Original Paper

Effect of Surgical Incision on Pain and Respiratory Function after Abdominal Surgery: A Randomized Clinical Trial

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ABBREVIATIONS: Arterial O_2 tension (PaO_2); Arterial CO_2 tension ($PaCO_2$); Visual Analogue Scale (VAS); Oxygen saturation (SaO_2); Partial carbon dioxide pressure ($PaCO_2$); Bicarbonates (HCO_3); Base buffer (pH); Base excess or deficiency (BE)

ABSTRACT

Background/Aims: The aim of the present study was to assess the severity of respiratory disturbances occurring after abdominal surgery and to identify surgical incisions that entail the least respiratory complications and postoperative pain.

Methodology: A total of 105 patients divided into two groups were included in this randomized clinical trial. Seventy-five patients in the first group underwent upper abdominal surgery, and were operated on by use of vertical, oblique, transverse and elliptic incision. The remaining 30 patients in the second group were submitted to low abdominal surgery by use of vertical and oblique incision. Arterial blood gases and pulmonary shunt development were determined at 12 h preoperatively, and at 6 h, 72 h and 144 h postoperatively. During the postoperative course, VAS-pain score and use of tramadol were observed according to the type of surgical incision employed.

Results: Most severe respiratory disturbances in terms of PaO_2 decrease, activating compensatory hyperventilation, pulmonary shunt increase, the highest VAS-pain score and consumption of tramadol were induced by the following upper abdominal incisions: transversal laparotomy according to Orr, elliptic periumbilical laparotomy, upper midline laparotomy, transrectal laparotomy and subcostal laparotomy. In the group of low abdominal surgery (low midline laparotomy and inguinal incision) consumption of tramadol was statistically significantly lower, but no statistically significant differences were recorded between the baseline preoperative and postoperative values of PaO_2, $PaCO_2$ and pulmonary shunt.

Conclusions: All low abdominal incisions were found to entail statistically significantly less respiratory disturbances, lower VAS-pain score and lower tramadol use when compared to upper abdominal incisions. The upper abdominal incisions observed caused substantial respiratory disturbances including hypoxia, hyperventilation and pulmonary shunt increase.

INTRODUCTION

Preoperative risk factors (obstructive syndrome, smoking, obesity, advancing age), intraoperative factors (monotonous respiration, impaired ventilation-perfusion ratio, duration of anesthesia), and postoperative factors (pain, immobility, abdominal distention, restrictive bandages) produce respiratory disturbances that lead to postoperative respiratory insufficiency. A decrease in PaO_2, increase in $PaCO_2$ and alveoloarterial difference in partial oxygen pressure on 100% O_2 inhalation, pointing to pulmonary shunt, are the first signs of respiratory insufficiency. Knowing these factors that may favor the development of respiratory insufficiency is of supreme importance for both the surgeon's performance and patient's safety.

METHODOLOGY

This randomized clinical trial included 105 patients submitted to different abdominal surgery procedures. The patients were divided into two groups. The first group of 75 patients had upper abdominal surgery by use of vertical incision (upper midline laparotomy, transrectal laparotomy), oblique incision (subcostal laparotomy), transverse incision (transversal laparotomy according to Orr) and elliptic incision (elliptic periumbilical laparotomy), and the second group of 30 patients had low abdominal surgery by use of vertical incision (low midline laparotomy) and oblique incision (inguinal incision).

Comparability of the patient groups was ensured by selection of patients with similar anthropometric values (age, sex, height and weight). The same patients before the operation served as their own controls. All study patients had ASA I physical status. Patients with current or previous pulmonary disease and those treated for cardiac disease were excluded from the study, to prevent the possible effect on study results.

On the day before the scheduled procedure, a cannula was placed in the patient's radial artery. Patency

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TABLE 1 Diagnosis and Operative Procedure in Patients with Different Abdominal Incisions (n=105)

Abdominal incisions	Diagnosis	Number	Operative procedure
Oblique subcostal laparotomy	Symptomatic gallstones	15	Classic Cholecystectomy
Transrectal laparotomy	Symptomatic gallstones	15	Classic Cholecystectomy
Upper midline laparotomy	Acute cholecystitis	5	Classic Cholecystectomy
	Duodenal ulcer	10	Parietal cell vagotomy
Elliptic periumblical laparotomy	Umbilical hernia	15	Mayo repair procedure
Transversal laparotomy (Orr)	Pancreatic head carcinoma	3	Pancreatoduodenectomy
	Pancreatic pseudocysts	7	Cystogastrostomy
	Chronic pancreatitis	5	Distal pancreatic resection
Low midline laparotomy	Familial polyposis	4	Total colectomy
	Ulcerative colitis	4	Subtotal colectomy
	Colon cancer	7	Subtotal colectomy
Inguinal incision	Inguinal hernia	15	Lichtenstein repair procedure

of the cannula during the six-day blood sampling was maintained by heparin solution. Arterial blood samples were obtained by syringes which were transported to the laboratory in ice to prevent the effect of high temperature on gas analysis accuracy (1). The following parameters were determined in arterial blood samples: partial oxygen pressure (PaO_2), oxygen saturation (SaO_2), partial carbon dioxide pressure ($PaCO_2$), bicarbonates (HCO_3), base buffer (pH), and base excess or deficiency (BE). Arterial blood gases and acid-base balance were determined on an analyzer Radiometer (ABL2, Copenhagen, Finland). The extent of pulmonary shunt was assessed by inhalation of 100% oxygen and subsequent gas analyses. The patients inhaled 100% oxygen through a one-way valve connected to oxygen bottle. Arterial blood samples were obtained before and after oxygen inhalation, during a 20-min period. Determination of the alveoloarterial oxygen gradient was followed by pulmonary shunt determination from nomogram according to Chung (2). The patients were tested on four occasions, i.e. 12h preoperatively, and 6 h, 72 h and 144 h postoperatively. All measurements were taken in patient rooms, with the patients' full orientation and cooperation. The patients were in a semisupine position, with the legs and trunk at an angle of 45°. During 100% oxygen inhalation, nasal clamps were placed and the patients were verbally instructed and assisted by a nurse.

Relationship between the type of surgical incision and pain and between the effect of analgesic and rate of respiratory disturbance recovery was assessed by the administration of tramadol (3) during the postoperative period. The postoperative pain severity was graded according to the visual analogue scale (VAS) (4,5). The patients were asked to indicate the subjective postoperative pain severity by a vertical line placed across the horizontal line between 0 and 100mm, as follows: mild (0-30mm) on the left side of the scale, moderate (30-60mm), and severe (60-100mm) on the right side of the scale. Tramadol was intramuscularly administered in a dose of 1.5mg/kg body weight, whenever a pain score exceeding 30mm was indicated on the horizontal line. The postoperative pain was measured at 6 h, 24 h, 72 h and 144 h postoperatively, severity on VAS and tramadol use.

Respiration parameters indicating the development of respiratory insufficiency included PaO_2 decrease to <10.5kPa, $PaCO_2$ increase to >6.0kPa, pulmonary shunt value increase by 20% from the normal values and spirometric values reduction by 20% from the normal values. Analysis of variance, Duncan's test, Student's *t*-test for independent samples, and χ^2-test were used for statistical analysis, employing the Microsoft Excel for Windows Version 11.0. (Microsoft Corporation, USA) and Statistica for Windows Release 11.0 (Statsoft Inc, USA).

RESULTS

Diagnoses and types of operation performed by use of various abdominal incisions are presented in **Table 1**. Examinations performed before the surgery showed that there were no statistically significant differences between the two patient groups according to sex (χ^2=1.51; p=0.317), age (t=1.63; p=0.10), height (t=0.43; p=0.66) and weight (t=1.73; p=0.09).

1) Upper abdominal incisions: In the patients operated on by oblique subcostal laparotomy, a mild, statistically non-significant PaO_2 decrease was recorded at 6 h postoperatively, where after it gradually returned to the baseline preoperative value **(Table 2)**. A statistically significant pulmonary shunt increase was measured at 6h postoperatively as compared to the baseline preoperative value and persisted till 144 h, when the measured value did not differ statistically significantly from the preoperative value **(Table 2)**.

In the patients operated on by transrectal laparotomy, a statistically significant PaO_2 decrease from the baseline preoperative value was recorded at 6 h and persisted till 72 h postoperatively **(Table 2)**. A statistically significant increase was also observed in the pulmonary shunt values at 6 h postoperatively and persisted until the end of the study period **(Table 2)**.

In the patients operated on by use of upper midline laparotomy, a statistically significant PaO_2 decrease indicating mild hypoxemia was recorded at 6 h postoperatively. At 72 h postoperatively, however, the PaO_2 values reached the limits that did not statistically significantly differ from the baseline preoperative

TABLE 2 Gas Exchange and Pulmonary Shunt in the Patients with Upper Abdominal Incisions (n=75) and Low Abdominal Incisions (n=30)

		Values (mean ± standard deviation) in patients						
		Upper abdominal incisions					Low abdominal incisions	
		Oblique subcostal laparotomy	Transrectal laparotomy	Upper midline laparotomy	Elliptic periumbilical laparotomy	Transversal laparotomy (Orr)	Low midline laparotomy	Inguinal incision
PaO_2 (kPa)	preoperative	11.0±1.1	12.5±0.5	11.8±1.3	12.3±0.5	12.4±0.4	12.3±0.6	11.8±1.2
	6h	10.5±0.6	10.8±0.9	9.9±0.7	10.8±1.0	10.2±0.7	12.0±0.8	11.5±1.3
		(0.441)†	(0.022)†	(0.001)†	(0.001)†	(0.001)†	(0.461)†	(0.742)†
	72h	10.7±0.7	12.0±0.6	11.7±1.0	11.1±0.8	11.1±0.6	12.2±1.0	11.7±0.9
		(0.814)†	(0.311)†	(1.000)†	(0.003)†	(0.005)†	(0.742)†	(1.000)†
	144h	10.9±1.2	11.9±1.1	11.6±1.1	11.3±0.9	11.0±0.6	12.1±1.1	11.6±1.1
		(0.900)†	(0.061)†	(1.000)†	(0.003)†	(0.005)†	(0.799)†	(0.912)†
$PaCO_2$ (kPa)	preoperative	4.4±0.8	4.2±0.9	4.3± 0.8	4.6±0.4	4.4±0.8	4.3±0.8	4.6±0.6
	6h	3.9±0.6	4.1±1.1	3.9±1.1	4.2±0.7	3.9±0.7	4.1±0.8	4.3±0.8
		(0.061)†	(0.966)†	(0.073)†	(0.461)†	(0.061)†	(1.000)†	(1.000)†
	72h	4.0±0.9	4.2±0.7	4.1±0.7	4.3±0.9	4.1±1.1	4.2±0.6	4.4±0.6
		(0.754)†	(1.000)†	(0.855)†	(0.721)†	(0.741)†	(1.000)†	(1.000)†
	144h	4.0±0.8	4.2±1.1	4.3±0.5	4.2±0.8	4.2±0.8	4.3±0.4	4.5±0.7
		(0.751)†	(1.000)†	(0.988)†	(0.722)†	(0.714)†	(1.000)†	(1.000)†
Pulmonary shunt	preoperative	4.5±0.8	4.8±0.6	5.9±1.1	4.8±1.1	7.8±0.8	6.0±0.9	5.7±0.6
	6h	9.1±0.8	9.0±0.9	10.1±0.8	10.0±0.5	12.5±0.6	6.8±0.6	6.1±0.6
		(0.001)†	(0.001)†	(0.001)†	(0.001)†	(0.001)†	(0.112)†	(0.567)†
	72h	7.0±0.8	8.2±0.8	9.0±0.7	9.0±1.1	12.1±1.0	7.0±1.1	5.8±0.7
		(0.005)†	(0.002)†	(0.001)†	(0.001)†	(0.001)†	(0.062)†	(1.000)†
	144h	5.8±1.6	7.2±0.6	8.0±0.5	9.2±0.4	11.8±0.8	6.2±0.9	6.0±0.9
		(0.059)†	(0.005)†	(0.002)†	(0.001)†	(0.001)†	(1.000)†	(1.000)†

PaO_2: arterial O_2 tension; $PaCO_2$: arterial CO_2 tension. †Comparison to preoperative value.

values **(Table 2)**. A statistically significant increase in the pulmonary shunt values was observed at 6 h, and persisted at 72 h and 144 h postoperatively **(Table 2)**.

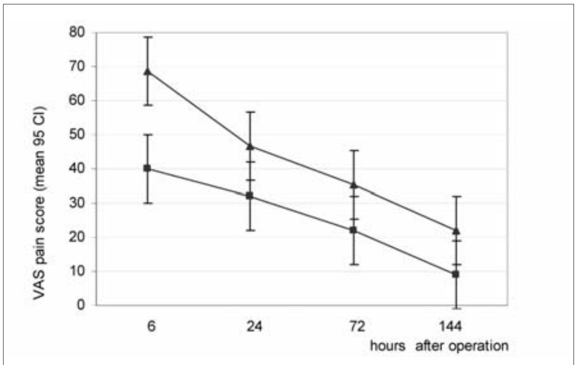

FIGURE 1 Self reported pain intensity (VAS score, possible range X-Y) after surgery in patients with different abdominal incisions. Triangles – upper abdominal incisions (n=75); Squares – low abdominal incisions (n=30).

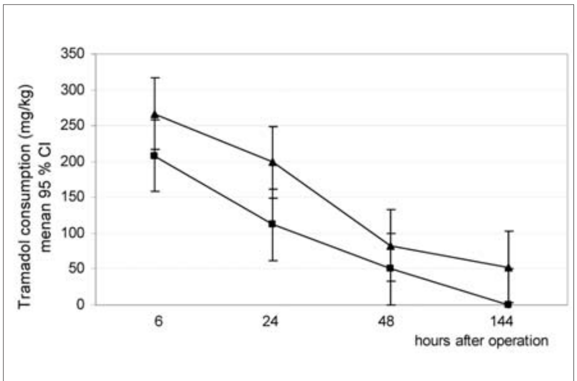

FIGURE 2 Tramadol consumption (mg/kg; possible range X-Y) after surgery in patients with different abdominal incisions. Triangles – upper abdominal incisions (n=75); Squares – low abdominal incisions (n=30).

In the patients operated on by elliptic periumbilical laparotomy, the statistically significant PaO_2 decrease recorded at 6h postoperatively persisted until the end of the period of observation, i.e. until 144 h postoperatively **(Table 2)**. A statistically significant increase in the pulmonary shunt values was observed at 6 h postoperatively as compared to the baseline preoperative value, and persisted until 144 h postoperatively **(Table 2)**.

In the patients operated on by transversal laparotomy according to Orr, the statistically significant PaO_2 decrease persisted throughout the postoperative period **(Table 2)**. A statistically significant increase in the pulmonary shunt values compared to the baseline preoperative value was recorded at 6 h and persisted until 144 h postoperatively.

In the patients operated on by the mentioned upper abdominal incisions, no statistically significant changes were observed in the values of $PaCO_2$ during the postoperative period. However, these values were within the limits indicating hypocapnia due to compensatory hyperventilation **(Table 2)**. During the study period, there were no statistically significant changes in the acid-base values either.

Transverse incision (transversal laparotomy according Orr) and elliptic incision (elliptic periumbilical laparotomy) of the upper abdomen were associated with most severe pain and greatest use of tramadol postoperatively **(Figures 1 and 2)**.

2) Low abdominal incisions: In the patients operated on by midline laparotomy and inguinal incision, no statistically significant changes were recorded during the study period in the values of PaO_2, $PaCO_2$, acid-base balance parameters, and pulmonary shunt as compared to their baseline preoperative values **(Table 2)**. Low abdominal incisions entailed a less statistically significantly VAS pain score and consumption of tramadol than upper abdominal incisions group **(Figures 1 and 2)**.

DISCUSSION

Postoperative respiratory insufficiency develops due to inadequate breathing caused by deficient respiratory excursions. This is caused by the presence of postoperative pain (6-8), which prevents deep breathing and expectoration, by unfavorable position of the patient, abdominal distention, obesity (9), smoking (10,11), and presence of restrictive bandages (12,13). Old age, sex and coexisting pulmonary diseases also play a major role in the development of late respiratory insufficiency (14).

Intestinal paresis usually occurs after upper abdominal surgery and is an important factor for respiratory disturbances that develop during the postoperative period. Intestinal paresis is closely related to the type and localization of the surgical incision, length of surgical incision, operated organ, and visceral and somatic irritation due to technical manipulations in the abdominal cavity. Meteoristic and distended intestine enlarges abdominal circumference, thrusting the diaphragm cranially and reducing its movements. Elevated diaphragm along with postoperative pain is incapable of perfusing all segments of the lungs, thus leading to regional hypoxemia. Compressed alveoli increase the intrapulmonary shunt (15,16), with an increase in the arterioalveolar oxygen ratio (17), favoring the development of atelectases (18). Study of the pulmonary shunt dynamics reveals the ventilation-perfusion abnormalities and magnitude of the blood flow that bypasses the normally ventilated alveoli and returns non-oxygenated to the left heart as a venous admixture to the arterial blood. The most important causes of the pulmonary shunt increase in surgical patients are atelectases, pneumonia and lung embolization, wet lungs and alveocapillary block.

The effect of analgesia on the reduction of respiratory disturbances following abdominal surgery is well known (19-21). A relationship between surgical incision with postoperative pain severity and respiratory disturbances has been described. In the available literature, there is no uniform opinion on the effect of length, localization and shape of surgical incision on postoperative pain and respiratory disturbances. Some authors (22-26) report that vertical surgical incisions cause greater pulmonary function impairment than transverse ones, whereas others (27-29) found no association between particular surgical incisions and development of major respiratory disturbances. O'Dwyer (30) and Assalia (31) investigated the impact of incision length on pulmonary function in classical cholecystectomy, and concluded that patients with minor (6cm) surgical incision (minicholecystectomy) had less severe pain, shorter hospital stay and faster respiratory recovery as compared to those operated on by long incision (15cm). In contrast, Schmitz (32) reports that the length of surgical incision is not statistically significantly related to the occurrence of postoperative pain.

In the present study vertical incision in upper midline laparotomy is advantageous for causing little bleeding, little nerve damage, fast peritoneum exposure, and possibility of bidirectional extension, allowing full control of the operative field. During the study period, the patients operated on by upper midline laparotomy had decreased PaO_2 and increased pulmonary shunt at 72 h and 144 h postoperatively, which pointed to impaired respiratory mechanics due to linea alba interruption. This results in more severe postoperative pain, because the sutured aponeurosis is exposed to strain by both rectus abdominis muscles.

Vertical transverse incision was found to produce less hypoxia, hyperventilation and pulmonary shunt than midline laparotomy, because the sutured aponeurosis was exposed to strain by only one rectus abdominis muscle, thus resulting in less pain and by far greater abdominal wall stability.

Oblique incisions (subcostal and inguinal incision) were found to produce only slight or no nerve damage, and to separate fibrous tissues along their fiber pressure direction, resulting in minimal scarring, preserved muscle function and better fascial healing, and consequentially in minimal pain and mobility impairment for the patient. Oblique subcostal incision entailed the least pronounced respiratory disturbances in the upper abdomen. Hypoxia and pulmonary shunt returned to normal as early as 72 h postoperatively. On discharge, the patients had normal pulmonary function and clinical status.

Transverse and elliptic incisions are advantageous for providing convenient control of the operative field and facilitating the work technically, however, resection of a number of muscle groups and nerves is their major shortcoming, as it entails more pronounced postoperative pain, prolonged immobility, and greater possibility of postoperative herniation. In the present study, these types of incision were associated with the highest level of hypoxia and pulmonary shunt, most severe postoperative pain, and greatest use of analgesic throughout the postoperative period. Extremely high respiratory disturbances were observed to persist even at 144 h postoperatively, making the development of pulmonary complications highly probable. Therefore, adequate respiration during the postoperative period should be ensured in all patients operated on by these incisions, to prevent major atelectases and pneumonia.

Low abdominal incisions (low midline laparotomy and inguinal incision) were observed to cause statistically significantly less respiratory disturbances and less postoperative pain compared to upper abdominal incisions, which is quite conceivable due to their localization and effect on breathing.

CONCLUSION

All low abdominal incisions entailed a less statistically significantly partial oxygen pressure and carbon dioxide decrease, less pulmonary shunt increase, less pain and less use of analgesic than upper abdominal incisions. Upper abdominal incisions caused substantial respiratory impairments and disturbances in terms of hypoxia, hyperventilation and pulmonary shunt increase. Among vertical incisions in the upper abdomen, transrectal laparotomy induced less respiratory disturbances than upper midline laparotomy, because mild hypoxia with increased pulmonary shunt normalized by 144 h postoperatively. Oblique subcostal laparotomy in the upper abdomen produced least pronounced pain and respiratory disturbances. Respiratory parameters returned to the baseline preoperative values within 72 h. Transverse incision (transversal laparotomy according to Orr) and elliptic incision (elliptic periumbilical laparotomy) of the upper abdomen had the poorest postoperative values of respiratory parameters. These incisions were associated with most severe hypoxia, highest pulmonary shunt values, most severe pain, and greatest use of tramadol postoperatively. It is therefore of paramount importance to pay attention to patients scheduled for operation by use of the incisions associated with respiratory risk, thus to timely prevent or at least minimize respiratory complications, especially in patients with cardiac or chronic pulmonary disease.

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