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Rib approximation without intercostal nerve compression reduces post-thoracotomy pain: a prospective randomized study

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Abstract

Objective: One of the most important considerations in the care of thoracic surgery patients is the control of pain, which leads to increased morbidity and relevant mortality. **Methods:** Between February and May 2009, 60 patients undergoing full muscle-sparing posterior minithoracotomy were prospectively randomized into two groups, according to the thoracotomy closure techniques. In the first group (group A), two holes were drilled into the sixth rib using a hand perforator, and sutures were passed through the holes in the sixth rib and were circled from the upper edge of the fifth rib, thereby compressing the intercostal nerve underneath the fifth rib. In the second group (group B), the intercostal muscle underneath the fifth rib was partially dissected along with the intercostal nerve, corresponding to the holes on the sixth rib. Two 1/0 polyglactin (Vicyrl) sutures were passed through the holes in the sixth rib and above the intercostal nerve. **Results:** There were 30 patients in each group. The visual analog score, observer verbal ranking scale (OVRS) scores for pain, and Ramsay sedation scores were used to follow-up on postoperative analgesia and sedation. The von Frey hair test was used to evaluate hyperalgesia of the patients. The patients in group B had lower visual analog scores at rest and during coughing. The patients in group B had lower OVRS scores than group A patients. The groups were not statistically different in terms of the Ramsay sedation scores and von Frey hair tests. **Conclusions:** Thoracotomy closure by a technique that avoids intercostal nerve compression significantly decreases post-thoracotomy pain.

Keywords: Pain; Surgery; Thoracotomy; Intercostal nerve

1. Introduction

Post-thoracotomy pain is the most severe form of pain after surgery and is continuously exacerbated by respiration. Various surgical techniques for treating this pain have been developed and evaluated [1,2]. Post-thoracotomy pain syndrome (PPS) is relatively common and is encountered in approximately 50% of patients who have undergone thoracotomy [3]. The main source of pain after thoracotomy is probably from injury to the intercostal nerves. Therefore, modification of surgical techniques in ways that can decrease acute pain might also decrease chronic pain [4]. In this prospective study, we compared two thoracotomy closure techniques, that is, using intercostal and intracostal sutures, after intercostal nerve dissection for post-thoracotomy pain control. We evaluated postoperative pain, necessity of analgesic usage, and long-term hyperalgesia.

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2. Patients and methods

Following the approval of the University Ethics Committee, between February and May 2009, 60 patients undergoing full muscle-sparing posterior minithoracotomy for various lung resections were prospectively randomized into two groups, namely A and B, according to the thoracotomy closure techniques. The exclusion criteria included age >70 years, previous induction therapy, presence of preoperative pain, rib fracture during surgery, and patients undergoing thoracotomy with muscle division.

Epidural catheter was inserted awake and checked for patency before anesthesia in all patients. Epidural analgesia during and after surgery comprised of a mixture of 0.2 g bupivacaine and 500 μg fentanyl diluted in 100 cm^3 saline infused continuously at a rate of 4 cm^3 h^{-1} with a 4-cm^3 bolus every 30 min. The catheter was removed on the third postoperative day (p.o.d.) in all patients. Full muscle-sparing (both muscles, latissimus dorsi/serratus anterior were protected) posterior minithoracotomy through auscultation triangle (Fig. 1(a)) was performed in all patients, and the chest was entered via the fifth intercostal space (ICS). Two retractors were used for spreading of the ribs and muscles

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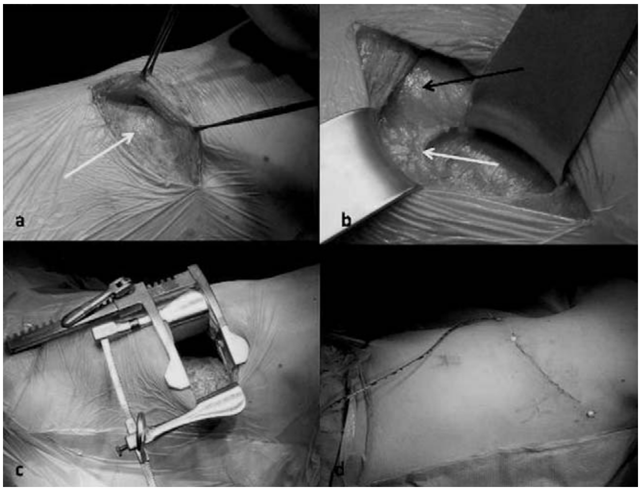

Fig. 1. Full muscle spare thoracotomy; (a) white arrow shows muscle of latissimus dorsi, (b) black arrow shows muscle of serratus anterior and white arrow shows auscultation triangle, (c) two retractors was used for rib and muscle spreading, (d) end of operation and photograph of incision.

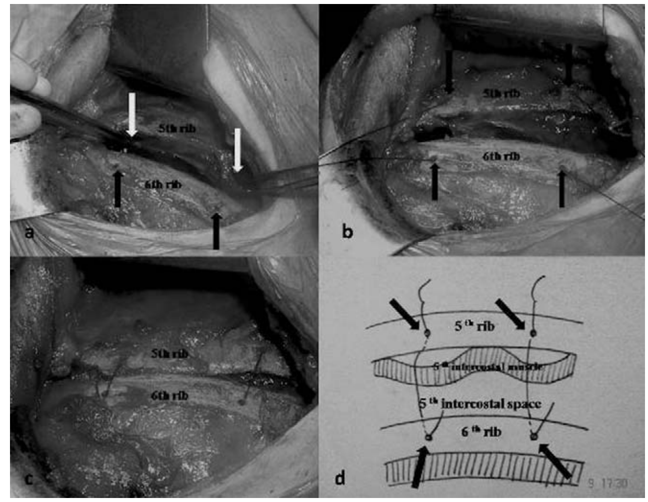

Fig. 3. Figure of intracostal sutures after intercostal nerve dissection technique (group B); (a) the intercostal muscle underneath the fifth rib was partially dissected along with the intercostal nerve, corresponding to the holes on the sixth rib (white arrow — dissected intercostal muscle, black arrow — holes on the sixth rib), (b) two holes corresponding to the holes in the sixth rib were drilled into the fifth rib (black arrow — holes on the 6th and 5th ribs), (c) after thoracotomy was closed, (d) shows a schematic diagram of the thoracotomy closure technique in group B patients.

(Fig. 1 (b)). All patients were operated on by the same surgical team. The patients and observers were blinded for the randomization.

In group A, two holes were drilled into the sixth rib using a hand perforator (Fig. 2(a)), and 1/0 polyglactin (Vicryl) sutures were passed through the holes in the sixth rib and circled through the upper edge of the fifth rib (Fig. 2(b)) to approximate the ribs (Fig. 2(c)). Fig. 2(d) shows a schematic diagram of the thoracotomy closure technique in group A patients.

In group B patients, the intercostal muscle underneath the fifth rib was partially dissected along with the intercostal nerve, corresponding to the holes on the sixth rib (Fig. 3(a)), and two holes corresponding to the holes in the sixth rib were drilled into the fifth rib using a hand perforator. Two 1/0 polyglactin (Vicryl) sutures were passed through the holes in the sixth rib, then above the intercostal nerve underneath the fifth rib, and then through the holes in the fifth rib (Fig. 3(b)) to approximate the ribs (Fig. 3(c)). Compression of the intercostal nerve was avoided by this technique. Fig. 3(d) shows a schematic diagram of the thoracotomy closure technique in group B patients.

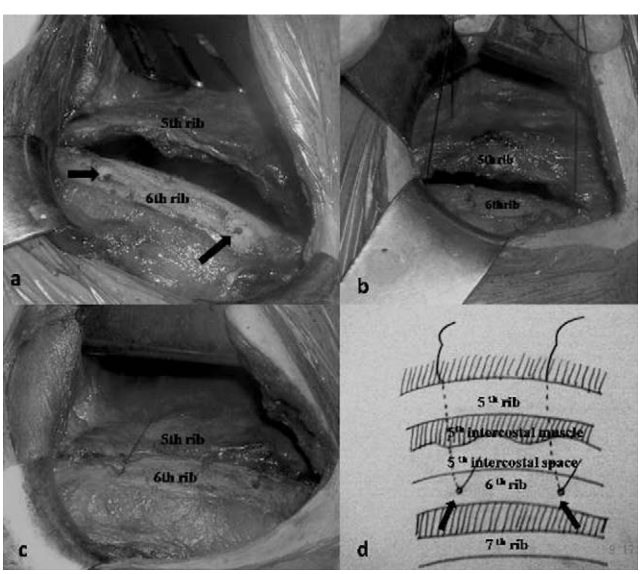

Fig. 2. Figure of intercostal sutures technique (group A); (a) two holes on the sixth rib (black arrow — holes on the sixth rib), (b) 1/0 Vicryl sutures were passed through the holes in the sixth rib and circled through the upper edge of the fifth rib, (c) after thoracotomy was closed, (d) shows a schematic diagram of the thoracotomy closure technique in group A patients.

The patients were administered the mixture of bupivacaine and fentanyl (0.2 g:500 μg (100 cm^3)$^{-1}$ saline) through the epidural catheters using a patient-controlled analgesia system (PCAS). The epidural catheter was removed on the third p.o.d. in all patients. In addition to epidural analgesia, the patients were also administered pethidine 50 mg im 4 times a day on the first p.o.d. along with ketoprofen 2×150 mg po and paracetamol 3×500 mg po.

The following parameters were used to evaluate analgesia control and sedation:

1. consumption of epidural bupivacaine and fentanyl during the 2nd, 4th, 8th, 16th, 24th, and 48th postoperative h;
2. visual analog score (VAS) at rest and during coughing in the 2nd, 4th, 8th, 16th, 24th, and 48th postoperative h;
3. observer verbal ranking scale (OVRS) and Ramsay sedation score (RSS) in the 2nd, 4th, 8th, 16th, 24th, and 48th postoperative h.

The von Frey hair test was used to evaluate hyperalgesia among patients on the 2nd, 15th, and 30th p.o.d.

All assessment of pain was made by observers, who were mentioned to be blinded to the techniques.

Power calculations suggested that a minimum of 25 patients per group would be detected on 15% difference in VAS, OVRS, RSS and von Frey hair test between the groups ($\alpha = 0.05$, $\beta = 0.2$).

The percent alterations in the drug consumptions of the patients as recorded by the PCAS were used for statistical comparison. For the other parameters (VAS, OVRS, RSS, and von Frey hair test), we used the differences in the scores for statistical analysis. We used unpaired *t*-tests for the analysis of the differences between the groups.

3. Results

A total of 60 patients were preoperatively randomized into two groups. There were 13 (42%) females in each of the groups A and B, and the mean age of the patients in groups A and B was 55.7 years (range, 33–68 years) and 52.3 years (range, 30–69 years), respectively. As many as 19 patients (60%) in group A and 21 (68%) in group B were operated upon for malignancies, and 11 (40%) patients in group A and nine (32%) in group B were operated upon for benign diseases. Lobectomy was performed in 20 (66%) patients in group A and 22 (72%) patients in group B (Table 1). The average duration of hospital stay was 3.2 and 3.7 days in groups A and B, respectively (Table 1).

Table 2 (Figs. 4 and 5) shows the distribution of analgesic consumption through the epidural catheters, VAS, OVRS scores, and RSSs, and Table 3 shows the results of the von Frey hair test for each of the groups.

3.1. Statistical analysis

Drug consumption from the epidural PCAS during the 2nd, 4th, 8th, 16th, 24th, and 48th postoperative h in group B patients was lower than that in group A patients. These differences were not statistically significant for the variable drug consumption ($p = 0.1456$).

The VAS at rest in the 2nd, 4th, 8th, 16th, 24th, and 48th postoperative h were lower in group B patients than in group

Table 1. Demographic characteristics of patients.

	Group A	Group B
Number of patients	30	30
Mean age (years)	55.7	52.3
Gender		
Male	17 (58%)	17 (58%)
Female	13 (42%)	13 (42%)
Respiratory function test		
FEV1 (%, mean)	83	78
FVC (%, mean)	89	85
Type of resection		
Lobectomy	19 (63%)	22 (72%)
Segmentectomy		1 (4%)
Wedge resection	9 (30%)	7 (24%)
Cystectomy	2 (7%)	
Disease		
Malignant		
Adenocarcinoma	7 (24%)	7 (23%)
SCC	12 (36%)	14 (47%)
Benign		
Bronchiectasis	3 (10%)	4 (13%)
Bronchogenic cyst	1 (4%)	1 (3%)
Organized pneumonia	1 (4%)	
SPN	4 (14%)	2 (7%)
Hydatid cyst	2 (8%)	2 (7%)
Mean duration of hospital stay (days)	3.2	3.7

FEV1: forced expiratory volume in the first second, FVC: forced vital capacity, SCC: squamous cell carcinoma, SPN: solitary pulmonary nodule.

Table 2. The mean results of pain evaluation of the patients.

	2nd hour (group A/group B)	4th hour (group A/group B)	8th hour (group A/group B)	16th hour (group A/group B)	24th hour (group A/group B)	48th hour (group A/group B)
Analgesic consumption from epidural PCAS (bupivacaine + fentanyl; cm^3)	21.6 (15–27)/15.2 (8–22)	50.0 (39–61)/24.9 (17–31)	66.2 (51–78)/39.6 (25–58)	84.6 (69–98)/49.9 (31–60)	101 (81–122)/64.7 (44–78)	150.3 (122–191)/82.2 (56–123)
VAS (visual analog score) (0–10) group A/group B (first line: at rest and second line: during coughing)	7.54 (6–9)/6.53 (5–8)	7.45 (6–9)/6.00 (5–7)	7.18 (5–9)/5.4 (4–7)	6.45 (5–8)/5.0 (4–6)	6.09 (5–8)/4.13 (3–6)	5.90 (5–7)/3.46 (3–6)
	9.72 (9–10)/9.06 (8–10)	9.72 (9–10)/8.86 (8–10)	9.36 (8–10)/8.20 (7–9)	8.81 (8–9)/7.80 (7–9)	8.54 (8–9)/6.93 (6–9)	8.45 (8–9)/6.46 (6–8)
OVRS scores (0–3)	2.90 (2–3)/2.06 (1–3)	2.72 (2–3)/1.66 (1–2)	2.45 (2–3)/1.26 (1–2)	2.09 (2–3)/0.8 (0–1)	1.90 (1–2)/0.13 (0–1)	1.54 (1–2)/0.06 (0–1)
Ramsay sedation score (RSS)	1.09 (1–2)/1.60 (1–2)	1.54 (1–2)/2.4 (1–3)	2.09 (2–3)/2.66 (1–3)	2.54 (2–3)/2.73 (1–3)	2.81 (2–3)/2.86 (2–3)	2.90 (2–3)/3.00 (3–3)

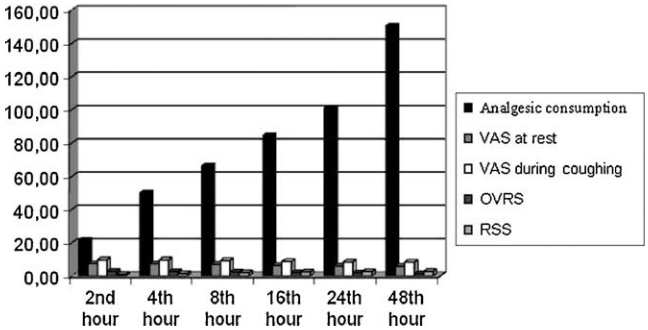

Fig. 4. The mean results of pain evaluation of the patients of group A.

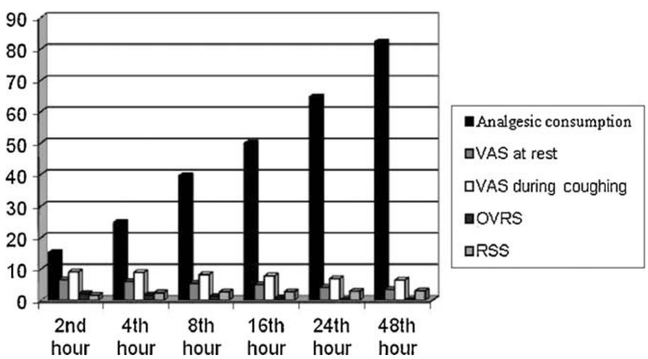

Fig. 5. The mean results of pain evaluation of the patients of group B.

A patients. These differences were considered to be statistically significant ($p = 0.0123$).

VAS during coughing in the 2nd, 4th, 8th, 16th, 24th, and 48th postoperative h were lower in group B patients than in group A patients. This was considered to be statistically significant ($p = 0.0310$).

The OVRS scores in the 2nd, 4th, 8th, 16th, 24th, and 48th postoperative h were lower in group B patients than in group A patients. This was considered to be very statistically significant ($p = 0.009$).

The differences between the groups with regard to RSS and von Frey hair tests were considered to be not statistically significant. P values for RSS and von Frey hair test were 0.3177 and 0.7355, respectively.

4. Discussion

Considerable information is available on the physiology of pain and the development of techniques of drug administration using different equipments; however, pain control after surgery still remains an important problem. Studies have shown that mild to moderate pain after surgery is common and can occur in up to 50% of patients [5], and thoracotomy is widely recognized as one of the most painful surgical procedures [6].

Table 3. The evaluation of postoperative hyperalgesia using von Frey hair test (mean scores in cm).

	Postoperative day 2	Postoperative day 15	Postoperative day 30
Group A	2.75	2.66	2.25
Group B	2.75	2.50	2.16

Post-thoracotomy pain is an acute traumatic pain and is referred to as the post-thoracotomy pain syndrome, if it lasts more than 2 months. Many studies have shown that chronic post-thoracotomy pain can persist for up to 2 months to 5 years and is reported to have an incidence between 50% and 80% [6—8]. Post-thoracotomy pain control represents a critical problem in postoperative clinical management after lung resection. Pain strongly limits pulmonary ventilation resulting in functional lung restriction. Coughing and clearing of secretions may be compromised, leading to possible bronchial obstruction, atelectasis, and/or lung infection. Pain is, therefore, considered to be a major independent factor responsible for increased operative morbidity and mortality [7,9].

Increasing knowledge and technical refinements in all surgical disciplines have shown that reduction in tissue damage occurring consequent to the use of limited surgical approaches may prove effective in significantly decreasing early postoperative pain [10,11] and adequate pain control in the early postoperative period is one of the most effective ways to prevent respiratory complications and achieve a quicker functional recovery after lung surgery [5,7].

However, pain after thoracotomy is caused by the interaction between several factors and includes incisional pain, pain due to interruption of the muscular and ligamentous structures by the retractors used during the surgical procedure, and the pain of pleural irritation secondary to the presence of the chest tube [12]. The most important etiological factor in the development of post-thoracotomy pain is probably intercostal nerve injury [13].

There are several methods that are currently in use for post-thoracotomy pain management, including systemic opioid administration, non-steroidal anti-inflammatory drugs, ketamine, and regional anesthesia techniques such as epidural, paravertebral, intercostal, and intrapleural blocks [14,15].

Although none of the surgical techniques have been proven to decrease the incidence of chronic pain, intercostal nerve damage due to rib retraction appears to be involved in the development of neuralgia [16].

Landrenau and colleagues reported that PPS can result from intercostal neurinoma after trauma, rib fractures, local infection, pleuritis, costochondritis, costochondral dislocation, or local tumor recurrence [17]. Because the most likely cause of PPS is intercostal nerve damage, the intercostal incision should be performed carefully during the surgery [17]. Wallace and Wallace reported a review of both myofascial and neuropathic characteristics of chronic post-thoracotomy pain [18]. There are also a few prospective studies regarding intercostal nerve protection during thoracotomy closure.

In the study conducted by Cerfolio and colleagues, 140 patients who underwent chest closure with pericostal sutures (sutures placed on top of the fifth and seventh ribs) and another 140 patients who underwent chest closure with intracostal sutures (sutures placed on top of the fifth rib and through the small holes drilled in the bed of the sixth rib) were compared. They concluded that intracostal sutures were less painful than pericostal sutures, as evaluated at 2 weeks, 1 month, 2 months, and 3 months after thoracotomy [2]. In their other study, a different technique was used, and in 56 of 114 patients, the intercostal muscle underneath the fifth rib was harvested along with the rib before placing a chest retractor to avoid nerve compression. They concluded that harvesting the intercostal muscle flap before chest retraction decreased post-thoracotomy pain [4]. Furthermore, in their recent study, they concluded that harvesting an intercostal muscle flap and leaving the muscle intact such that it hangs under the retractor leads to further reduction in post-thoracotomy pain [19]. We tried Cerfolio's intercostals muscle-harvesting technique but observed interrupted exposure because of our full muscle-sparing minithoracotomy technique. We therefore developed a partial harvesting technique at the end of surgery to avoid limited exposure during surgery. This is different from Cerfolio's technique in that we used a partial harvesting technique at the end of surgery and just now closing thorax.

De Kock and colleagues used mechanical hyperalgesia using a von Frey hair test in their study and compression of the study's groups in the postoperative 2nd week, and 1st and 6th months [20]. In our study, we used the von Frey hair test on postoperative 2nd, 15th, and 30th days for hyperalgesia in the two groups and did not find any differences.

In our study, we compared two thoracotomy closure techniques, that is, using intercostal sutures and intracostal sutures, after partial intercostal nerve dissection. Although two holes were drilled on the top rib during the study period, this has been modified and sutures were passed through the top of the fifth rib as both techniques avoided nerve compression. We found that the drug consumption of patients as evaluated from the epidural PCAS on the 2nd, 4th, 8th, 16th, 24th, and 48th h in patients, who received intracostal sutures after intercostal nerve dissection, was lower as compared with the patients, who received intercostal sutures, and the results were statistically significant. The VASs at rest in the 2nd, 4th, 8th, 16th, 24th, and 48th h and during coughing in the 2nd, 4th, 8th, 16th, 24th, and 48th h in patients, who received intracostal sutures after intercostal nerve dissection, were lower than the respective scores of patients, who received intercostal sutures, and the differences were statistically significant. The OVRS scores in the 24th and 48th h were lower in patients, who received intracostal sutures after intercostal nerve dissection, as compared with the patients, who received intercostal sutures, and the differences were statistically significant. On the basis of our results, we have converted our thoracotomy closure technique from intercostal sutures to intracostal with intercostal nerve dissection.

In conclusion; our study confirmed that acute post-thoracotomy pain was much less in patients with rib approximation by the use of intracostal sutures after intercostal nerve dissection. Fifth and sixth intercostal nerve compression was prevented by drilling holes into the fifth and sixth ribs and partial intercostal nerve dissection, which is a fairly straightforward procedure and requires only two additional minutes of operating time. The decrease in acute post-thoracotomy pain may result in the decreased risk of chronic PPS. The ideal way to achieve complete pain relief remains unknown. The common conclusion is that for patients undergoing thoracotomy, analgesia should be commenced in the preoperative period itself, continued perioperatively, and should finally be reduced in the postoperative period.

The use of a thoracotomy closure technique avoiding intercostal nerve compression after partial dissection of the intercostal muscles significantly decreases acute post-thoracotomy pain and promotes early discharge of the patient from the hospital following thoracotomy.

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