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Anaesthesiological considerations in small-incision and laparoscopic cholecystectomy in symptomatic cholecystolithiasis: implications for pulmonary function. A randomized clinical trial*

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Background: Upper abdominal surgery, including laparoscopic cholecystectomy (LC), is associated with post-operative pulmonary dysfunction. LC has, by consensus, become the treatment of choice for symptomatic cholecystolithiasis. Small-incision cholecystectomy (SIC), a procedure that does not require a pneumoperitoneum, threatens to be lost to clinical practice, even though there is evidence of equality. We hypothesized that the SIC technique should be equal, and might even be superior, to LC when considering post-operative pulmonary function because of the short incision length.
Methods: A single-centre randomized clinical trial was performed including patients scheduled for elective cholecystectomy. Pulmonary flow-volume curves were measured pre-operatively, post-operatively and at follow-up. Blood gas analyses were measured pre-operatively, in the recovery phase and on post-operative day 1. Anaesthesia, analgesics and peri-operative care were standardized by protocol. Post-operatively, patients and caregivers were blind to the procedure.
Results: Two hundred and fifty-seven patients were analysed. There was one pulmonary complication (pneumonia) in the LC group. In both groups, similar reductions of approximately 20% in pulmonary function parameters occurred, with complete recovery to pre-operative values. Patients in the SIC group consumed more analgesia when compared with the LC group, without any impact on blood gas analysis. Patients converted to a conventional open technique showed significant differences in six of the eight parameters in pulmonary function tests.
Conclusion: When evaluated with strict methodology and standardization of care, no clinically relevant differences were found between SIC and LC with regard to pulmonary function. Our results suggest that the popularity of the laparoscopic technique cannot be attributed to pulmonary preservation.

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Key words: Anaesthesia; laparoscopy; laparotomy; lung; post-operative pain; respiratory function.

Subsequent to its publication in 1882 (1), open cholecystectomy (OC) was considered as a safe standard for cholecystectomy for about 100 years, although this technique was associated with relevant anaesthesiological and pulmonary risks. A decrease in the length of the incision, known as small-incision cholecystectomy (SIC), with a concomitant decrease in post-operative morbidity, was reported as early as the mid-1970s (2). However, before SIC could find general acceptance, laparoscopic cholecystectomy (LC) was introduced in the late 1980s (3). The LC procedure gained rapid and immense popularity (4), and became the surgical treatment of choice, even though its superiority has not been demonstrated (5).

Many important factors have been implicated in the pulmonary compromise seen after upper abdominal surgery, as well as in the cardiovascular risks. These factors include the site and size of the incision, post-operative pain and reflex inhibition of diaphragmatic function (6). Compared with the traditional

*A paper describing the clinical results (complications, etc.) of this randomized trial (with multiple outcome measures) has been accepted for publication by the Archives of Surgery. The pulmonary outcome measures of this randomized trial, as described in this paper, have not been submitted elsewhere.

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open technique, the cardiopulmonary changes, particularly heart rate and arterial blood pressure changes, following LC have been suggested to be of a lesser order. This combination has convinced many anaesthesiologists that patient care is improved using the laparoscopic technique (7). However, LC involves adaptation of anaesthesia techniques, as well as patient selection. Pneumoperitoneum has its own procedure-related effects. Intra-abdominal pressure has been associated with extensive elevation of the diaphragm and increased intrathoracic as well as intracranial pressure. Depression of haemodynamic functions, particularly in cardiac output, may place patients with congestive heart failure at increased risk, whereas those with pulmonary disease are exposed to increases in V_A/Q mismatch, increased ventilation requirements and the risk of pneumothorax peri-operatively (8–10).

A loss of functional residual capacity (FRC), as well as the diaphragmatic contribution to tidal volume, has been suggested to be principally a result of pain-induced shallow breathing (splinting) (6, 11, 12). However, only partial restoration of pulmonary function is demonstrated when analgesia is adequately applied (13), implicating other factors and invalidating the eloquent argument that a laparoscopic technique is justified for pulmonary reasons. Controlled prospective studies between LC and SIC, in which anaesthesia considerations and pulmonary function are the principal outcomes, have not been reported.

With improvements in the insight into differences between splinting and pulmonary dysfunction, leading to adaptations in peri-operative management and pain control methods, such as patient-controlled analgesia (PCA), the suggestion that the laparoscopic technique should be preferred over the small-incision technique can be questioned. Pulmonary function differences between LC and SIC have been studied in only a few, technically oriented, randomized trials, which have reported inconsistent outcomes (14–20), involve small numbers of patients (14, 18, 19) and seem to incorporate some important methodological shortcomings (15, 19, 20).

As the literature is ambiguous, we decided to perform a large single-centre randomized trial. The aim was to evaluate pulmonary function in patients randomized between LC and SIC by measuring flow-volume curves and blood gases in a blind fashion.

Patients and methods

Ethics committee approval for this trial was obtained from St. Elisabeth Hospital (Tilburg, The Netherlands) in September 2000. Patients were recruited from January 2001 to January 2004. Patients referred to our surgical outpatient clinic with symptomatic cholecystolithiasis were eligible for inclusion in the trial. All patients had symptomatic gallstones confirmed by ultrasonography. If patients met the inclusion criteria, and no exclusion criteria were present, written informed consent was obtained and patients were consecutively scheduled for elective cholecystectomy.

Endpoints and outcome

The principal outcome measures of this paper are pulmonary function and related aspects. For the study as a whole, multiple outcomes were evaluated, including mortality, complications, health status, cosmetic results and cost analyses (21). Although not the primary focus of this paper, complication rates (22) are mentioned to allow for comparison.

Inclusion and exclusion criteria

The inclusion criteria were as follows: male or female patients with symptomatic cholecystolithiasis; age of 18 years or older at recruitment; American Society of Anesthesiologists (ASA) classification I or II (23); no known relevant allergies; a signed informed consent letter. Obesity was not considered as an exclusion criterion.

The exclusion criteria were as follows: age younger than 18 years; choledocholithiasis (icterus, acholic stools and bilirubin of twice normal range); cholangitis; known pregnancy; ASA class III and higher; known cirrhosis of the liver; history of abdominal malignancy; previous surgery which would exclude a laparoscopic procedure; psychiatric disease or other reasons (e.g. inadequate Dutch language skills) making follow-up or answers on the questionnaires unreliable.

Patients suffering from acute cholecystitis could only be included after a cooling down period of 3 months and normalization of biochemistry. Inclusion of patients with choledocholithiasis after successful endoscopic treatment was also allowed when liver enzymes had normalized.

Randomization and blinding

A random number table was used to generate the allocation sequence, with allocation concealment guaranteed by sealed envelopes (24). To further eliminate bias, patients were randomized in the operation theatre after induction of anaesthesia by calling the secretary who opened an envelope. All patient data were recorded in a case record form,

with the procedure reported as 'trial cholecystectomy' (25). Wounds and port sites were dressed with identical opaque dressings, stained using iodine, regardless of the surgical procedure performed, to allow blinding for patients, nurses, technicians and physicians during the post-operative period (26). The type of operation was revealed on the morning of discharge.

Standardized anaesthesia protocol

To avoid bias during the peri-operative recovery, all patients were subjected to a standard anaesthesia regime. Any violations to this regime were recorded. Standard pre-medication included diazepam (Valium) (5 mg orally when <50 kg or >65 years; otherwise 10 mg orally) and atropine (0.25 mg intramuscularly when <50 kg or >65 years; otherwise 0.5 mg intramuscularly), given 60 min before the operation.

At induction, all patients received 2 g cefazoline (Kefzol) intravenously. The patients were pre-oxygenated with 100% O_2 for 3 min. Anaesthesia was induced with thiopental (Pentothal) (5 mg/kg intravenous bolus in 2 min), sufentanil (Sufenta) (0.1 μg/kg intravenous bolus; +0.05 μg/kg bolus when indicated) and rocuronium bromide (Esmeron) (0.6 mg/kg intravenously). Routine use of neostigmine with atropine (Prostigmin) was avoided, except where neuromuscular monitoring (TOF-guard) showed a train-of-four of less than four twitches, with fade of more than 30%. Intubation took place with an endotracheal tube (size 8 or 9), and respiration was initiated with a tidal volume of 8 ml/kg, respiration rate of 12 breaths/min, positive end-expiratory pressure (PEEP) of 5 cmH_2O and an end-tidal CO_2 target of 4.0–4.7 kPa. This has been documented to achieve a P_aCO_2 of end-tidal CO_2 + 0.8 kPa. Average intra-abdominal pressures during LC vary between 10 and 14 mmHg in our hospital, with the maximum pressure limited to 14 mmHg. If needed to maintain normocapnia, tidal volume increases of 1-ml/kg steps were alternated with increasing ventilation frequency. Particularly during the termination of anaesthesia, no CO_2 over 7.3 kPa was accepted.

Respiration was continued with O_2 at 40% in air and sevoflurane (Ultane) at 1 MAC (minimal alveolar concentration), corrected for age. Sufentanil (Sufenta) (0.05 μg/kg intravenous bolus) was given if there was a change in blood pressure or heart rate from the pre-operative value of more than 30%. Rocuronium bromide (Esmeron) (0.125 mg/kg intravenous bolus) was given when indicated by a change in respiratory pressure or when requested by the surgeon.

After induction, patients were positioned on the operation table at an anti-Trendelenburg position of 20°. In accordance with good clinical practice, values of ≤20% of baseline were maintained. Patients left the operation room pain-free and without nausea. Patients were moved directly to recovery, where they were given 2 l/min oxygen via a nasal cannula. This was up through the arterial blood gas evaluation. They were attached to the standard, non-invasive monitoring up through the moment of the arterial blood gas evaluation. Nursing staff (one nurse to three patients) followed all patients. Criteria for discharge from recovery were checked using the Aldrete score, and were confirmed by the anaesthesiologist responsible.

Analgesics in the post-operative period were supplied according to a standard scheme. On arrival in recovery, 1 g paracetamol (suppository) was given, followed, as needed, by diclofenac (Voltaren) (75 mg intravenously to a maximum of 3 times a day). In the recovery room, pethidine (Demerol) 0.5 mg/kg was given once if requested. Morphine 10 mg intravenously, followed by boluses of 5 mg intravenously, to a maximum of 4 times a day, was given for further pain relief. Paracetamol (1 g suppository) was given every 6 h for the first 48 h post-operatively.

Medication for nausea consisted of metoclopramide (Primperan) (10 mg intravenously in 5 min), haloperidol (Haldol) (2.5 mg; and, when indicated, 2.5 mg extra) and ondansetron (Zofran) (4 mg intravenously), if necessary.

The supply of analgesics for pain minimization was objectified using a visual analogue scale (VAS) ruler. Both pain and nausea scores were measured by the VAS ruler in the recovery room every 10 min for 60 min, and were noted in the case record form. When the score was >4, the next step in medication was taken. Patients stayed in the recovery room for at least 1 h to guarantee adequate pain control. Patients were sent to the ward pain-free and without nausea. On the ward, the pain and nausea scores (scored every 2 h) and the standard medication regime were continued until patients had a score of ≤4 for at least 12 h.

Surgical techniques

For LC, an open introduction was performed in all patients, regardless of previous abdominal surgery. Pneumoperitoneum was created with intra-abdominal pressures of up to 12 mmHg. Three trocars were inserted. The dissection of the cystic duct and artery, and identification of Calot's triangle

were performed using a three-point 'flag' technique (27). The cystic duct and artery were clipped and transected. After complete dissection, the gallbladder was removed.

The SIC approach involved a transverse incision of no more than 8 cm over the right musculus rectus abdominis (19). Only standard surgical instruments were used, as well as regular operation room (OR) lights; no special equipment was employed. Access to the peritoneum was obtained by a muscle splitting technique, as opposed to transection, comparable with the technique used in an open appendectomy. The gallbladder was dissected 'fundus first'. If necessary, the gallbladder was punctured to remove its liquid contents. The cystic duct and artery were ligated and the gallbladder was removed. Posterior and anterior fascias were closed separately. After wound closure, the length of the incision was measured. If the length of the incision exceeded 8 cm, the operation was considered as a conversion to OC.

A learning curve for the SIC technique was allowed prior to the study. As all surgeons had extensive experience with OC, after approximately five procedures each, adequate experience in the procedure was deemed to be present.

Pulmonary function tests

Pulmonary function tests were performed immediately pre-operatively, on the first post-operative day and at the 6-week outpatient check-up. During the tests, the best flow-volume curve of three attempts was taken for analysis. The maximal vital capacity (VC_{max}), forced expiratory volume in 1 s (FEV_1), forced vital capacity (FVC), maximum expiratory flow when 25%, 50% and 75% of the FVC has been exhaled (FEF_{25}, FEF_{50}, FEF_{75}), peak expiratory flow (PEF) and forced inspiratory volume in 1 s (FIV_1) were documented. The FEF values have been suggested to be particularly sensitive for detecting perioperative function changes (28). The pulmonary function tests were performed in our respiratory laboratory using Jaeger-masterscreen PFT (Viasys, Hoechberg, Germany).

Arterial blood gas analyses were performed three times. The pre-operative and 24-h post-operative samples were taken under room air conditions; the sample during recovery was taken at a fraction of inspired oxygen (F_iO_2) of 34% (2 l flow via nasal cannula) at 1 h after detubation. From these arterial blood samples, oxygen saturation, acidity (pH), partial oxygen pressure (pO_2), partial carbon dioxide pressure (pCO_2), base excess and bicarbonate concentration (HCO_3) were determined.

Post-operative protocol

Early oral intake (within 4 h) and mobilization were encouraged, and patients were eligible for discharge as soon as they felt well enough. Standard practice was to keep all patients at least one night; some, because of limitations in their home environment, for example, stayed longer. In effect, many patients elected to leave the hospital on the afternoon of the first or second post-operative day. Shortly before discharge, wound dressings were removed for wound inspection, and the type of operation was revealed. Follow-up took place after 2 weeks, 6 weeks and 3 months, according to a standardized scheme.

Sample size

To avoid *post hoc* analyses, multiple outcome measures were defined for evaluation in this trial. Analysis of cost aspects was used to determine the power and sample size of the study as a whole. On this basis, we estimated that 120 patients per group would be needed to detect a difference of 10% in direct costs with $\alpha = 0.05$ and $\beta = 0.9$.

No interim analysis was planned, but a monitoring committee was tasked to terminate inclusion if a substantial difference in mortality and complication rate occurred. They were supplied with information on request and this was performed once during the study.

Statistics

The administration and collection of data were based on a patient-linked trial registration number to guarantee the patients' privacy and to facilitate a blind evaluation. An Access database was set up for collection and analysis of data. Calculations were made using SPSS 11.0 (SPSS Inc., Chicago, IL).

Principal comparisons were made on an intend-to-treat basis. In the main comparison, the pulmonary function parameters of all LCs were compared with those of all SICs. Three subgroup analyses followed. In the first, successful LCs were compared with successful SICs, in order to evaluate differences in per protocol treatments. In the second subgroup, all successful cholecystectomies were compared with all converted cholecystectomies, regardless of randomization, to demonstrate a difference between per protocol and converted procedures. Finally, the third subgroup compared converted LCs with converted SICs, in order to demonstrate any superiority of LC, even when converted. The second subgroup was also used to validate the sensitivity of the pulmonary function test.

Results of normally distributed, continuous data are presented as means with their standard deviations (SDs) in parentheses, or as medians with ranges in the case of a non-Gaussian distribution. The normality of the data was checked using the Kolmogorov–Smirnov test. Levene's test was used to check the equality of variances. When the condition of normality and equal variances was met, the *t*-test was used for independent data. When the equality of variances or normality was absent, the non-parametric Mann–Whitney *U*-test was used for independent data. The repeated measures analysis of variance (ANOVA) test was used to analyse the pulmonary function test results, as well as the arterial blood gas analyses, as these measurements were performed repeatedly in time. For dichotomous outcomes, the chi-squared test was used.

Results

All trial patients were included and operated on between January 2001 and March 2004. During this period, 366 patients visiting our outpatient clinic for symptomatic cholecystolithiasis fulfilled the inclusion criteria, gave informed consent and were initially included in the trial. One hundred and two patients did not reach randomization for a variety of reasons (Fig. 1). Of the remaining 264 patients, seven patients were excluded after randomization: unwilling to continue in the trial ($n = 2$), intra-operative

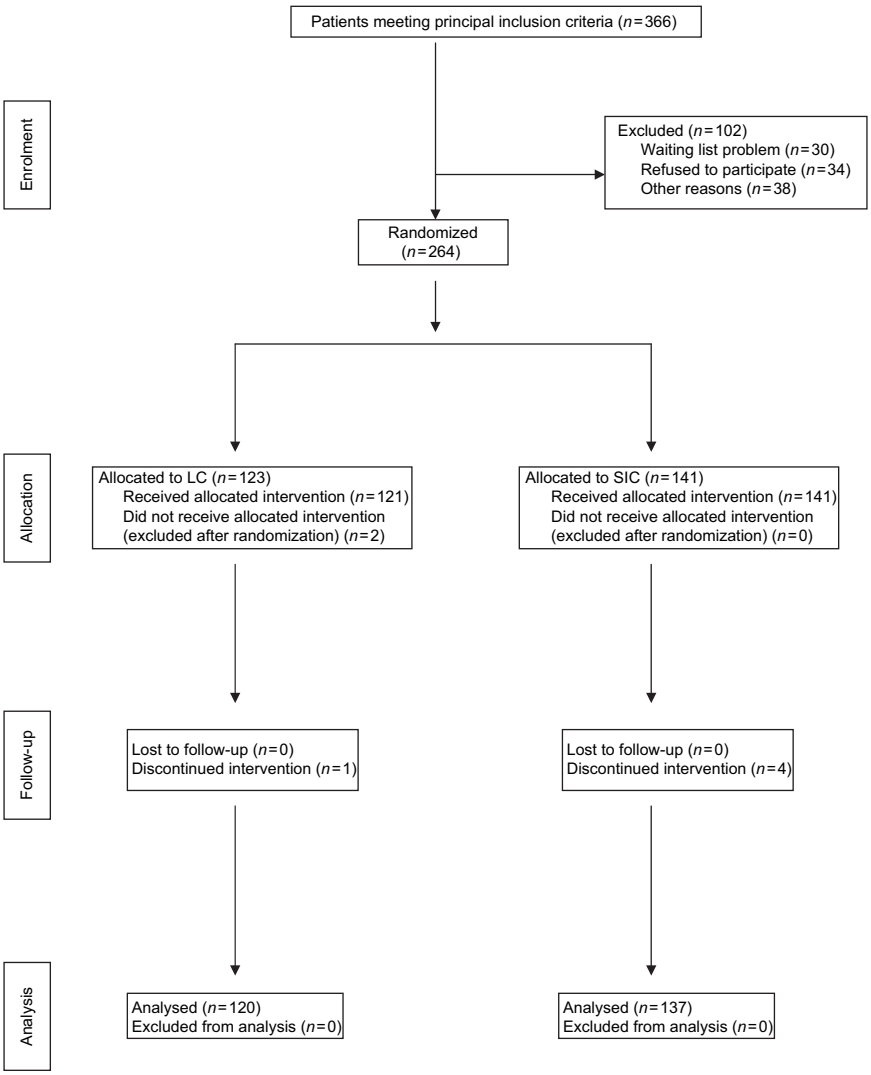

Fig. 1. Revised Consolidated Standards of Reporting Trials (CONSORT) statement diagram showing the flow of participants through each stage of the randomized trial (34).

suspicion of malignancy ($n = 2$), transfer to a non-surgical ward ($n = 1$), inadvertent participation in multiple trials ($n = 1$) and inadequate Dutch language skills ($n = 1$). Two hundred and fifty-seven patients were left for analysis (LC, $n = 120$; SIC, $n = 137$; Fig. 1).

The groups were similar with regard to age, sex, body mass index (BMI) and ASA classification (Table 1).

A number of anaesthesiological complications occurred in the direct peri-operative period. In the LC group, one patient became asystolic during insufflation of the pneumoperitoneum and one patient had a limited cerebrovascular accident (thrombotic) in recovery. In the SIC group, one patient developed positive cardiac enzymes compatible with ischaemia. During the post-operative period, three patients in the LC group developed phlebitis and one developed pneumonia. Although no mortalities occurred during the study, 21 (18%) and 16 (12%) complications occurred in the LC and SIC groups, respectively. The majority (16 and 13, respectively) occurred post-operatively on an incidental basis. Actual skin-to-skin time varied from 72 min (SD, 26 min) to 60 min (SD, 18 min) ($P < 0.001$) for LC and SIC, respectively, with total anaesthesia also being shorter for the SIC group. Conversion rates were 12% and 16%, respectively. The hospital stay was not significantly different [LC, 2.4 days (SD, 4.6 days); SIC, 3.1 days (SD, 12.4 days); $P = 0.560$]. The consumption of analgesics and muscle relaxants was equal and unremarkable.

The mean pulmonary function test results for the three consecutive measurements are listed in Table 2.

Table 1

Patient characteristics.

	Laparoscopic cholecystectomy ($n = 120$)	Small-incision cholecystectomy ($n = 137$)	Statistical analysis
Male	31 (26%)	30 (22%)	NS
Female	89 (74%)	107 (78%)	
Age (years)			
Mean (SD)	48.4 (14.1)	48.5 (14.0)	NS
Median (range)	49 (18–77)	48 (18–80)	
Body mass index (kg/m^2)			
Mean (SD)	27.5 (4.8)	27.9 (4.6)	NS
Median (range)	26.8 (27.4)	27.2 (25.2)	
ASA			
I	81 (68%)	91 (66%)	NS
II	39 (32%)	46 (34%)	

ASA, American Society of Anesthesiologists; NS, not significant; SD, standard deviation.

In both groups, an overall 20% post-operative reduction in pulmonary function was documented, as well as complete return to baseline at the 6-week follow-up. Statistical analysis (ANOVA) of these data showed no significant differences between the two groups for any of the eight parameters. The results are shown as a percentage of the predicted test result for the individual patient (FIV_1 in litres).

Blood gas data are presented in Table 3. Although there are statistically significant differences between the two techniques for the parameters pO_2, pCO_2 and pH, these had no influence on discharge from recovery. pO_2 was slightly lower in both groups, both in recovery (11.4 vs. 12.0 kPa for the LC and SIC groups, respectively) and on the first post-operative day (11.5 vs. 10.8 kPa, respectively), despite supplemental oxygen during the first hour of recovery in all patients. This pO_2 decrease was, interestingly, largest in the LC group. pCO_2 was higher in the recovery measurement for both groups, with a slightly larger increase in the SIC group (5.9 vs. 6.1 kPa), and

Table 2

Overview of pulmonary function results comparing laparoscopic cholecystectomy (LC) and small-incision cholecystectomy (SIC) patients. Results are presented as means (with standard deviation) of percentages of individual predictive values.

Parameter	Time	LC ($n = 103$)	SIC ($n = 118$)	Statistical analysis
VC_{max} (%)	Pre-op	105.0 (14.0)	105.9 (15.0)	NS
	Post-op	82.7 (18.1)	81.0 (19.4)	
	Follow-up	105.5 (14.5)	106.3 (15.4)	
FEV_1 (%)	Pre-op	103.2 (15.0)	103.7 (16.2)	NS
	Post-op	80.9 (19.1)	79.8 (19.9)	
	Follow-up	102.2 (15.4)	103.4 (16.6)	
FVC (%)	Pre-op	106.2 (14.6)	107.0 (15.5)	NS
	Post-op	83.6 (19.8)	81.8 (20.6)	
	Follow-up	106.0 (15.0)	107.5 (15.9)	
FEF_{25} (%)	Pre-op	101.1 (21.6)	100.4 (24.9)	NS
	Post-op	77.6 (23.2)	77.5 (22.4)	
	Follow-up	101 (22.6)	98.1 (24.5)	
FEF_{50} (%)	Pre-op	86.4 (25.8)	86.6 (27.1)	NS
	Post-op	67.7 (23.4)	67.3 (23.5)	
	Follow-up	84.8 (25.8)	84.4 (26.9)	
FEF_{75} (%)	Pre-op	75.1 (30.1)	77.5 (30.0)	NS
	Post-op	55.6 (25.4)	57.8 (24.0)	
	Follow-up	70.0 (29.5)	73.3 (30.2)	
PEF (%)	Pre-op	103.1 (16.9)	105.2 (18.5)	NS
	Post-op	76.1 (21.4)	76.0 (20.8)	
	Follow-up	104.1 (18.4)	104.8 (19.3)	
FIV_1 (l)	Pre-op	3.50 (0.91)	3.52 (0.97)	NS
	Post-op	2.57 (0.85)	2.45 (0.73)	
	Follow-up	3.59 (0.88)	3.55 (0.95)	

FEF_{25}, FEF_{50}, FEF_{75}, maximum expiratory flow when 25%, 50% and 75% of FVC has been exhaled; FEV_1, forced expiratory volume in 1 s; FIV_1, forced inspiratory volume in 1 s; FVC, forced vital capacity; NS, not significant; PEF, peak expiratory flow; VC_{max}, maximal vital capacity.

Table 3

Overview of blood gas analysis results comparing laparoscopic cholecystectomy (LC) and small-incision cholecystectomy (SIC) patients. Results are presented as means (with standard deviation) of percentages of individual predictive values.

Parameter	Time	LC ($n = 93$)	SIC ($n = 126$)	Statistical analysis
p_{O_2} (kPa)	Pre-op	12.5 (2.9)	12.8 (3.6)	$P = 0.025$
	Recovery	11.4 (2.1)	12.0 (3.6)	
	Post-op	11.5 (2.4)	10.8 (2.2)	
p_{CO_2} (kPa)	Pre-op	5.3 (0.5)	5.3 (0.5)	$P = 0.042$
	Recovery	5.9 (0.7)	6.1 (0.6)	
	Post-op	5.2 (0.5)	5.2 (0.5)	
O_2 saturation (%)	Pre-op	96.9 (4.4)	97.2 (1.9)	NS
	Recovery	96.1 (1.8)	95.8 (2.8)	
	Post-op	96.8 (2.2)	96.4 (3.6)	
pH	Pre-op	7.41 (0.02)	7.41 (0.02)	$P = 0.032$
	Recovery	7.34 (0.04)	7.33 (0.03)	
	Post-op	7.41 (0.02)	7.41 (0.02)	
Bicarbonate (mmol/l)	Pre-op	24.9 (1.9)	24.9 (2.0)	NS
	Recovery	23.0 (2.0)	23.3 (2.0)	
	Post-op	24.1 (2.1)	24.4 (2.0)	
Base excess (mmol/l)	Pre-op	0.7 (1.7)	0.8 (1.8)	NS
	Recovery	– 2.4 (1.9)	– 2.3 (1.8)	
	Post-op	– 0.1 (1.7)	0.3 (1.8)	

NS, not significant; p_{CO_2}, partial carbon dioxide pressure; pH, acidity; p_{O_2}, partial oxygen pressure.

a concomitant change in pH. No significant difference was found between the two groups in the time of stay in recovery [LC, 85 min (SD, 19 min); SIC, 85 min (SD, 17 min)].

Subgroup analysis comparison of the two groups, with exclusion of data from all converted cases from both groups, showed a comparable decrease in pulmonary function without clinical or significant differences.

The second subgroup analysis compared all successful procedures with all converted procedures. Analysis showed that there were significant differences in six of the eight parameters (Table 4). Conversion of either technique resulted in an average decrease in pulmonary function parameters of about 30%. Although not significantly different, the parameters FEF_{75} and FIV_1 showed the same tendency.

In the third subgroup analysis, involving 14 and 22 patients from the LC and SIC groups, respectively, no significant differences between any of the eight pulmonary function parameters were found, with a slightly larger decrease in the SIC group.

The amounts of analgesics used per patient (VAS $\geq$4) during the post-operative period up to discharge, as well as the number of violations in the analgesic protocol, are reported in Table 5A, B. The number of potential violations was calculated based on the number of VAS measurements for each patient during the total post-operative period. Pain was regulated carefully in our hospital via the use of a nurse-driven acute pain service. Whilst in recovery, the SIC group consumed significantly more morphine per patient than the LC group, but the consumption was similar in the two groups once on the ward.

Discussion

The acceptance of LC as the technique of choice appears to have little foundation. Our study was set up to specifically evaluate the arguments used for this preference. It included pulmonary function changes after open upper abdominal surgery, and the suggestion that optimal pain management at the same time would further decrease pulmonary function.

Using a prospective, randomized methodology, 257 patients were analysed in an LC vs. SIC trial to determine the impact of these techniques on selected pulmonary function tests and arterial blood gas measurements.

Our findings of a comparable clinical outcome for LC and SIC are in line with other data (29). We also found pulmonary dysfunction in the immediate post-operative period and an increased consumption of morphine in the SIC group during the post-operative period. However, this increased consumption seemed to have no clinical consequences and produced no measurable differences in pulmonary function tests or arterial blood gas analyses, although other studies have reported different results (14–20).

In some earlier clinical studies comparing LC and SIC, the methodology as well as the choice of the

Table 4

Overview of pulmonary function results comparing converted and non-converted patients. Results are presented as means (with standard deviation) of percentages of individual predictive values.

Parameter	Time	Not converted (n = 189)	Converted (n = 32)	Statistical analysis
VC_{max} (%)	Pre-op	105.8 (14.7)	103.7 (13.5)	$P = 0.012$
	Post-op	83.0 (18.9)	74.1 (19.8)	
	Follow-up	106.0 (15.0)	105.2 (14.4)	
FEV_1 (%)	Pre-op	103.6 (15.6)	102.6 (15.6)	$P = 0.016$
	Post-op	81.6 (19.1)	72.7 (20.5)	
	Follow-up	102.9 (16.4)	102.6 (13.7)	
FVC (%)	Pre-op	106.9 (15.2)	105.2 (14.4)	$P = 0.007$
	Post-op	84.0 (20.0)	74.4 (19.8)	
	Follow-up	106.9 (15.8)	106.4 (13.9)	
FEF_{25} (%)	Pre-op	100.9 (23.7)	99.4 (21.4)	$P = 0.046$
	Post-op	79.1 (23.0)	68.2 (18.6)	
	Follow-up	100.0 (24.3)	96.3 (19.0)	
FEF_{50} (%)	Pre-op	86.5 (26.6)	86.7 (26.4)	$P = 0.018$
	Post-op	69.1 (23.6)	57.7 (19.8)	
	Follow-up	85 (27.0)	81.9 (22.5)	
FEF_{75} (%)	Pre-op	76.8 (30.3)	73.8 (28.2)	NS
	Post-op	58.3 (24.3)	47.6 (25.0)	
	Follow-up	72.6 (29.5)	66.8 (32.1)	
PEF (%)	Pre-op	104.3 (18.0)	103.7 (16.5)	$P = 0.045$
	Post-op	77.3 (21.0)	68.1 (19.8)	
	Follow-up	104.7 (19.3)	103.2 (16.0)	
FIV_1 (l)	Pre-op	3.54 (0.96)	3.34 (0.81)	NS
	Post-op	2.55 (0.81)	2.20 (0.59)	
	Follow-up	3.59 (0.94)	3.44 (0.80)	

FEF_{25}, FEF_{50}, FEF_{75}, maximum expiratory flow when 25%, 50% and 75% of FVC has been exhaled; FEV_1, forced expiratory volume in 1 s; FIV_1, forced inspiratory volume in 1 s; FVC, forced vital capacity; NS, not significant; PEF, peak expiratory flow; VC_{max}, maximal vital capacity.

parameters evaluated may have skewed the results (29–32). In order to avoid subtle opportunities for bias, strict standardization of anaesthesia management, analgesic use and peri-operative care must be guaranteed by the protocol. Single-centre trials have a natural advantage in the standardization of treatment. Our study has addressed a number of these limitations, whilst focusing on anaesthesia and pulmonary function. Pulmonary aspects are deemed to be an important clinical reason why many anaesthesiologists prefer a laparoscopic technique over an open technique (14–16, 18–20).

In the trials reported to date, only two or three pulmonary function parameters were selected. Arguments supporting this selection were absent (14–16, 18–20). Moreover, three trials suggested the superiority of a specific procedure on the basis of a difference in only one (15, 19) or two (14) pulmonary function parameters. Three trials incorporated sample sizes of less than 15 patients per arm (14, 18, 19), and only one trial used a blind approach (18). Details on peri-operative anaesthesia management were not provided in five trials (14–16, 18, 19). One larger trial, with 64 patients in each group, found that the laparoscopic technique was superior, and included pulmonary function testing and analgesic use. However, this multicentre trial did not attempt to blind patients or physicians, details on anaesthesia management were not provided, and an incision of 10 cm was considered as small, ignoring the more acceptable 8-cm limitation (16). Harju et al. (20) evaluated pulmonary function in only a proportion of their included patients, and found no difference between LC and SIC.

Impairment in pulmonary function was found post-operatively with no differences between the two groups. This impairment increased markedly from 20% to 30% in the converted operations for both groups, indicating that measurements by flow-volume curves are a valid tool to detect differences in pulmonary function. Considering the diversity in the literature, it is not clear whether a single pulmonary function test parameter can be designated as the most appropriate for identifying pulmonary dysfunction following upper abdominal surgery. A reduction in FEF has been suggested by some authors to be effort-independent, unlike VC, PEF and FIV_1. Our results do not support this suggestion, as the

Table 5A

Overview of analgesic use in the recovery room.

	Laparoscopic cholecystectomy (LC)		Small-incision cholecystectomy (SIC)		
	Sum (mg)	Mean consumption/ patient (mg)	Sum (mg)	Mean consumption/ patient (mg)	Statistical analysis
Pethidine	3716	35	4634	37	NS
Diclofenac	8200	78	10700	85	NS
Morphine	433	4	1010	8	$P < 0.001$

NS, not significant. Visual analogue scale score available for analysis: LC, 105/120 (87%); SIC, 126/137 (92%).

Table 5B

Overview of violations of the protocol.

	Laparoscopic cholecystectomy (LC)	Small-incision cholecystectomy (SIC)
Number of violation opportunities	856	1097
Times committed		
No pain medication with VAS > 4	35 (4.1%)	76 (6.9%)
Pain medication with VAS < 4	9 (1.1%)	5 (0.5%)

VAS, visual analogue scale score.

actual changes between pre- and post-operative measurements were similar for the parameters VC_{max}, FEV_1, PEF and the FEF series (33). The suggestion that muscular damage and resultant pain should be designated as the factors limiting pulmonary function could also not be substantiated (11–13, 28). We noted with interest that a lower p_{O_2} was found in the LC group despite the lower opioid intake in this group. Although more pain medication was given to the SIC group, this was only in the immediate post-operative period and had no apparent clinical significance (Table 5A). This difference in consumption did not impact on the eligibility for discharge from recovery or hospital. Although day-care surgery is now general practice, at the time of the trial in our hospital it was not, and all patients stayed overnight. Although not an endpoint, and in recognition that this type of surgery is increasingly being performed as day-care surgery, based on the lack of a difference in recovery stay, we propose that, using the Aldrete score, and with the general requirement that patients be adequately responsive before leaving recovery, opioid consumption should not limit early discharge. For discharge eligibility in day surgery in our hospital, patients must have consumed fluids and a light meal, as well as be pain free, adequately responsive and self-supporting. No patient is allowed to leave the hospital unaccompanied.

With the increased interest in day-care techniques, the relevance of rapid and safe surgical procedures is on the rise. A significantly shorter operative time was found in SIC. Theoretically, with increasing experience, this operative time could be reduced further, impacting on the duration of anaesthesia and allowing ample time for discharge without an overnight stay.

The one case of pneumonia should be considered a coincidence. Our findings suggest that there are no clinically relevant differences in pulmonary function following LC and SIC. As pulmonary function was measured on the first day and 6 weeks post-operatively, differences between the two techniques might have been missed during the first 2 weeks post-operatively. Future research should focus on this recovery period.

Our findings should be generally applicable in general surgical practice. The SIC procedure was associated with a shorter total anaesthesia time, no increase in complication rates and no increase in the length of hospital stay. However, ASA III and IV patients were not included in the study. In these specific populations, the clinically unimportant pulmonary function changes observed may have a much larger impact. The CO_2 burden in LC, requiring greater ventilation, in combination with decreased cardiac output, may also be relevant in ASA III and IV patients. Moreover, the anaesthetic management

of SIC seems to be straightforward, and involves a decrease in some peri-operative risks attributed to the pneumoperitoneum.

Our acute pain service quickly recognized that, with good immediate post-operative pain management, the consumption of medication was low, raising the question of the need for PCA techniques for this procedure. In our study, we were unable to differentiate between the mechanisms suggested to limit pulmonary function (i.e. splinting or diaphragmatic dysfunction). Further research is needed in ASA III and IV patients to quantify pulmonary function changes.

Conclusions

Our study concurs with historical data, demonstrating a temporary decrease in pulmonary function in all forms of upper abdominal surgery, laparoscopic or open. This study demonstrates that SIC is comparable with LC in terms of the decrease in pulmonary function and blood gas analysis. Although initial analgesic consumption was higher in the SIC group, this did not impact on the time to discharge from recovery or the utilization of analgesia on the ward. Our study suggests that, from an anaesthesiological approach to peri-operative management, pulmonary and analgesic arguments indicate that these techniques are interchangeable when performed in an ASA I and II population.

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