Pain and Physical Function Are Similar Following Axillary, Muscle-Sparing vs Posterolateral Thoracotomy*

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Study objectives: We set out to determine whether there is a difference in postoperative pain and recovery after the patient undergoes the axillary muscle-sparing incision (ie, muscle-sparing thoracotomy [MT]) vs the modified posterolateral incision (ie, posterolateral thoracotomy [PT]).

Design: Analysis of a database originally collected to determine the effect of the timing of epidural analgesia on long-term outcome after thoracotomy.

Setting: The Hospital of the University of Pennsylvania.

Patients: Patients presenting for lobectomy, segmentectomy, or bilobectomy.

Measurements: Pain, physical activity, and the extent that pain interfered with activities following major thoracotomy were prospectively assessed with standard questionnaires (ie, the brief pain inventory and the Medical Outcomes Study 36-item short form) on postoperative days 1 to 5, and at postoperative weeks 4, 8, 12, 24, 36, and 48 by a blinded research assistant. Perioperative care was standardized and included patient-controlled thoracic epidural analgesia until thoracostomy tube removal.

Results: Eighty-two subjects underwent MT and 38 subjects underwent PT during the 16-month accrual period. There were no significant differences in demographics. Pain reported during hospitalization and after hospital discharge did not differ with respect to incision type (p ≥ 0.17). Postoperative physical activity levels were significantly less than those reported preoperatively, with a trend toward better functioning in the MT groups after 8 weeks. Incision type did not predict complications, morbidity, or mortality.

Conclusions: When comparing patients who had undergone vertical, axillary, wholly MT to those who had undergone modified serratus muscle-sparing PT, postoperative differences in pain were not apparent. One should not anticipate reduced pain or more rapid overall recovery following MT, at least when epidural analgesia is used aggressively for perioperative pain control.

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Recovery from thoracotomy depends on a number of variables, including preoperative morbidity, disease burden, extent of surgery, and perioperative analgesia. While the care of thoracotomy patients has been refined considerably over the last 20 years, high rates of morbidity are still incurred. The reported incidence of postoperative pulmonary complications ranges from 25 to 49%. Postthoracotomy pain can be severe, and it has been reported to be present in from 21% to 49% of patients even 1 year after undergoing the surgical procedure. There is little doubt that pain that stresses physiologic reserve and limits the clearance of secretions and the recovery of pulmonary function is a major factor in the etiology of pulmonary complications. Among the factors that have been investigated as potentially influencing the
levels of acute and chronic pain following thoracotomy has been the choice of incision.

The classic approach to thoracotomy is the posterolateral incision, and many thoracic surgeons have moved to utilizing a posterolateral serratus-sparing anterior muscle incision (ie, posterolateral thoracotomy [PT]). However, a variety of completely muscle-sparing thoracotomies are now performed with increasing frequency as well. The lateral muscle-sparing approach requires the raising of skin flaps and has been shown to result in a significant incidence of postoperative seromas.6 We and others have preferred a vertical, axillary muscle-sparing thoracotomy (MT) that obviates the need for skin flaps and is cosmetically advantageous by virtue of being essentially hidden under the arm, but this incision requires no less rib spreading than other approaches.5

Although the choice of incision is guided in part by the exposure required, both cosmesis and, more importantly, the potential for improved recovery are also factors. Both vertical, axillary MT and the horizontal muscle-sparing incisions have been reported to produce less pain,6–8 less interference with pulmonary function,9 better residual shoulder function,10,11 and better cosmesis. The reports of decreased postoperative pain are consistent with studies that have demonstrated less intercostal nerve dysfunction following MT compared with PT.12 However, a similar amount of published data suggests that, on the contrary, muscle-sparing incisions do not reduce perioperative pain.11–13 Moreover, few data are available to demonstrate whether the type of incision can affect chronic pain and physical functioning following major thoracotomy.14,15 And finally, none of the available studies compare a pure group of patients who have undergone MT with those who have undergone PT. Our objective, then, was to evaluate whether MT favorably impacts pain and physical function compared to serratus-sparing PT during hospitalization and up to 48 weeks after hospital discharge.

Materials and Methods

Data were collected as part of an institutional review board-approved prospective, randomized, and double-blinded study that was initially designed to evaluate the effect of the timing of the initiation of epidural analgesia on the recovery of function.5 Patients were eligible for enrollment in the study if they were undergoing thoracotomy for segmentectomy, lobectomy, or bilobectomy by either PT or MT. Pneumonectomy patients were excluded due to chronic pain syndromes from fibrosis of the chest cavity.9 Patients had to be free from chronic pain, opioid use, neurologic impairment, severe cardiovascular disease (New York Heart Association class III to IV or Canadian Cardiovascular Society class III to IV), severe pulmonary disease (ie, FEV1 < 50% predicted, pulse oximetric saturation < 93% on room air; PaCO2 > 44 mm Hg), or contraindications to epidural catheter placement (eg, coagulopathy, systemic infection, or spinal stenosis). These data were reanalyzed with respect to incision type.

Preoperative American Society of Anesthesiologists physical status,17 the criteria of Goldman et al,18 and FEV1 were used to determine preoperative physical severity. The American Society of Anesthesiologists physical status rates patients on a scale of I (healthy and disease-free) through V (very likely to die even with operative intervention) based on the presence and impact of the acute and chronic disease burden. The criteria of Goldman et al18 are multivariate risk predictors of perioperative myocardial infarction.

Preoperative pain and physical activity were assessed with the Brief Pain Inventory (BPI)19,20 and the Medical Outcomes Study 36-item short form (SF-36).21 The BPI includes 16 questions that measure the level of pain (ie, worst, least, average, and current) and how that pain interferes with activity (ie, general activity, mood, walking, work, relations with other people, sleep, and enjoyment of life), all on a discrete scale of 0 to 10. A 10-question subset of the SF-36 was used to assess physical activity, in which each activity was assessed on a discrete scale of 1 to 3. Patients were randomized (random block sizes with an overall assignment of 1:1) to receive epidural analgesia that was initiated at least 45 min before the incision was made or was initiated at the time of rib approximation for chest closure. Anesthetic care was otherwise standardized for all subjects.

The type of incision was determined by the surgeons who were blinded with respect to epidural randomization. For patients undergoing PT, the skin incision extended the width of the latissimus dorsi muscle. The latissimus muscle was completely divided, but the serratus anterior muscle was entirely spared and reflected anteriorly. The chest was opened in the fifth intercostal space. The incision for the MT extended approximately 7 cm caudal from just below the axillary hairline along the anterior border of the latissimus (Fig 1). The latissimus muscle was completely spared and did not require mobilization. The insertions of the serratus anterior muscle on ribs 4 and 5 were dissected off of these ribs, allowing the muscle to be lifted off of the chest wall to allow the intercostal incision to be made in the fourth intercostal space (Fig 2). For both approaches, the intercostal incision is extended far anteriorly and posteriorly beyond the limits of the skin incision. A small portion of the posterior sixth rib was occasionally resected (shingled) during PT.

![Skin incision](image1)

![Muscular incision](image2)

**Figure 1.** The incision (large dashed line) for the vertical MT starts just below the axillary hairline and runs vertically for 8 cm just anterior to the border of the latissimus dorsi. The thoracotomy (small dashed line) is made in the fourth intercostal space. Reprinted with permission of Kaiser et al.5
but never during MT. Both types of incisions were closed with three or four interrupted pericostal sutures and a running absorbable suture on the muscle, subcutaneous, and skin layers of the incision for PT, and on the subcutaneous and skin layers of the incision for MT.

All patients received aggressive postoperative epidural analgesia, which consisted of patient-controlled epidural analgesia of 0.05% bupivacaine (0.5 mg/mL) and fentanyl citrate 0.001% (10 μg/mL) at 4 mL/h with optional boluses of 3 mL every 10 min, that was initiated at the time of rib approximation. This was titrated by members of the Acute Pain Service who were blinded with respect to treatment group. Patients received supplemental therapy with ketorolac for shoulder pain. As per institutional routine, epidural catheters were removed shortly after thoracotomy tube removal, typically on postoperative days 3 to 5. Therapy with oral analgesics after epidural anesthesia removal included ibuprofen, 600 mg qid, oxycodone hydrochloride, 5 to 10 mg, and acetaminophen, 325 to 650 mg every 4 to 6 h prn, except in cases in which one of these agents was contraindicated or poorly tolerated. Patients were weaned from these drugs on an outpatient basis as tolerated. Each postoperative morning, the BPI was obtained, analgesic consumption was recorded, and the chart was reviewed for milestones and complications. After hospital discharge, patients were contacted by phone 4, 8, 12, 24, 36, and 48 weeks after surgery, and the same scripted interview using the BPI and the 10 question subset of the SF-36 was administered. All data were collected by a research assistant who was blinded with respect to the incision used, epidural assignment, and hospital course.

Demographic data were analyzed using one-way analysis of variance (ANOVA), the Mann-Whitney U test, and the Fisher exact test (two-tailed) for continuous, ordinal, and proportional data, respectively. Pain and functionality scores were treated as continuous variables and were analyzed using multifactorial (ie, incision, gender, treatment, and time) repeated-measures ANOVA using a statistical software package (Statistica, version 6.0; StatSoft, Inc; Tulsa, OK). Differences were considered significant at $p < 0.05$.

A power analysis showed that given our sample of 120 patients in a 2:1 distribution, we would have at least 83% power to detect a 25% difference in pain scores between incision types at 3 months postoperatively using our SD of 28 (ie, 2.8 of 10) for our pain scores. Significance was at $p < 0.05$, assuming four covariates (ie, incision, gender, treatment, and time) in our repeated-measures analysis.

**Results**

**Patient Recruitment and Adherence to Protocol**

Patients were recruited from March 1998 to July 1999, with follow-up completed in August 2000. One hundred fifty-seven patients were randomized, with 37 patients being eliminated (surgery had been extended to include pneumonectomy and/or chest wall resection, 18 patients; nonfunctional epidural catheters, 11 patients; repeat thoracotomy, 4 patients; death, 2 patients; withdrawal from the study, 1 patient).

**Patient/Tumor Characteristics**

The patient characteristics (Table 1) show no demographic differences between the MT and PT groups. The American Society of Anesthesiologists physical status, the criteria of Goldman et al,18 and FEV$_1$ were used to determine the preoperative physical severity. There was no difference in tumor stage between the incision groups.

Approximately twice as many subjects underwent MT as underwent PT. The Kolmogorov-Smirnov test indicated no significant differences in the variances of the two groups, with the smaller PT group having a larger variance at all time points. Variance increased as patients were censored (see data on the long-term follow-up in the next sections). Kaplan-Meier analysis showed that there was no difference between the rates of enrollment for the PT and MT groups throughout the study.

**Enrollment by Surgeon**

Three surgeons were actively operating during the enrollment period. All of them subspecialized in thoracic surgery and were not performing cardiac surgery. Study enrollment was split between them as follows: surgeon 1, 66%; surgeon 2, 22%; and surgeon 3, 12%. There were no statistical differences in the proportions of MTs vs PTs performed among the surgeons. Including “surgeon” as a confounder, clustering by “surgeon” did not impact the relationship of the incision to pain, nor did it impact the relationship of incision to activity.

**Early Postoperative Pain**

Postoperative pain control was excellent during hospitalization both for patients in both the MT and
PT groups but was without significant decline in any of the pain measures during hospitalization (p ≥ 0.20). During hospitalization, patients in the MT group had a nonsignificant trend toward higher pain scores. From postoperative day 1 to 5, the average (± SD) pain score (over the last 24 h) for the PT group was 2.9 ± 0.47), the mean worst pain was 5.3 ± 0.51, and the mean least pain was 0.8 ± 0.28. The average pain score for the MT group was 3.0 ± 0.49, the mean worst pain 5.5 ± 0.55, and the mean least pain 1.3 ± 0.22. There were no differences between the groups in the volume of epidural medication received (p = 0.51), the number of patient-controlled boluses delivered (p = 0.45), or the number of patient demands made during the lockout phase of the patient-controlled epidural analgesia (p = 0.46). There was also no difference between the groups in the amount of supplemental ketorolac (p = 0.94) and nonepidural opioids (p = 0.22) administered. The median length of hospital stay was 5 days for both groups (p = 0.77).

Late Postoperative Pain

For the total cohort, the out-of-hospital response rates to questionnaires were > 85% for weeks 4, 8, 12, and 24. At week 36, this rate declined to 81%, and then to 72% at 48 weeks. Incision type had no effect on the likelihood to follow-up alone (p = 0.78) and when tumor stage was considered a confounder (p = 0.55). Incision type alone had no impact on the likelihood of reporting pain or the use of opioid or nonopioid analgesics at all time points (p > 0.43), even when tumor stage was considered as a confounder (p > 0.44). The percentages of patients reporting pain at all time points were not different between the incision types (70% at 4 weeks, decreasing to 45% at 8 and 12 weeks, 35% at 24 weeks, and then 21% at 36 and 48 weeks). The percentages of patients receiving opioid and nonopioid analgesics did not vary with respect to incision type (p = 0.80).

Four weeks postoperatively, the patients reported pain similar to that on postoperative days 1 to 5. These pain scores decreased in the following two plateaus: weeks 8 to 12 and 24; and then weeks 36 and 48 (Fig 3). During weeks 8 to 24, the worst pain ranged from 2.5 to 2.2, the average pain ranged from 1.5 to 1.3, and the least pain ranged from 0.4 to 0.3. During weeks 36 and 48, the worst pain ranged from 1.5 to 1.1, the average pain was 0.8, and the least pain ranged from 0.4 to 0.3. At these time points as well, incision type played no consistent role in the level of pain reported by the patients. Significant differences in the distribution of the origin of the

### Table 1—Patient Demographics

<table>
<thead>
<tr>
<th>Variables</th>
<th>No.</th>
<th>Male*</th>
<th>Female</th>
<th>Height, cm</th>
<th>Weight, kg</th>
<th>Age, yr</th>
<th>ASA-PS</th>
<th>FEV1, % predicted</th>
<th>Goldman Score</th>
<th>Duration of Surgery, min</th>
<th>Mortality, %</th>
<th>30-Day Mortality</th>
<th>Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>PT Group</td>
<td>38</td>
<td>19/19</td>
<td>19</td>
<td>166 (16.4)</td>
<td>75.8 (22.5)</td>
<td>61.2 (3.3)</td>
<td>60 (2)</td>
<td>0.59</td>
<td>0.58</td>
<td>0.14</td>
<td>0.24</td>
<td>0.66</td>
<td>0.21</td>
</tr>
<tr>
<td>MT Group</td>
<td>82</td>
<td>39/43</td>
<td>43</td>
<td>166 (15.4)</td>
<td>75.7 (18.6)</td>
<td>61 (3.3)</td>
<td>60 (2)</td>
<td>0.59</td>
<td>0.58</td>
<td>0.14</td>
<td>0.24</td>
<td>0.66</td>
<td>0.21</td>
</tr>
<tr>
<td><strong>p Value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>PT Group</td>
<td>0.15</td>
<td>0.25</td>
<td>0.42</td>
<td>0.22</td>
<td>0.30</td>
<td>0.42</td>
<td>0.58</td>
<td>0.58</td>
<td>0.14</td>
<td>0.24</td>
<td>0.66</td>
<td>0.21</td>
</tr>
</tbody>
</table>

*Values are given as the mean (SD), the median (lower quartile to upper quartile), or the No. of events, unless otherwise indicated. ASA-PS = American Society of Anesthesiologists-Physical Status.

†Includes nonmalignant lesions or inconclusive pathologic specimens.

Values are given as the mean (SD); the median (lower quartile to upper quartile), or the No. of events, unless otherwise indicated. ASA-PS = American Society of Anesthesiologists-Physical Status.

Late Postoperative Overall Function

The BPI measures the impact that pain has on inhibiting the function of general activity, mood, walking, normal work, relationships, sleep, and enjoyment of life; scores ranged from 0 (no impact) to 10 (completely inhibits pain). The impact of pain scores also showed no influence of incision type \( p = 0.38 \) but followed a slightly different pattern than the pain scores. Although mean pain scores at 4 weeks postoperatively were not significantly different than those during postoperative days 1 to 5, the influence of pain on general activity for the entire cohort was markedly less (at 4 weeks, 1.7 ± 0.44; for postoperative days 1 to 5, 3.8 ± 0.56). Regardless of incision type, pain only minimally interfered (scores < 3 of 10) with general activity, mood, walking, normal work, relationships, sleep, and enjoyment of life from 4 to 48 weeks after surgery.

Physical activity levels were measured with a subset of the SF-36, which asked whether the subject was “completely limited, limited a little, or not limited at all” in 10 activities ranging from dressing to walking more than a mile. Activity scores preoperatively for the two incision groups were 26 \( p = 0.55 \). At 4 weeks, the activity scores for both the PT and MT groups had dropped significantly down to 22 \( p = 0.99; p = 0.02 \) vs their preoperative values. Throughout the remainder of the 48-week follow-up period, the MT group trended toward greater physical activity, with the overall multivariate ANOVA indicating \( p = 0.061 \) (Fig 4).

The timing of the epidural analgesia did not impact acute or chronic pain, nor did it impact functionality or physical activity. On reanalysis, with incision type as the primary factor, the timing of epidural analgesia had no impact as a covariate in the analysis of pain or recovery of function. Throughout all time points and in all analyses, women reported more pain than men regardless of the incision type.2 Incision type did not predict arrhythmia, myocardial ischemia, in-hospital death, or 30-day mortality.

Discussion

In this prospective study of 120 patients undergoing major thoracotomy, the incision made during MT was not associated with decreased pain, improved recovery of function, or decreased complication rate compared to that made during PT during 48 weeks of follow-up. It must be recognized that, although there were no demonstrable differences between groups, this study did not randomize subjects by incision type. While this is a potential source of bias, a number of factors suggest that this limitation is not likely to have influenced our results.

Since tumor size and stage were equivalent between the PT and MT groups, it does not appear that one incision was selected over the other on the basis
of these factors. Patient comorbidities in the two groups were similar, as seen by the lack of difference in preoperative lung function, Goldman score, or American Society of Anesthesiologists status (Table 1), thus the choice of incision was not biased by physical status. We think that both incisions provide sufficient access for an uncompromised cancer operation, including complete mediastinal lymphadenectomy. If a chest wall resection were to have been needed, thus requiring a PT incision, the patient would not have been invited to participate in the study. While the surgical team was not blinded to the type of incision, the Acute Pain Service, which managed the pain regimen postoperatively, and the research nurse, who collected all in-hospital and at-home data, were blinded to the incision type. Perioperative pain management was standardized by protocol. Consequently, no treatment regimens or changes were based on incision type.

However, because there was a trend toward improved physical functioning in the MT group, and there are some data to support improved functioning with the MT incision (see below), it is possible that there was systemic bias introduced by the incision type employed that was based on a subject’s occupation or avocation. It is unclear whether subjects who relied on shoulder function for their occupation or hobbies would be active and healthier, and thus make the MT incision seem better, or whether their increased activity would increase their pain and make the MT incision seem worse. We doubt that such a bias existed to the extent that our results were affected.

We have been unable to identify any surgeon-dependent differences in care that might be expected to impact pain or the recovery of function. Further, no impact on the relationship between pain and incision was seen in our statistical analysis, which included using “surgeon” as a confounder and also clustering by “surgeon.” Clearly, there could still be effects and biases due to the level of experience of the surgeons. While all of our surgeons were fellowship-trained in cardiothoracic surgery and were only practicing thoracic surgery, surgeon 1, who had a much larger practice and thus a larger enrollment, had at least 8 more years of thoracic surgical experience than the other two surgeons. It is not clear whether this could have biased the results, because we could find no clear pattern in the choice of incision type, intraoperative or postoperative care characteristics, or any outcomes as being surgeon-specific.

The strengths of this study are the number of patients, its prospective nature, and the fact that no prior comparative study has included a group in which 100% of patients in the MT group had undergone the now popular vertical, axillary muscle-sparing incision. Further, no prior study has used well-validated surveys and outcome measures for a 1-year follow-up.

In our institution, we have found that after employing very aggressive epidural analgesia and supplemental nonsteroidal antiinflammatory agents, 21% of our thoracotomy patients reported pain 1 year after surgery. This is approximately one half of previously reported rates and raises the question of whether aggressive perioperative pain management is responsible for these low rates of postthoracotomy pain. It is possible that our failure to appreciate a difference with respect to incision type may be the result of this relatively low rate of postthoracotomy pain, rendering it difficult to appreciate small differences between the groups. In fact, if we were to propose using these data as pilot data for a larger study to more definitively determine whether there was a difference in pain levels between these incisions at any time point, a power analysis indicates that we would need between 720 and 7,300 patients per group, depending on whether we predicted finding MT or PT as inducing the least pain. But conversely, with the 120 patients analyzed in this study, we had at least 83% power to demonstrate a difference of 25% in pain at 3 months with a p value of 0.05. Thus, our conclusions rest on fairly firm ground.

One explanation for why there appears to be no major difference in pain with MT vs PT may be that aggressive perioperative epidural analgesia specifically targets the tissue disruption that might lead to greater pain in the PT group. Neurophysiologic assessment, for example, has shown that intercostal nerve function is more commonly impaired 1 month after surgery with the PT incision when compared with the MT incision. Since aggressive epidural analgesia may be important for decreasing the chronic pain that accompanies lower extremity amputation, in which the disruption of sensory input is thought to contribute to the development of chronic pain, it may be that increased pain due to greater intercostal nerve dysfunction in the PT group is prevented by aggressive epidural analgesia.

Another possible factor underlying our finding that incision type does not appear to be associated with differences in pain levels may be due to the contribution to postthoracotomy pain from incision of the skin and pleura and the retraction of muscles and intercostal nerves. Both incisions elicit profound pain of both somatic and visceral origin, and the differences in pain from muscle division alone, which is presumably higher in the PT group, may not be severe enough to impart a difference in outcome when measured against, for example, the degree of
rib spreading. In fact, we have noted clinically that one generally needs to spread the ribs wider apart during MT than during PT in order to compensate for the diminished field of view allowed by the smaller, axillary skin incision. Further, the incision made during MT crosses at least two dermatomes, and possibly three dermatomes, whereas the incision made during PT runs along only a single dermatome, and this too may play a role in the pain experienced by the patients.

Shoulder function has been shown to decrease less in patients undergoing muscle-sparing incisions. This is to be expected given the sparing of the latissimus dorsi muscle, which has attachment to the humerus muscle. No study, including the present one, has shown any difference in functional outcomes resulting from this diminished shoulder strength. However, our data indicate a trend toward improved physical functioning for the MT group from weeks 8 through 48 (Fig 4), and we are addressing this finding in current research.

In summary, in this long-term study with prospectively acquired data on pain and functional outcome for a large cohort, we failed to find a significant difference between MT and PT in early or late pain or in recovery of function. One might choose a muscle-sparing incision in particular patients for purposes of cosmesis or the potential preservation of ipsilateral arm function, but it does not appear that one should anticipate reductions in pain or more rapid overall recovery of function following surgery using this incision, at least when epidural analgesia is used aggressively for perioperative pain control.

REFERENCES