EUROPEAN JOURNAL OF
CARDIO-THORACIC
SURGERY

ELSEVIER

European Journal of Cardio-thoracic Surgery 29 (2006) 873—879

www.elsevier.com/locate/ejcts

A study exploring the role of intercostal nerve damage in chronic pain after thoracic surgery

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Received 7 December 2005; received in revised form 8 March 2006; accepted 13 March 2006; Available online 3 May 2006

Abstract

Objective: Our aim was to investigate the prevalence of intra-operative nerve damage and its association with chronic pain. **Methods:** Our prospective study of 33 patients used nerve conduction studies to assess intercostal nerve function during elective thoracic surgical procedures. We used two methods to study nerve conduction: pre-operative magnetic stimulation (in 10 patients) and intra-operative nerve conduction studies (in all patients) We correlated these findings with specific intra-operative parameters, pain and psychological questionnaires pre-op and 3 month post-op and altered cutaneous sensation. **Results:** Magstim (magnetic stimulation) assessments were not reliable and were therefore abandoned. Intraoperative intercostal nerve studies revealed two distinct patterns of nerve injury and also that nerve injury was less in those cases where a rib was not resected. However, intercostal nerve damage detected at the time of operation is not associated with chronic pain or altered cutaneous sensation at 3 months post-op. **Conclusions:** The study findings suggest that either the amount of intra-operative intercostal nerve damage is not indicative of long-term nerve damage or that there is a more significant cause for chronic pain other than intercostal nerve injury.

Keywords: Chronic pain; Intercostal nerves; Thoracotomy; Nerve conduction; Nerve injury

1. Introduction

Reports in the literature find the prevalence of chronic pain after thoracic surgery to be 9—80% for thoracotomy and 5—33% for VATS (video-assisted thoracoscopic surgery) [1—14]. The prevalence may be influenced by a number of factors. The patients' perception of post-operative pain may be influenced by the style of explanation of the operation and inpatient stay that prepares the patient for surgery. It may be influenced by differences in intra-operative technique, method of anaesthesia, method of post-operative analgesia and the experience of the operating surgeon. Of particular relevance is how the authors defined chronic pain, how long after surgery it was assessed, and how the data was collected, analysed and presented. Some studies have also reported the impact the pain has on patients' lives and how it limits their daily activity [1—3]. Chronic pain after thoracic surgery is clearly a significant problem that requires further investigation.

The cause of the chronic pain has not been established. A study has shown that high levels of immediate post-operative pain is associated with an increase in the likelihood of chronic pain, which suggests it is a process that starts around the time of the operation rather than secondary to tissue healing [4]. Rogers describes numerous possible causes for pain after thoracic surgery [15]. There is evidence to suggest chronic pain results from nerve damage at the time of surgery: studies have shown intercostal nerve damage by demonstrating loss of intercostal nerve conduction during surgery and the loss of abdominal reflexes after thoracic surgery is associated with pain [16,17]. A strong neuropathic component is also indicated by chronic pain being frequently accompanied by abnormal cutaneous sensation and often treated with antidepressants and antipsychotics rather than opiates.

Our aim was to investigate the prevalence of the nerve damage during thoracic surgery and its association with chronic pain. We also explored the intra-operative factors that may influence nerve damage and chronic pain.

2. Method and materials

The study was performed in the Thoracic Surgery Unit in Nottingham City Hospital and ran from December 2004 to September 2005. Local ethics committee approval was obtained prior to commencement of the study.

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doi:10.1016/j.ejcts.2006.03.031

2.1. Patient selection and recruitment

Patients were selected from the planned operating lists for elective thoracotomy or thoracolaparotomy. Only one eligible patient per operating list was studied. List construction was made independently of this study. The eligible patient that was earliest on the operating list was selected for the study. Children (under 18 years old) were not involved in the study. Patients were excluded if they had previous thoracic wall trauma such as multiple rib fractures or previous thoracic wall surgery involving a thoracotomy or VATS (video-assisted thoracic surgery) because of the possibility of existing intercostal nerve injury. Patients were also excluded if they had a known neurological disease with peripheral manifestations including neuropathy associated with diabetes because their disease may have made interpretation of nerve function measurements difficult. There was a potential risk that the equipment used to stimulate intercostal nerves could affect battery-powered medical devices and therefore patients with a cardiac pacemaker, cardiac defibrillator or cochlear implants were excluded.

Refusal of consent excluded the patient from the study. Patients were invited to participate in the study in pre-assessment clinic or on admission to the ward. The study was explained verbally and an information sheet supplied. Written informed consent was always obtained.

2.2. Pre-operative assessment

Prior to surgery patients completed a pain questionnaire: the Short-form McGill Pain Questionnaire (SF-MPQ) which consists of three pain scales: word descriptors with an intensity scale (pain score 1, maximum 45), a visual analogue scale (pain score 2, results presented as a proportion) and a tick-box overall intensity score (pain score 3, range 0–5) [18]. A Hospital Anxiety and Depression Scale questionnaire (HADS), maximum score 42, was also completed [19–22]. We attempted to measure intercostal nerve function in fully conscious participants pre-operatively using a magnetic nerve stimulator (magstim). The nerve stimulator coil was applied perpendicular to the skin overlying the proximal region of the intercostal nerve just lateral to the vertebral body. Two cutaneous button electrodes were placed on the anterior chest overlying the distal portion of intercostal muscle and used to record muscle-evoked potentials (MEPs). A reference cutaneous electrode was placed on the contralateral border of the sternum. The magstim delivered a short magnetic pulse that excited the intercostal nerve, which in turn stimulated the intercostal muscle and the MEP recorded. The patient felt muscle contraction though this was never uncomfortable in any cases. A nerve stimulator/recording device was used to provide precise impulse delivery and MEP measurements (Neurosign 800, Magstim Company, Whitland, Carmarthenshire).

2.3. Intra-operative assessment

Intra-operative intercostal nerve conduction studies were performed, based on the method reported by Rogers [17]. Under general anaesthetic, with the ribs and intercostal muscles exposed, a hand-held monopolar electrical nerve stimulator probe was used to excite the intercostal nerve just lateral to erector spinae. A ground electrode was placed in erector spinae muscle. A pair of recording needle electrodes, mounted 1 cm apart on a rubber-shod right-angled hand-held clamp, was inserted into the most anterior portion of the corresponding intercostal muscle, and MEPs recorded. A reference electrode was placed in serratus anterior muscle. The stimulus was increased from 3.5 mA (with a 300 μs pulse width) upto a maximum of 10 mV, until a supramaximal stimulus was achieved and then the MEP recorded. The latency between stimulus and MEP was deduced and the velocity calculated by dividing the distance between stimulating probe and recording electrodes by the latency. A nerve conduction measurement was made at each of the intercostal spaces one and two above the intercostal incision and one and two spaces below the incision. Measurements were made at four stages during the operation: (i) before the intercostal muscle space incision; (ii) after the intercostal muscle incision but before insertion of the rib retractor; (iii) following the lung or oesophageal resection just after the rib retractor was removed; (iv) after closure of the intercostal space. The surgeon was blinded to the results of the MEP measurements, although he could see whether the intercostal muscle visibly twitched or not. These measurements added 10–20 min onto the length of operation.

In order to perform these intercostal nerve conduction studies the method of anaesthesia had to be modified to reduce variations in factors that may influence nerve conduction and to prevent complete blockade of the neuromuscular junction. Core and peripheral temperatures were monitored and the patient cooled or warmed externally to maintain the intercostal nerve temperature as steady as possible. Induction of anaesthesia was performed using 1 μg/kg remifentanil bolus and 1.5–2.5 mg/kg propofol. Anaesthesia was maintained using desfluarane (1.0–1.3 minimum alveolar concentration) and an intravenous infusion of remifentanil. Relaxation was achieved using atracurium: a 0.5 mg/kg bolus followed by an infusion which was adjusted to maintain a minimum two visual twitches of adductor pollicis upon a train-of-four (TOF) stimulation of the ulnar nerve. Immediate post-op analgesia was provided by an epidural infusion of local anaesthetic and opiate or a paravertebral infusion of local anaesthetic with an intravenous morphine infusion under patient control (PCA), though no local anaesthetic was infused prior to the last nerve conduction measurement.

Operations were performed by one of three teams each led by a consultant (consultants A, B, C). For lung resections all used similar posterolateral thoracotomy skin incisions, divided latissimus dorsi muscle and approached through the 5th or 6th space. Consultants B and C always entered the pleural space through sub-periostial rib resection and closed the intercostal space with a continuous intercostal muscle suture. Consultant A entered using diathermy along the upper border of the rib, without rib resection, and closed using three interrupted sutures that ran over the upper border of the rib above and under the lower border, but above the intercostal bundle, of the rib below ('pericostal' closure). For oesophageal operations consultant B used a

Table 1
Patient characteristics and study findings

Characteristic or variable	Mean (SD) or proportion of study population
Sex (male)	70%
Age (years)	62 (13)
BMI	27.5 (4.9)
Pre-operative HADS score	8.7 (6.4)
Pre-op pain	
Score 1	0.8 (2.0)
Score 2	4.2 (9.6)
Score 3	0.4 (0.9)
Side (right)	33%
Consultant	
A	58%
B	27%
C	15%
Diagnosis	
Primary lung Ca	73%
Lung metastasis	6%
Oesophageal Ca	18%
Benign oesophageal	3%
Approach	
Thoracotomy	82%
Thoracolaparotomy	18%
Intercostal incision	
Superior border	61%
Rib resection	39%
Rib fracture present	15%
Closure technique	
Pericostal	67%
Intercostal muscle	33%
Drain size	
28FG	27%
32FG	39%
36FG	33%
Drain number	
1	18%
2	64%
3	18%
Post-op analgesia	
Epidural	88%
Paravertebral	12%
Maximum rib spread (mm)	104 (23)
Retractor time (min)	100 (43)
Total intra-operative nerve damage	
After retractor removed	47%
After closure	52%
Location of nerve injury	
Whole length of nerve	38%
At site of retractor only	62%
Analgesia use	
6 weeks post-op	56%
3 months	32%
Report numbness	
6 weeks	69%
3 months	69%
Numbness area (cm^2)	
6 weeks	92 (116)
3 months	63 (89)
Pain score 1	
6 weeks	4.5 (4.7)
3 months	3.3 (3.5)
Pain score 2	
6 weeks	13.1 (14.0)
3 months	11.0 (14.7)
Pain score 3	
6 weeks	1.1 (0.7)
3 months	0.8 (0.8)
HADS score at 3 months	7.1 (6.2)

thoracotomy incision with phrenotomy and consultants A and C used a thoracolaparotomy incision without rib resection. In each case the maximum spread of ribs at the thoracotomy and the length of time the retractor was in situ were recorded.

Patients were blinded to the results of the intra-operative nerve conduction studies.

2.4. Post-operative assessment

At the 6-week outpatient review the participants completed a SF-MPQ pain questionnaire. Their chest wall was examined at that time for pin-prick sensation around the surgical wound and drain sites. This area was marked with ink and traced onto paper where it was measured using paper marked with 1 mm and 1 cm gridlines. If patients were unable to attend the base hospital (in Nottingham) the pain questionnaire was posted to them and included a question asking them to confirm or not the presence of altered skin sensation or numbness around the scar.

At the 3-month outpatient review the pain questionnaire and examination were repeated, as was the psychological HADS questionnaire. Postal contact was made with non-attendees.

2.5. Statistics

Data analysis was performed using the SPSS statistical package. Univariate analysis was performed using Chi square (χ^2) and independent *T*-test as appropriate.

3. Results

Fifty patients were initially recruited. Seventeen were lost because of technical difficulties obtaining intra-operative readings, withdrawal of consent post-op and death. Intra-operative problems were complete neuromuscular blockade, often despite the presence of two twitches from train-of-four stimuli, patient's temperature too low, and insufficient time to complete the measurements. Data from 33 patients were analysed for inclusion in the study. Their characteristics are shown in Table 1. The pre-op pain score 2 was significantly higher than zero (mean 4.2) because this included indigestion type pain and any discomfort perceived as being caused by the cancer, such as chest 'tightness' or pleurisy. Continuous data is presented as a mean and standard deviation and categorical data as a proportion of the study group. Of the 24 patients with a primary lung carcinoma 16 had lobectomy, five pneumonectomy, two sleeve lobectomy and one was exploratory. When three drains were used, two were sized 28-36FG but the third was always a soft 19FG drain.

3.1. Pre-operative electromagnetic stimulation (magstim)

Although some excellent recordings were achieved, many recordings were not interpretable. If we had repeated the measurements on the patients post-operatively as planned we would be unable to discern that any changes in the MEPs recorded would be due to nerve damage rather than irregularities in the method of measurement. This technique was therefore abandoned.

3.2. Intra-operative intercostal nerve studies

There was no nerve damage detected after thoracotomy or thoracolaparotomy but prior to insertion of the retractor, except for a single nerve in one patient. Total intra-operative nerve damage is the proportion of all the nerves studied in all subjects that failed to conduct impulses along their length and cause intercostal muscle contraction. The number of nerves damaged after intercostal space closure for each individual shows a roughly normal distribution (Fig. 1). Conduction studies revealed nerve injury occurs either as a discrete block at the site of the retractor only, but conducts either side of this point, or fails along the whole length of the nerve. Analyses of these patterns of nerve injury were investigated by comparing these two groups, excluding those with more nerve injury after closure. Nerves damaged along their whole length ($n = 5$) are associated with significantly longer retractor times (mean 141 vs 95 min, $p = 0.04$) compared to nerves with discrete blocks ($n = 10$), though there is no association with pain scores, numbness or analgesia use. Analyses comparing those with further nerves damaged by intercostal space closure ($n = 7$) with those without such damage ($n = 25$) showed no significant association with pain scores, numbness or analgesia use. 'Numbness' represents any abnormal cutaneous sensation, not just reduced or absent sensation. Although the reported incidence of numbness at 6 weeks and 3 months is the same (18 out of 26 participants for both), the measured area of abnormal sensation in the 20 subjects who were assessed at both times generally shrinks (Fig. 2). Analgesia use and all pain scores fall with time, as did the mean HADS score.

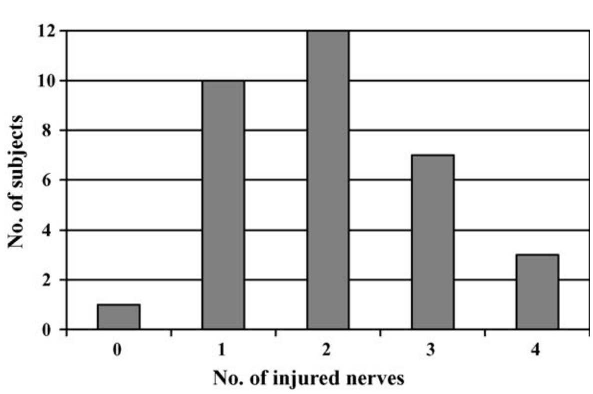

Fig. 1. The number of injured nerves after intercostal space closure.

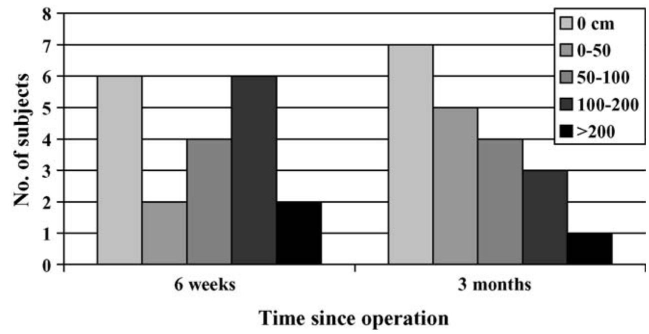

Fig. 2. Measured area of abnormal cutaneous sensation ('numbness') at 6 weeks and 3 months post-op ($n = 20$).

For investigation into the factors that may predict intercostal nerve injury analyses were performed comparing those with zero to two nerves damaged ($n = 23$) with those with three to four nerves damaged ($n = 10$). Results are expressed as means for continuous data and proportions for categorical, with p-values (significance given as $p < 0.05$) (Table 2). This shows that nerve damage is not significantly associated with most factors except for technique of closure of the intercostal space: interrupted pericostal sutures are associated with 78% of the low nerve damage group but only 40% of the high nerve damage group ($p = 0.03$). Although thoracotomy is associated with more nerve damage, this is not significant.

Analyses were performed to try to identify factors associated with chronic pain, using pain scale 3 in the SF-MPQ as the defining factor for determining the presence of chronic pain (Table 3). This shows that the presence of chronic pain is not associated with most factors including the number of injured intercostal nerves. The only factors that significantly predict chronic pain are a higher pre-op pain score 1 ($p = 0.05$) and higher 6 week post-op pain scores ($p = 0.008$, 0.001 and 0.002 for scores 1, 2 and 3, respectively). Chronic pain is also significantly associated with higher post-op HADS scores ($p = 0.008$) though not pre-op scores. There was no association between pain and the number of drains, the size of the drains or the number of intercostal spaces through which drains were placed.

Factors that may be associated with the presence of abnormal cutaneous sensation at 3 months post-op were analysed (Table 4). This shows that most factors, including the number of nerves damaged at operation, are not significantly associated with 'numbness'. However, the presence of a rib fracture is the only factor associated with an absence of numbness ($p = 0.006$) and numbness at 6 weeks post-op does predict its presence at 3 months ($p < 0.001$).

4. Discussion

The aim of this study was to explore the role of intercostal nerve injury in the development of chronic post-thoracotomy pain. The impetus was the study by Rogers et al. [17] that demonstrated intercostal nerves are damaged during thoracic procedures, though an association with subsequent chronic pain was not reported. Our study involved only elective patients since these planned operations would allow sufficient time for the patient to decide whether or not to

Table 2
Predictive factors for intra-operative nerve damage

Factor	Statistical test	Mean or proportion of group		Significance (p-value)
		Zero to two nerves damaged (n = 23)	Three to four nerves damaged (n = 10)	
Age (years)	Independent T-test	63	61	0.8
BMI	Independent T-test	27.1	28.5	0.5
Approach (thoracotomy)	χ^2	74%	100%	0.07
Intercostal incision (rib resection)	χ^2	60%	30%	0.1
Rib fracture present	χ^2	17%	10%	0.6
Max spread (mm)	Independent T-test	104	104	1.0
Retractor time (min)	Independent T-test	109	80	0.07
Closure (pericostal)	χ^2	78%	40%	0.03

participate. Our use of a pre-op pain and psychological scores allowed us to analyse whether pre-existing chest symptoms or feelings of anxiety or depession influenced the development of chronic pain.

It was disappointing that the magstim (magnetic stimulator) nerve conduction studies in this setting were not sufficiently accurate to be of practical use. The inconsistency in the readings was caused by difficulty both in locating the intercostal nerve root for stimulation and also in placement of recording electrodes for recording. Precise placement of button skin electrodes over the relevant anterior intercostal muscle was sometimes impossible because fat, breast tissue and pectoralis muscle made it difficult to identify the relevant intercostal space, which meant we were unsure whether readings were from the intercostal muscle we thought was producing the MEP or from other chest wall muscles. There was no visible twitching of individual intercostal muscles, which may have helped identify activity. Had this technique been successful it would have acted as an excellent baseline measurement prior to the influence of any anaesthetic agents, and which could have been repeated in the outpatient setting to verify and follow-up the intra-operative nerve studies.

The intra-operative studies had to rely on considerable co-operation from the anaesthetists to follow a specific protocol. There was heavy reliance on two twitches after train-of-four (TOF) stimulation of adductor pollicis to

Table 3
Predictive factors and associations for chronic pain at 3 months post-op

Factor	Statistical test	Mean or proportion of group		Significance (p-value)
		No pain (n = 15[a])	Pain (n = 16[a])	
Age (years)	Independent T-test	60	64	0.3
Sex (male)	χ^2	80%	63%	0.3
BMI	Independent T-test	26.8	28.1	0.4
Pre-op HADS score	Independent T-test	7.5	9.8	0.4
Pre-op pain				
Score 1	Independent T-test	0.1	1.7	0.05
Score 2	Independent T-test	4.0	4.9	0.8
Score 3	Independent T-test	0.2	0.7	0.2
Approach (thoracotomy)	χ^2	73%	88%	0.3
Intercostal incision (rib resection)	χ^2	27%	44%	0.3
Rib fracture present	χ^2	13%	19%	0.7
Max spread (mm)	Independent T-test	104	102	0.7
Retractor time (min)	Independent T-test	100	106	0.8
Closure (pericostal)	χ^2	80%	63%	0.3
Number of injured nerves	Independent T-test	1.9	2.1	0.6
Drain size	$\chi^{2\,b}$	–	–	0.6
Drain number	$\chi^{2\,b}$	–	–	0.4
Post-op analgesia (epidural)	χ^2	87%	88%	0.9
6 week				
Pain score 1	Independent T-test	2.2	6.7	0.008
Pain score 2	Independent T-test	4.7	21.0	0.001
Pain score 3	Independent T-test	0.7	1.5	0.002
Analgesia use	χ^2	43%	60%	0.5
Report numbness	χ^2	60%	73%	0.5
Numbness area (cm^2)	Independent T-test	75	103	0.6
3 month				
Analgesia use	χ^2	23%	40%	0.3
Numbness present	χ^2	69%	69%	1.0
HADS score	Independent T-test	4.1	9.8	0.008

[a] Data missing for two participants.
[b] χ^2 analysis with linear-by-linear association.

Table 4
Predictive factors for the presence of numbness at 3 months

Factor	Statistical test	Mean or proportion of group		Significance (p-value)
		No numbness (n = 8[a])	Numbness (n = 18[a])	
Age (years)	Independent T-test	64	59	0.4
BMI	Independent T-test	30.1	26.3	0.06
Approach (throacotomy)	χ^2	100%	72%	0.1
Intercostal incision (rib resection)	χ^2	38%	39%	0.9
Rib fracture present	χ^2	38%	0	0.006
Max spread (mm)	Independent T-test	96	108	0.2
Retractor time (min)	Independent T-test	89	109	0.2
Closure (pericostal)	χ^2	63%	72%	0.6
Number of injured nerves	Independent T-test	2.4	1.8	0.2
6 week				
Report numbness	χ^2	14%	100%	<0.001
Numbness area (cm^2)	Independent T-test	5	151	<0.001

[a] Data missing for seven participants.

estimate the degree of relaxation. However, in some cases this did not appear to be accurate: some patients had a cough reflex despite no TOF twitches, and some appeared to have complete thoracic blockade despite three or four TOF twitches. This difficulty is reflected in the high number of patients who we were unable to study. Testing the ability of the intercostal nerves to conduct impulses was limited by exposure of the ribs and intercostal muscles. Although we were confident of the function of the nerves within the surgical field, we were not able to test the more proximal or distal aspects of the nerve out of sight, which possibly get damaged through traction injury. In this way we may be underestimating the degree of nerve injury. Although some cases showed more nerves had been injured from the time the retractor was removed to the completion of intercostal space closure (six in the pericostal closure group and three in the intercostal muscle closure group), there were also some cases where the nerve conduction had recovered over the same period (two from each closure group). This may be due to the nerve injury resolving or to the waning effect of the neuromuscular relaxant. If some or all of the nerves do recover with time, which is likely, then the intra-operative studies will overestimate the degree of persisting nerve injury. Specific types of nerve injury, such as due to closure, may cause long-term damage, whereas other types may not.

Ideally as many aspects as possible of the operative technique would be controlled and some aspects randomised between groups. In this study three surgeons and their trainees were recruited, whose techniques differ, subtly or more obviously, for almost every aspect of every operation. Hence, although we have measured some aspects of the operation that could affect intercostal nerve function, there are an enormous number of unchecked variables.

The finding of two patterns of nerve injury is interesting, especially with the association with retractor time. This may represent two different mechanisms of injury: direct pressure on the nerve by the retractor causing a discreet point of trauma that is likely to develop relatively quickly, whilst traction on the nerve causes a much slower-onset injury affecting the whole nerve, probably due to ischaemia of the persistently stretched tissues. The consequences of these different patterns of injury are not clear since there are no significant associations with the outcomes we measured. The fall in analgesia use and pain scores with time was expected, as was the shrinkage in area of abnormal cutaneous sensation as adjacent healthy cutaneous sensory nerves encroached upon the damaged area.

We had expected increased BMI, thoracotomy approach, increased retractor spread and increased retractor time to all significantly increase the incidence of intercostal nerve injury, though this was not supported by our study. Although thoracotomy did appear to cause more nerve damage compared to thoracolaparotomy this was not significant. Paradoxically, increased retractor time appeared to reduce nerve injury, which the authors cannot explain. The technique used by surgeon A (diathermy along the top of the rib and use of interrupted pericostal sutures to close) appears to result in less detectable nerve injury at the time of operation and may represent a superior method. However whatever method was used nerve injury caused by closure did not affect any measured outcomes.

Although the pain scale 3 of the SF-MPQ was used to define chronic pain at 3 months, the results of analyses using the other pain scales was very similar. The study findings did not support our expectations that intercostal nerve injury would be associated with chronic pain. This may be because our intra-operative measurements were not indicative for long-term intercostal nerve injury as described above, or because some nerve injuries only cause painless numbness rather than a painful syndrome, or because there is a separate, more significant cause for chronic pain other than intercostal nerve injury. The association of chronic pain with a significantly higher pre-op pain score 1 suggests that pre-existing pain experience may increase the risk of developing post-op pain. This may be an effect of psychological conditioning or because of a sensitization of the nociceptive system at a spinal level leading to hyper-responsiveness and a phenomenon known as 'wind-up', as described by Erdek [23]. The association of chronic pain with significantly higher post-op HAD scores demonstrates the close relationship between chronic pain states and anxiety/depression, and is an expected finding. Earlier high pain scores (at 6 weeks) associated with chronic pain supports previous study findings [4]. This may be important when it comes to considering earlier treatment of post-thoracotomy pain. The equivalent incidence of numbness at 3 months for both pain and no pain groups is surprising and suggests that sensory nerve damage (at intercostal or cutaneous level) detected this way, is not associated with pain syndromes. Analysis of factors that may predict altered cutaneous sensation at 3 months again demonstrates a lack of association with our intra-operative nerve studies, which was unexpected. The lower BMI and the absence of rib fractures in the numbness group cannot be explained by the authors. This study did not attempt to measure the amount of damage to the parietal pleura, which may be a contributing factor in causing pre-operative pain due to inflammation or infiltration, and to post-operative pain caused by intra-operative trauma.

Future studies could investigate whether attempts to reduce the specific patterns of intercostal nerve damage at operation result in less chronic pain. Discrete point-pressure damage by the retractor on the nerve may be reduced by modifying retractor design to increase the area, and hence reduce the pressure, of contact with the neurovascular bundle. Whole-nerve damage due to traction injury may be reduced by regular release of the retractor after a period of time to allow the free flow of oxygenised blood through the tissues under tension.

5. Conclusion

The cause of chronic pain after thoracic surgery has not been established, though some published reports support the role of intercostal nerve damage. Our study found two distinct patterns of nerve injury and also demonstrated differences between surgical techniques. Thoracotomy with rib resection resulted in more detectable nerve damage than diathermy along the top of the rib and pericostal closure. However, intercostal nerve damage at the time of operation is not associated with chronic pain or altered cutaneous sensation at 3 months post-op, suggesting that either the amount of intra-operative nerve damage is not indicative of long-term nerve damage or that there is a more significant cause for chronic pain other than intercostal nerve injury.

Acknowledgements

Thanks to thoracic anaesthetists K. Alagesan, N. Okonkwo, R. Nicols, P. Wake, H. Skinner, M. Levitt, Chris Hovey from Magstim for lending the nerve conduction equipment and P. Choudhary in neurophysiology.

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