda olan karbondioksit gazıdır. Karbondioksit ile oluşturulan pnömoperiton laparoskopik ameliyatlarda cerrahlara uygun alan oluşturmasına rağmen peritoneal yapı üzerinde birtakım istenmeyen değişikliklere de sebep olmaktadır. Bu yan etkilerden bazıları kaçınılmaz olmasına rağmen bazı yan etkilerde uygulama şekline bağlı değişiklik gösterebilmektedir. Karbondioksit ile oluşturulan pnömoperitonun peritoneal yapı üzerine etkilerine ilişkin literatürdeki yapılan deneysel ve klinik çalışmalar dikkate alınarak bu derleme hazırlandı. Pnomöperiton oluşumu peritoneal çevreyi ve dolayısıyla organizmayı etkiler. Bu etkilenim intraabdominal basınç artışı, karbondioksitin lokal peritoneal destrüktif etkileri, karbondioksit emilimi ve kimyasal metabolik değişimler gibi sebeplerle olmaktadır. Özellikle ek hastalığı olan ya da obez hastalarda pnömoperitonun yaptığı etkiler hakkında farkındalığa sahip olunması önemlidir. Bu farkındalık hastaların pnömoperitonun yaptığı istenmeyen değişikliklerden etkilenimini azaltacağı kanısındayız

Anahtar kelimeler: Karbondioksit Pnömoperiton, Laparoskopi, Karbondioksit İnsuflasyonu

Introduction

Pneumoperitoneum created with carbon dioxide insufflation is still a widely used method throughout the world in laparoscopic surgery. During the development of laparoscopic techniques, several gases have been used for this purpose. However, none have become as widely used as carbon dioxide. While providing an appropriate area to be worked on by the surgeon, it is also however, the reason for a series of unwanted side-effects. To date there have been many experimental and clinical studies in literature on the effects of carbon dioxide gas on the peritoneal structure. In this paper, literature was reviewed and a compilation was formed of the effects on the peritoneal structure of pneumoperitoneum created with carbon dioxide.

Peritoneal Cavity Morphology

The peritoneum is the largest serous membrane in the body and consists of 3 layers, the mesothelium, the basal membrane and connective tissue. Mesothelial cells are arranged over the basal membrane in the form of a single row and there are connectors and desmosomes at intervals. In addition, there are microvilli on the apical surface of mesothelial cells (1).The mesothelium has a similar structure in all areas of the peritoneum, but there are changes in thickness in the underlying connective tissue and cells. The thinnest mesothelium is in the anterior wall (2). The mesothelial cells may be cubic, smooth or intermittent in form. Cubic cells are often parenchymal over organs and the smooth cells are to be found more on the intestine, omentum and parietal peritoneum (3).

The Effects of Carbon Dioxide Pneumoperitoneum on the Peritoneal Structure

There have been experimental and clinical studies related to damage to the peritoneal structure in laparoscopic surgery (4,

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5). In addition to impairment of the morphological structure of the peritoneum, it may also cause a series of metabolic changes. For reasons such as gas insufflation, hypothermia, pressure, dryness or light, the creation of pneumoperitoneum may cause events such as peritoneal spillage, reduced fibrinolysis, changes in immune response, reductions in growth factor production, metabolic acidosis and focal tissue oxygen pressure (6).

Several gases have been used in laparoscopic surgery such as carbon dioxide, helium, xenon and air and studies have been conducted on this subject. However, carbon dioxide, which is colourless, non-combustible and easily available, is the most widely used gas. As absorption and elimination are simple, there is no risk of gas embolism (7, 8). Although carbon dioxide is the most widely used gas, it also has several

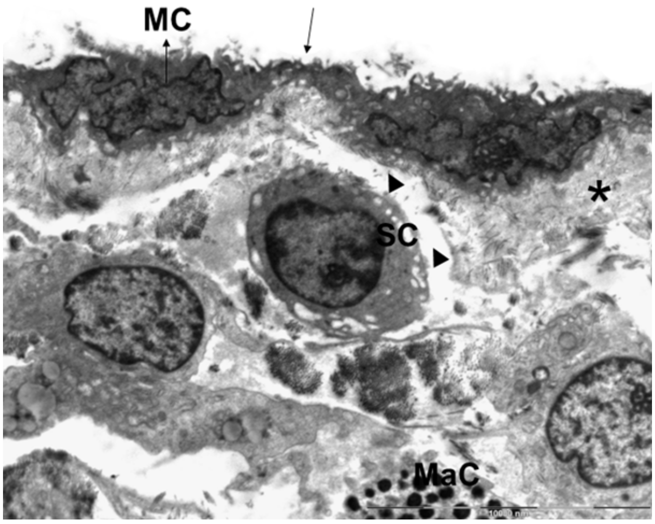

Image 1. Cross-section of a normal appearance peritoneum. Mesothelium After the Trocar Placement: Intercellular junctions are normal thickness (arrow). MC: Mesothelial Cell, Triangle: Elastic fibres, asterisk: collagen, SC: smooth muscle cell, MaC: Mast cell

undesired effects. In a study conducted on rats to examine the changes in the peritoneum created by carbon dioxide, changes in the morphology of the peritoneum were determined to occur 1-2 hours after desufflation. There were sporadic contractions in the mesothelial cells of the peritoneal surface and ballooning occurred between these. As the process continued, so more damage developed, reaching its highest level at the 12th hour. In the spaces between the mesothelial cells, macrophages and lymphocytes started to be seen and in 24 hours there was proliferation. At the 48th hour, repair of the peritoneum started and the basal lamina was re-covered (9).

In a study by the current authors, laparoscopic cholecystectomy was applied with pneumoperitoneum created with carbon dioxide. During this process, the changes in the peritoneal structure were examined cross-sectionally by transmission electron microscopy. No change was seen in the sample at the start of the pneumoperitoneum. In the biopsies taken after the cholecystectomy (at 42.7 mins), thickening was observed in the mesothelial cells. However, no desquamation or basal membrane peeling was observed. The mesothelial cells exposed to carbon dioxide were seen to be a more dense structure in electron microscopy and apoptosis was also seen. There was an increase in the intracytoplasmic vacuoles and there were intermittent spaces between the epithelial cells. Oedema was observed in the subepithelial area (10).

Wildbrett et al investigated the effects of helium and carbon dioxide on the peritoneum in rats. There was seen to be a significant level of reduction in the tissue oxygen pressure of both helium and the carbon dioxide. When a mixture of 80% carbon dioxide and 20% oxygen was used, there was no significant change in the tissue oxygen pressure. In addition, while the Ph value was reduced with carbon dioxide, it was increased with helium (11).

In another study, air was compared with carbon dioxide. There was less clouding of the lens with the use of carbon dioxide, as there was a frequent need to clean the lens with the use of air. The return to daily activities was determined to be earlier with the use of carbon dioxide. As the air was not sterile, peritonitis was observed in 1 patient of that group, and a significantly higher level of shoulder pain, abdominal discomfort and wound infection. As the outcomes obtained were as good as those of carbon dioxide, that study reported that air could be used as a safe alternative and that it was cheaper was emphasised (12). In a similar study on rats, air and carbon dioxide were compared with laparotomy and a control group. In the laparotomy group, at 24 hours as the base, a decrease was seen in villi on the mesothelial cell surface only. In the air group, fusiform, spherical-shaped mesothelial cells were seen. In the carbon dioxide group, changes in cell shape and intercellular fissures were observed. Starting from the 2nd hour, the intercellular spaces reached the most severe level at 24 hours. Unprotected areas were formed on the basal lamina at 24 hours (13).

In a similar study on rats, a comparison was made of high and low pressure levels of filtered air and carbon dioxide. From the results of that study it was concluded that the integrity of the peritoneum was affected by the pneumoperitoneum and the degree of morphological change was related to the pressure level and that low pressure carbon dioxide created the least peritoneal change compared to high pressure carbon dioxide and air (14).

The effects of carbon dioxide on the peritoneum were investigated in 40 patients in another study. No evident change was observed in the first 60 minutes, but intercellular spaces started to be seen at 90 mins becoming significant at 2 hours. Few lymphocytes and macrophages were seen in the intercellular spaces at 2 hours (5).

While gas insufflation is being applied, a heating and humidifying procedure can be made. However, this heating and humidifying procedure is not a method which is applied in all clinics. Comparisons have been made beween pneumoperitoneum created with warmed, humidified gas and cold dry gas. The morphological changes were investigatd in rats in peritoneum created with both types of gas insufflation and by raising the abdominal wall without gas. Although several changes were observed, no statistically significant difference was determined (2315). In another study conducted on rats, similar peritoneal morphological changes were observed in both the group to which heated and humidified carbon dioxide was applied and the group to which cold, dry gas was applied. After the 6th hour in particular, the mesothelial desquamation rate was observed to be approximately 90% in the cold, dry gas group and approximately 50% in the heated, humidified gas group (16).

In a clinical study of 148 patients, the effects of cold carbon dioxide and heated, humidified carbon dioxide on postoperative pain were investigated. A significant reduction in pain on the operation day was determined in the group to which heated, humidified carbon dioxide was applied. However, on postoperative Day 1, no significant difference was determined. Cold carbon dioxide gas has been said to be the reason for hypothermia and increased sensitivity to pain (17).

Laparoscopic surgery is currently in widespread use for obese patients. V. Perilli et al investigated carbon dioxide elimination in obese patients. Normal weight and obese patients undergoing cholecystectomy were followed up from the start of induction to extubation. In obese patients, the process of complete carbon dioxide elimination was observed to be longer. Whereas normal weight patients reached the plateau phase of the carbon dioxide elimination curve in 20 mins, it took obese patients 30 mins. After desufflation, the regulation of the carbon dioxide level in normal weight patients was earlier than in obese patients. This can be attributed to a greater accumulation of carbon dioxide as obese patients have a larger body. Carbon dioxide elimination in laparoscopic surgery is slower in obese patients and in patients with pulmonary disease, this must be given even more importance (18).

In a study by Nasajyan et al, whether the pressure of carbon dioxide used in laparoscopy had any effect or not on postoperative nausea and vomiting was investigated in 50 patients. The patients were separated into 2 groups as 7-9mmHg and 14-15mmHg. In the evaluation, no statistically significant effect of normal or low pressure gas was determined on nausea and vomiting. However, a significantly lower level of postoperative shoulder pain was observed in the low pressure group (19). In a study on rats, research was made into the effect on ovaries and tubes of the pressure of carbon dioxide used in insufflation. In the ovary cortex epithelium, the carbon dioxide pressure was correlated with ischaemia-reperfusion which was observed with transmission electron microscope to have led to damage (20). In another study, postoperative pain levels and the amount of gas remaining in the abdomen following laparoscopy were investigated in patients with and without active aspiration. In the results obtained, the amount of residual gas in the abdomen and the postoperative scores were found to be lower in the patients with active aspiration (21).

There are studies in literature which have researched the effects of the creation of pneumoperitoneum on adhesion formation. In a rabbit study, the effect of carbon dioxide insufflation rate and pressure on adhesions was investigated. Results were evaluated by scoring adhesions on deep and superficial lesions. According to that study, in superficial lesions, both insufflation rate and insufflation pressure were found to be effective in increasing the adhesion score. In deep lesions, only insufflation pressure was found to be effective which is suspected to be due to anoxemia and peritoneal dryness. While the increase of adhesion scores in superficial and deep lesions is explained with anoxemia of insufflation pressure, the role of the insufflation rate in increasing the adhesion score in superficial lesions is evaluated as being due to increased dryness which increases mesothelial damage (22).

In a study on rats the effects on adhesions were investigated according to the duration and gas pressure of carbon dioxide and helium gases and additional oxygen. While an increase in adhesions was determined with increased duration and pressure, adhesions decreased with the addition of oxygen. That mesothelial hypoxia has been found to contribute to adhesions supports these results (23). In a similar study on rabbits, a hypoxic environment was made with helium or carbon dioxide and similar results were obtained (24).

In a study made on patients undergoing laparoscopic cholecystectomy, the protein denaturation temperature, enthalpy value and the specific heat-temperature change ratio was examined in peritoneal samples taken at the beginning and the end of the cholecystectomy procedure. The enthalpy values in the peritoneal samples exposed to carbon dioxide were found to have decreased. This was evaluated as the collagen stability found in the laminar layer and mesothelial cells having been impaired by carbon dioxide (25).

In addition to the morphological changes wrought on the peritoneum by carbon dioxide in a pneumoperitoneum created with carbon dioxide, there are haemodynamic effects. The reasons for these effects may be intraperitoneal pressure, blood carbon dioxide pressure level, the hypoxemic effect, the acidosis effect and the effect on the immune response due to local structural damage.

Umar et al monitored surgical patients haemodynamically from the start of carbon dioxide insufflation to 10 minutes after desufflation. The patients were operated on at 3 separate intra-abdominal pressures (8-10mmHg, 11-13mmHg, 14mmHg). The 3 groups were compared in respect of 5 separate measurements which were recorded in the period from the 10th minute of insufflation to 10 mins after desufflation. A statistically significant difference was determined at the time intervals in respect of heart rate, systolic blood pressure, mean arterial pressure and end-tidal carbon dioxide values. The reason for this was reported to be sympathetic stimulation and catecholamin expression associated with hypercarbia and reduced venous return due to increased intra-abdominal pressure. In addition, the increase in venous resistance with the sympathetic effect of the carbon dioxide absorbed from the peritoneum, contributes to increased heart rate and blood pressure (26).

In a study of rats with stomach cancer, it was observed that carbon dioxide pneumperitoneum affected the cytokine secretion functions of macrophages and the properties of phagocytosis and at the same time facilitated stomach cancer peritoneal metastasis (27). All of the side effects of pneumoperitoneum with carbon dioxide are shown in figure 1.

Conclusion

Laparoscopic surgery is becoming increasingly more widespread. Gases, such as carbon dioxide, helium, xenon and air have been used in insufflation and a working area for laparoscopy can even be formed by raising the abdominal wall without gas. However, the most widely used method of creating pneumoperitoneum currently is the use of carbon dioxide gas.

The basic parameters of increased abdominal pressure which damage the morphological structure of the peritoneum are the chemical effects of the carbon dioxide gas itself, whether it is warm and moist or cold and dry and the insufflation rate. Carbon dioxide gas shifts blood ph towards acidosis. Sympathetic activation and catecholamin discharge is a reason for hypercarbia in the blood. In addition, intra-abdominal hypoxia is created and this hypoxia contributes to mesothelial damage and adhesions. Insufflation applied with warm and humidified carbon dioxide reduces the mesothelial damage. An increase in insufflation pressure has the effect of increasing the formation of adhesions.

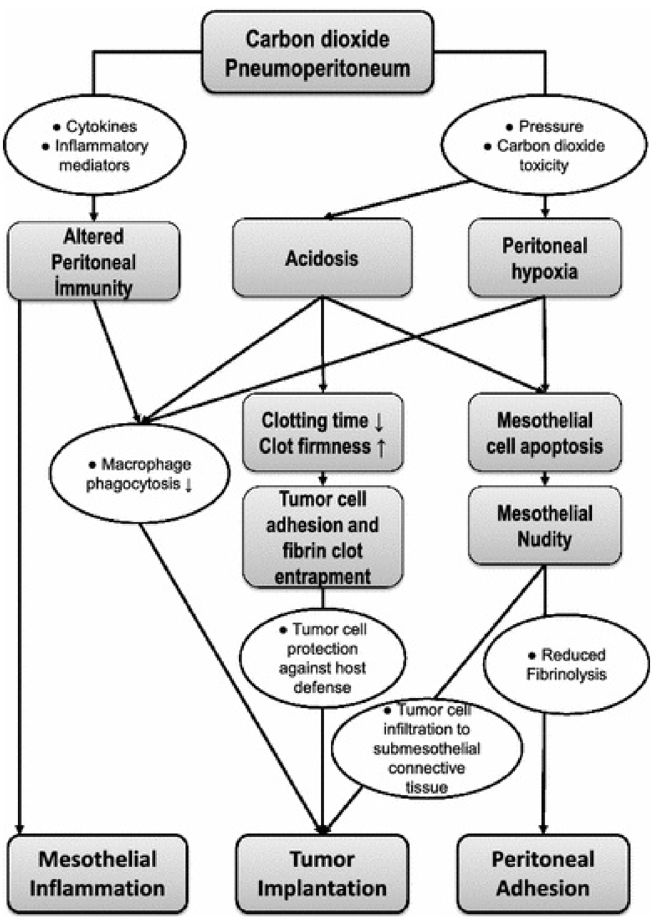

Figure 1. Side effects of carbon dioxide pneumoperitoneum(10)

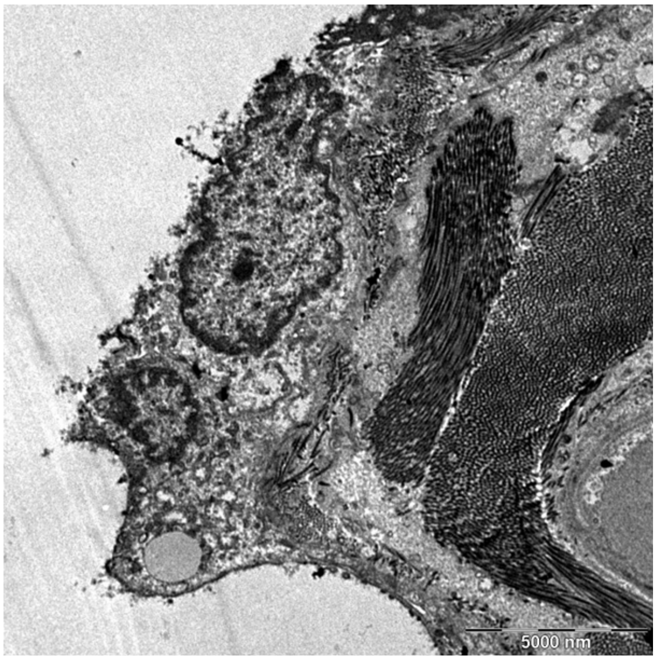

Image 2. Image of affected peritoneal membrane by carbon dioxide in cross-sectionally by transmission electron microscopy study

Just as these changes constitute a significant problem in several patient groups, they are important in those with obesity, heart disease and pulmonary disease. Compared to normal weight patients, in obese patients, carbon dioxide absorbed in the intra-abdominal area takes longer to clear.

The creation of pneumoperitoneum partially decreases venous return due to the increased intra-abdominal pressure. This affects haemodynamics. In addition, the effect of carbon dioxide of increasing sympathetic activity also contributes to haemodynamic changes. Knowledge and awareness of these series of effects of carbon dioxide in those with heart diseases and the availability of appropriate interventions and if necessary, a change of method are of vital importance.

In the light of this information, the basic changes can be summarised thus:

• Destructive effects on the peritoneal structure (mesothelial damage, microvillus loss, formation of fissure in the mesothelium, apoptosis and basal membrane peeling, peritoneal oedema).

• The destructive effects increase with an increase in pressure, when the gas administered is cold and dry and with a high insufflation rate.

• Through absorption, the carbon dioxide administered to the abdomen passes into the blood and causes hypercarbia. In obese patients and those with pulmonary disease, the effect lasts longer as eliination is difficult and prolonged.

• There are haemodynamic negative effects as venous return is partially inhibited due to the intra-abdominal pressure increase.

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