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ORIGINAL ARTICLE

If post-thoracotomy pain is the target, Integrated Thoracotomy is the choice

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Abstract

Objectives Despite the overgrowth of procedures done by VATS, there are still needs for thoracotomy. Post-thoracotomy pain plays an important role in many post-operative morbidities. Surgeons should make efforts to evolve new techniques to reduce post-thoracotomy pain with its associated morbidities. This trial aimed to study the impact of combining lack of rib retraction with protection of both intercostal nerves on post-operative pain.

Methods This was a prospective study of 57 patients who had Integrated thoracotomy (I group) which consists of modified French window with Double-Edge closure. The results of I group were compared to our previous study that contained two groups 60 patients each, double edge (DE group) in which standard thoracotomy was closed using double-edge technique and (PC group) in which pericostal sutures was used for closure of thoracotomy. Outcomes assessed were operative time, time to ambulation, doses of analgesics injected in the epidural catheter, post-operative complications, chest tube drainage, hospital stay, and pain score and use of analgesics during the first post-operative year.

Results All groups had similar demographics, operative time, and incisions length, but in I group, there were significantly a smaller number of lobectomies and pneumonectomies. Patients in I group had significantly lower time to ambulation, epidural doses and post-operative pain score throughout the first week. Patients in the (I group) had a significantly lower pain score throughout the first 9 months post-operatively. Up to 6 months post-operatively, there was significantly less use of analgesics among the I group.

Conclusion The combination of retractor-free exposures and neurovascular exclusion sutures for thoracotomy is safe and effective in decreasing post-thoracotomy pain and use of analgesics.

Keywords Analgesics · Pain · Post-operative · Thoracotomy

Introduction

Many patients suffer from post-operative pain following thoracotomy which plays an important role in the pathogenesis of several post-surgical morbidities [1]. Patients who developed high levels of early post-operative pain are at high risk to have post-thoracotomy pain syndrome (PTPS) which is defined as 'Pain that recurs or persists along a thoracotomy scar at least 2 months following the surgical procedure' [2]. Neurological pain due to intercostal nerves injury either during rib retraction or during thoracotomy closure forms the major component of post-thoracotomy pain [3]. Protection of upper and lower intercostal nerves through double-edge closure is effective in decreasing the acute and chronic post-thoracotomy pain [4]. Avoiding rib retraction through modified French window thoracotomy seems to result in less post-operative pain and earlier ambulation [5].

This trial aimed to study the impact of combining lack of rib retraction with protection of both intercostal nerves on post-operative pain. We compared patients in whom modified French window combined with double-edge closure was adopted with our previous results regarding double-edge closure alone and conventional thoracotomy [4].

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Patients and methods

In this prospective study from January 2015 to June 2017, 57 patients had undergone integrated thoracotomy which consists of modified French window with double-edge closure (I group) at the Department of Cardiothoracic Surgery of Menoufia University Hospital, Egypt.

All patients undergoing thoracotomy for management of different pathologies were included.

The non-inclusion criteria were (1) patients younger than 18 years; (2) patients with previous thoracotomy; (3) patients with previous sternotomy; (4) patients with chronic pain disease or any neuropathic pain; and (5) patients with preoperative rib fracture.

The exclusion criteria were (1) intraoperative need for rib retraction; (2) operative and post-operative mortality; (3) patients who required post-operative mechanical ventilation; (4) patients with a non-functioning epidural catheter; and (5) patients lost to follow-up.

All patients allocated to receive integrated thoracotomy (I group) had a thoracic epidural catheter, which was inserted just prior to induction of general anesthesia and removed on the third post-operative day. All patients had the standard posterolateral thoracotomy incision with division of the latissimus dorsi muscle and preservation of the serratus anterior muscle. The intercostal muscles were freed from the superior aspect of the rib. This rib may be the six or the seventh except when the diaphragm needed to be dealt with, the eighth rib was used. Surgical field exposure was achieved without usage of rib retraction; instead, resection of about one cm from both anterior and posterior ends of the corresponding rib (caudal rib) was made to create a rib flap with about 10 cm long that hung into the thoracic cavity (Fig. 1a, b).

For optimization of exposure, the rib flap was tracked inside the chest cavity using a 0-silk suture passed around it. An angiocatheter was inserted through the skin into the chest approximately three intercostal spaces below the level of the incision. A crimped polypropylene suture was passed through the angiocatheter and was used to loop the ends of the silk suture, pulled through the angiocatheter, and clamped on tension at the skin surface (Fig. 2a, b).

The desired procedures either pneumonectomies, lobectomies, or others (as wedge resections, bullectomies, parietal pleurectomy, pleural and mediastinal tumors and diaphragm Surgeries) were performed through the created window, and if buttressing of the bronchial stump was needed, pleural or pericardial flap was used instead of intercostal muscle flap.

Once the procedure was complete, the silk stay suture was released and closure of the intercostal space by double-edge closure technique was done using four-to-six simple sutures (no. 2 polyglycolic acid). A dissecting forceps or low electrocautery was used to slightly peel the intercostal muscle and neurovascular bundle from the inferior edge of the lower rib and the blunt needle was inserted below the edge, tracing the back of the rib with the needle tip. This maneuver was repeated on the lower border of the upper rib and the suture was passed over the intercostal muscle corresponding to the space of thoracotomy (Fig. 3).

Post-operative analgesic protocol consisted of intravenous 1 g of paracetamol every 8 h in the first 2 days then oral during the following 5 days and on demand doses in the epidural catheter (10 ml of 0.25% bupivacaine).

The total operative time, length of incision, chest tube drainage, complications (if any occurred), the time needed

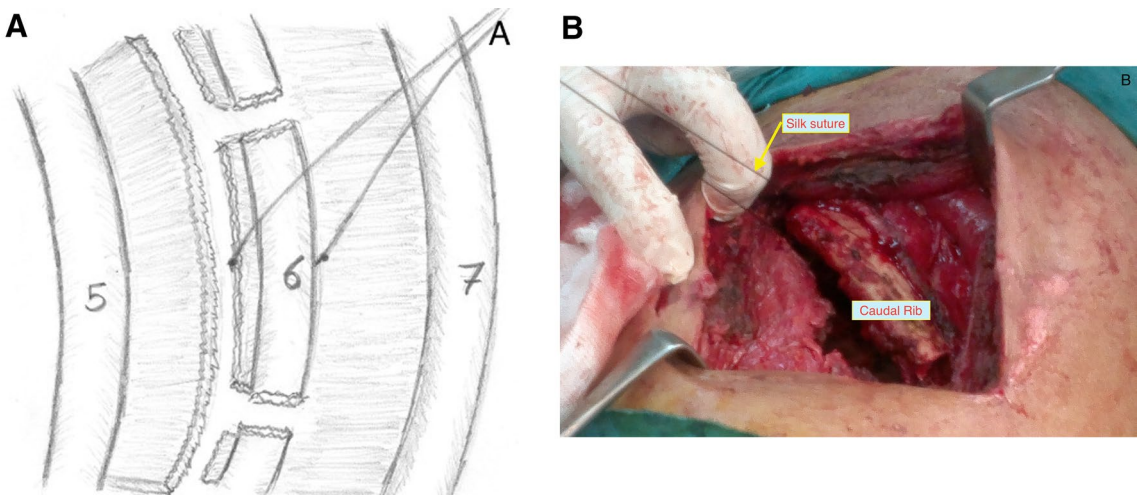

Fig. 1 **a**, **b** Creation of caudal rib flap

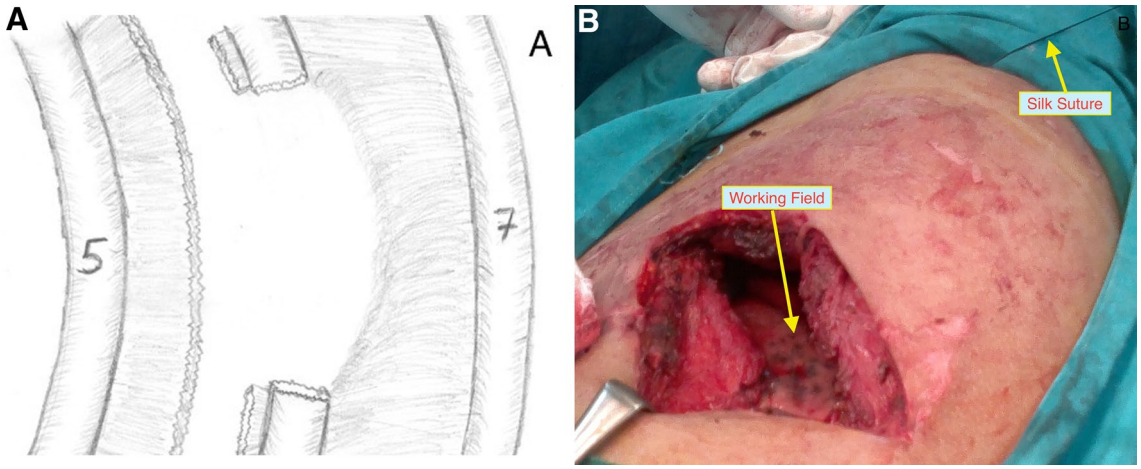

Fig. 2 **a**, **b** French window exposure by pulling the rib flap inside the chest

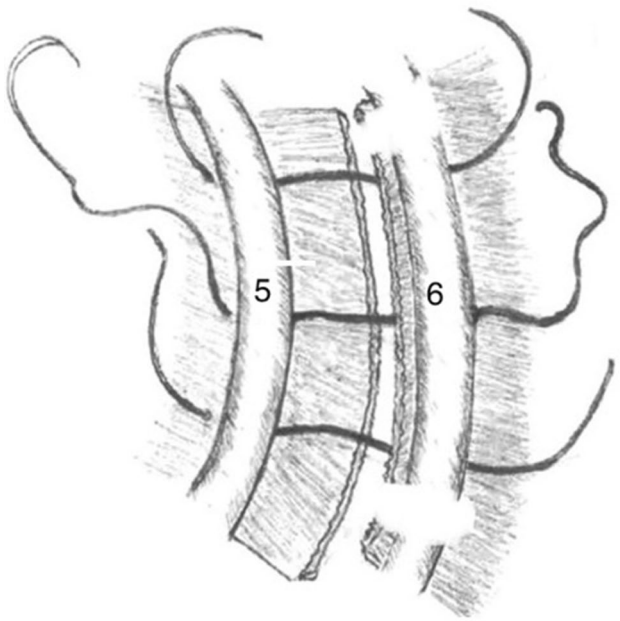

Fig. 3 Thoracotomy closure by double-edge closure

until ambulation, and post-operative hospital stay were recorded.

The primary outcome of this study was post-thoracotomy pain, which was measured using the numeric rating scale from 0 to 10 (0 = no pain, 10 = extreme pain) [6], which was explained to all patients preoperatively and was recorded post-operatively daily until the seventh day. Patients discharged before the seventh day were contacted by telephone to record the scale. Pain score and the use of analgesics at 2 weeks, 1, 3, 6, 9, and 12 months post-operatively were also recorded.

Table 1 Differences between the study groups

	I group	DE group	PC group
Type of thoracotomy	French window	Conventional	Conventional
Use of rib retractor	No	Yes	Yes
Type of closure stitch	Double edge	Double edge	Pericostal

The results of I group was compared to our previous study that contained two groups 60 patients each, and they were operated through conventional thoracotomy using rib spreaders and closed using either DE group with double-edge technique described above or PC group with conventional pericostal sutures [4] (Table 1).

Patients in DE group and PC group had the same inclusion and exclusion criteria as in I group and had a thoracic epidural catheter, which was inserted just prior to induction of general anesthesia and removed on the third post-operative day.

Data are presented as mean ± standard deviation. Statistical analyses were carried out using the Mann–Whitney U test, t test, and χ^2 test. Comparisons of data were made with the overall α error set at 0.05 (two-tailed). Analyses were conducted with the SPSS version 20 software (SPSS, Inc., Chicago, IL, USA).

Results

57 patients were allocated to this study after exclusions (I group) and were compared to our previous study groups, (DE group) and (PC group), with 60 patients each. There were no significant differences between the three groups regarding age, sex, side of the disease, and operative time. However, the number of lobectomies and pneumonectomies

Table 2 Demographic and clinical characteristics of patients in the three groups

	PC No = 60		DE No = 60		I No = 57		Test of significance	*P* value
Age								
Mean ± SD	41.33 ± 11.91		41.28 ± 12.06		41.72 ± 12.05		*F* test 0.02	0.98 NS
Operative time								
Mean ± SD	163.50 ± 39.21		159.42 ± 41.47		165.93 ± 40.77		*F* test 0.39	0.68 NS
	No	%	No	%	No	%	χ^2	
Sex								
Male	49	81.7	47	78.3	44	77.2	0.39	0.83
Female	11	18.3	13	21.7	13	22.8		NS
Type of operation								
Lobectomy	25	41.7	27	45.0	13	22.8	10.13	0.04
Pneumonectomy	4	6.7	3	5.0	1	1.8		S
Other	31	51.7	30	50.0	43	75.4		
Side of operation								
Right	38	63.3	35	58.3	30	52.6	1.38	0.50
Left	22	36.7	25	41.7	27	47.4		NS

SD standard deviation, *PC* pericostal suture group, *DE* double-edge suture group, *I* integrated thoracotomy group

was significantly less in I group (Table 2). There were 17 patients operated for malignant neoplasm in PC group and 14 patients in DE and I group.

Time to ambulation, epidural doses, and post-operative pain score throughout the first week were significantly lower in the I group, but there were no significant differences between the three groups about skin incision length, chest tube drainage, hospital stay, or post-operative complications (Table 3).

Patients in the I group had a significantly lower pain score throughout the first 9 months post-operatively. Up to 6 months post-operatively, there was significantly less use of analgesics among the I group (Table 4). We did not encounter any patient who developed atrial fibrillation nor pneumonia in all groups.

Discussion

Since the first publishing of thoracotomy incision by Howard Lilienthal [7] in 1910 and it progressively became the standard approach for many surgical procedures. Consequently, with increased number of patients undergoing thoracotomy, thoracic surgeons started to face a new common complaint in post-operative follow-up named pain that sometimes persists for too long-time annoying patients and cumbersome surgeons in controlling such pain that was named post-thoracotomy pain [8].

Not only, does the post-thoracotomy pain become the most common post-operative symptom, but also it was found to be a major risk factor for many other post-operative complications [9].

Neurological pain from intercostal nerves injury form the major component of post-thoracotomy pain and that explain why all patients describe their pain as burning, numbness and searing in nature. Neural degeneration, axonal sprouting, and localized neuromata because of intercostal nerves damage can generate persistent spontaneous nerve activity, which manifest as allodynia and hyperalgesia. Intercostal nerves can be damaged by rib retraction or pericostal sutures during thoracotomy closure [3]. Maguire et al. in 2006 used a questionnaire to determine the prevalence of post-thoracotomy neuropathic pain and found that it was 57% after 7–12 months [10].

The first reference of chronic post-thoracotomy pain dates from 1944 and it was based on observations of US Army surgeons after treating chest trauma during World War II. Since when many surgeons tried to modify surgical technique in closure of thoracotomy to avoid this annoying neurological damage causing post-thoracotomy pain, as it is noted in García–Tirado's systematic review in 2011 [11] showing 11 studies only dealing with surgical techniques; 6 articles dealing with thoracotomy closure techniques; 3 articles about the closure of space with resorbable osteosynthesis material; and finally, 2 studies comparing a thoracotomy closure technique combined with an intercostal separation technique vs a thoracotomy closure method.

This review with its last two studies aroused us to start new research by adding intraoperative non-compressive thoracotomy technique (modified French window) to our successful trial of double-edge closure and evaluating its

Table 3 Post-operative data

	The studied groups						Test of significance	*P* value
	PC No = 60		DE No = 60		I No = 57			
Time to ambulation (hours)								
Mean ± SD	14.47 ± 3.79		12.85 ± 2.75		10.95 ± 2.42		*F* test 2.67	0.009**
Skin incision length (cm)								
Mean ± SD	18.70 ± 3.41		18.68 ± 3.59		18.32 ± 3.28		*F* test 0.03	0.98 NS
Chest tube drainage (ml)								
Mean ± SD	394.67 ± 127.34		402.50 ± 147.93		397.89 ± 142.19		*F* test 0.31	0.76 NS
Chest tube duration (days)								
Mean ± SD	1.78 ± 0.61		1.82 ± 0.68		1.77 ± 0.5		*F* test 0.08	0.92 NS
Hospital stay (days)								
Mean ± SD	7.02 ± 1.73		6.73 ± 1.98		5.12 ± 1.64		*F* test 0.83	0.41 NS
Epidural doses								
Mean ± SD	3.65 ± 1.19		1.87 ± 0.87		1.04 ± 0.76		*F* test 9.36	< 0.001***
Pain score								
Day 1	6.0 ± 0.97		4.98 ± 0.81		3.51 ± 0.95		*F* test 6.21	< 0.001***
Day 2	4.93 ± 0.89		4.15 ± 0.71		2.61 ± 0.82		5.29	< 0.001***
Day 3	4.23 ± 0.81		3.53 ± 0.68		2.00 ± 0.73		5.14	< 0.001***
Day 4	3.77 ± 0.72		3.22 ± 0.45		1.68 ± 0.66		4.99*	< 0.001***
Day 5	3.02 ± 0.70		2.30 ± 0.46		1.28 ± 0.73		6.61*	< 0.001***
Day 6	2.73 ± 0.71		2.13 ± 0.47		0.86 ± 0.58		5.47*	< 0.001***
Day 7	2.05 ± 0.79		1.38 ± 0.69		0.46 ± 0.54		4.92*	< 0.001***
	No	%	No	%	No	%	χ^2	
Complications								
Air leak	7	11.7	6	10.0	3	5.3	3.22	0.92 NS
Bleeding	0	0.0	1	1.7	1	1.8		
Empyema	2	3.3	1	1.7	1	1.8		
Wound infection	5	8.3	4	6.7	5	8.8		
No complications	46	76.7	48	80.0	47	82.5		

SD standard deviation, *PC* pericostal suture group, *DE* double-edge suture group, *I* integrated thoracotomy group, *NS* statistically insignificant difference ($P > 0.05$)

*Kruskal–Wallis test

**Statistically significant difference ($P < 0.05$)

***High statistically significant difference ($P < 0.001$)

effect contrasting to outcome of our previous series of patients.

Fortunately, patients underwent the new integrated technique were comparable to our previous study groups regarding age, sex, and side of operations. Surprisingly, the operative time did not increase by applying the integrated method and remained with no difference from other groups of patients.

The skin incision length, chest tube drainage, and hospital stay are comparable in all groups with no difference, but we notice numerical shorter hospital stay in integrated group, but did not achieve statistical significance. Meanwhile, we had fewer complications rate in the integrated group providing more safe and appealing technique to patients.

Moreover, the integrated method's patients showed statistically significant more than 3 h earlier ambulation time than double edge and conventional pericostal patients with less epidural requirement and very low pain score over the first week. This was the same findings in Cerfolio et al.'s [12] study of 114 patients underwent posterolateral thoracotomy with elaborating our same principal of avoiding compression of the upper rib bundle not by the retractor but using the flap method in nearly half of their patients, they found also early ambulation and low numeric pain score above two in many days which in our integrated group fell below two form the third day denoting better response to our technique.

During ongoing follow-up of our patients for 1-year post-operative, we found significant decline in the pain score level

Table 4 Follow-up data

	The studied groups						Test of significance	*P* value
	PC No = 60		DE No = 60		I No = 57			
	Mean ± SD		Mean ± SD		Mean ± SD		Kruskal–Wallis test	
Pain score								
2 weeks	1.73 ± 0.80		1.08 ± 0.62		0.26 ± 0.44		4.73	< 0.001**
1 month	1.23 ± 0.72		0.67 ± 0.63		0.18 ± 0.38		4.24	< 0.001**
3 months	0.88 ± 0.72		0.48 ± 0.59		0.16 ± 0.37		3.22	< 0.001**
6 months	0.63 ± 0.74		0.33 ± 0.51		0.12 ± 0.33		2.31	< 0.001**
9 months	0.30 ± 0.56		0.17 ± 0.38		0.07 ± 0.26		1.23	0.03*
1 year	0.17 ± 0.38		0.13 ± 0.34		0.04 ± 0.19		0.51	0.07
	No	%	No	%	No	%	χ^2	
Patients use analgesics								
7 days	53	88.3	43	71.7	20	35.1	38.20	< 0.001**
2 weeks	49	81.7	35	58.3	11	19.3	50.08	< 0.001**
1 month	42	70.0	27	45.0	8	14.0	37.33	< 0.001**
3 months	32	53.3	17	28.3	6	10.5	25.33	< 0.001**
6 months	15	25.0	7	11.7	3	5.3	9.84	< 0.001**
9 months	10	16.7	5	8.3	2	3.5	5.99	0.05
1 year	5	8.3	4	6.7	1	1.8	2.55	0.28

SD standard deviation, *PC* pericostal suture group, *DE* double-edge suture group, *I* integrated thoracotomy group

*Statistically significant difference ($P < 0.05$)

**High statistically significant difference ($P < 0.001$)

of patients until the last follow-up visit at 1-year time, we found insignificant less pain score in the integrated group. This contrasting to our previous study when significant pain decline ceased at 6-month follow-up and the same in Sapkota et al. [13]. They investigated the effect of protecting both upper and lower intercostal nerves through intercostal muscle flap and intracostal suture and found significant pain reduction during the first post-operative month with loss of this significance at the second and third months post-operatively.

This lesser effect on long-term post-operative pain reduction, as we claimed previously to the shingle of the posterior 1 cm of the upper rib, was reevaluated as we made resection of about 1 cm from both anterior and posterior ends of the corresponding rib (caudal rib) also in the integrated group, but got a better pain score reduction up to 1 year. Therefore, our concept for post-thoracotomy pain theory was modified to think about the use of chest rib spreader retractor offering compression and compromising of intercostal nerves during the whole procedure time rather than the rib fracture itself.

For the use of analgesics, we found significant progressive decrease in number of patients using analgesics with time reaching only one patient at 1-year interval in comparison with our best group of double-edge closure that was four patients at 1-year interval and that was lesser than the results of 60 patients underwent intercostal muscle flap technique in Allama's [14] study and five of them still using analgesics at 6-month interval in contrast to three in our study at the same time.

In conclusion, despite the overgrowth of procedures done by video-assisted thoracoscopic surgery, there is still indications and needs for thoracotomy and we should continuously evolve techniques to improve the incision and its outcome.

Concerning the post-thoracotomy pain, we have a new concept that its prevention starts from the start of the operation and not the closure technique only. It is worthy enough to test the combination of retractor-free exposures and neurovascular exclusion sutures to provide the same operations with safe and less pain to our upcoming patients.

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