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INTERPLEURAL ANALGESIA

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The technique of interpleural analgesia for patients with acute or chronic pain has not yet been the subject of critical review. As there is now an extensive list of published studies of the use of this technique, it seems timely to attempt to define the place of interpleural analgesia and anaesthesia in clinical practice. This article attempts to review anatomical and pharmacological considerations, in addition to evaluating the efficacy of interpleural analgesia after different types of surgery and in chronic pain management.

BACKGROUND

Although block of the intercostal nerves is not new, interest in this technique was revived when Nunn and Slavin re-examined the anatomy of the intercostal space in cadavers [48]. These authors deduced that an injection deep to the posterior intercostal membrane would allow the injected solution to spread from the site of injection to adjacent intercostal spaces. This idea led O'Kelly and Garry to describe a technique of multiple intercostal nerve blocks using a single intercostal injection in a patient with multiple unilateral fractured ribs [49]. The first series of patients in whom this technique was used was described by Murphy in 1983 [44, 45], who used it in patients with multiple fractured ribs and in postoperative patients after gallbladder and kidney surgery. One year later, Reiestad and Kvalheim [54] published their results of continuous intercostal nerve block for postoperative pain relief and presented their modification of the technique, which is now termed "interpleural analgesia" [32].

ANATOMICAL CONSIDERATIONS

Recent studies have shown that there is considerably more variability in the anatomy of the intercostal space than is suggested in the classic textbooks of anatomy [3] and neural block [84]. Classically, the intercostal muscles are described in three layers (figs 1, 2). The external intercostal muscle originates from the tubercles and the lower borders of each rib and is directed obliquely downwards and forwards to be inserted into the upper borders of the adjacent ribs below. The internal intercostal muscle originates from the lower border of each rib and costal cartilage and is directed obliquely backwards to be inserted into the upper borders of the adjacent ribs below. The innermost layer of muscles, which corresponds to the transversus abdominis muscle in the abdomen, is composed of a group of muscles, the transversus thoracis group. The most important of these, the intercostalis intimus, runs obliquely downwards and backwards from the inner edge of the ribs to the upper borders of the adjacent ribs. Some fibres may bridge more than one intercostal space to be inserted into the 2nd or 3rd adjacent rib. The intercostal nerve is classically described as running under the shelter of the intercostal groove, and is situated below the intercostal vein and artery.

Nunn and Slavin [48] performed detailed studies in six cadavers subjected to postmortem. At the 6th intercostal space, 7 cm from the posterior midline, the ribs were found to have an average thickness of approximately 9 mm. At this point the external intercostal muscle was of variable thickness, but was well developed and bound internally by the posterior intercostal membrane—the aponeurotic extension of the internal intercostal muscle. In contrast to this sturdy membrane, the innermost intercostal muscle, the intercostalis intimus muscle was "a flimsy structure composed of several fascicles through which injected India ink passes freely to reach the subpleural space". The nerves, arteries and veins were consistently found in the tissue plane deep to the posterior intercostal membrane and superficial to the intercostalis intimus muscle, with no fixed relationships to the ribs above or below. The intercostal nerves were found to run "as three or four separate bundles with no single neural sheath" and with considerable variation in relationship to and size compared with associated intercostal arteries and veins. Studies by Hardy [26] on the anatomical variation in position of the nerves to the ribs concur with the findings of Nunn and Slavin. In 30 cadavers, the 2nd to 11th intercostal nerves were dissected and were found to occupy the classically described subcostal position in only 17% of cases.

As the intercostal nerves were found consistently to occupy the tissue plane deep to the posterior intercostal membrane and superficial to the intercostalis intimus muscle, initial attempts at con-

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KEY WORDS

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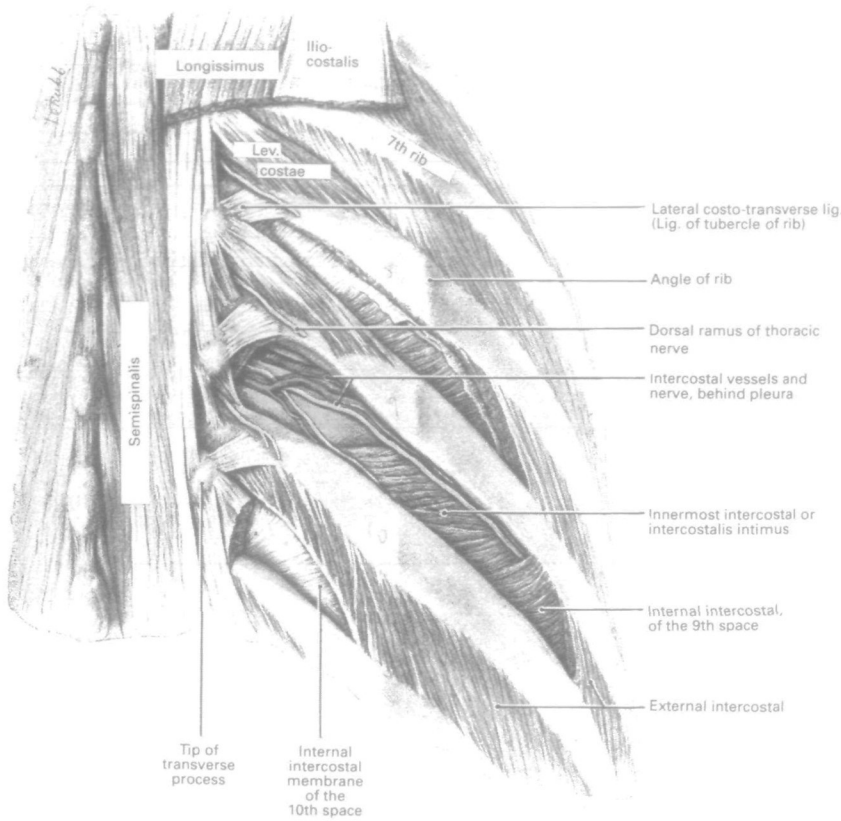

FIG. 1. Posterior end of intercostal space.

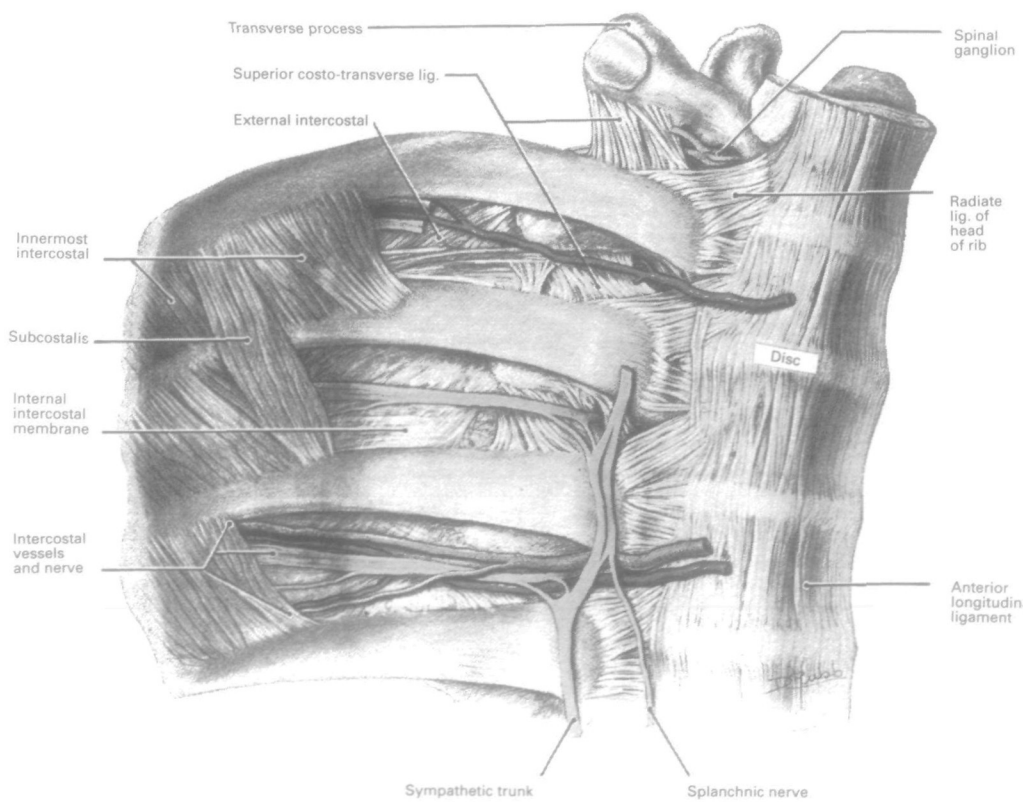

FIG. 2. Vertebral end of intercostal space.

tinuous intercostal nerve block were directed at location of this tissue plane and assessment of the degree of spread of solutions injected into this space. In a study in cadavers, Murphy [46] infused India ink through an extradural catheter inserted into this tissue plane and examined the spread of the ink within the chest cavity after removal of the thoracic viscera. It was found that "by pushing the parietal

pleura forward, the dye spread easily, sub-pleurally, to reach intercostal spaces above and below the one cannulated". In only 50% of the examinations did the ink spread medially to reach the paravertebral space. Similar results were found by Crossley and Hosie [14], who radiographically mapped the spread of iopamidol with lignocaine in 10 healthy volunteers. In contrast, Mowbray, Wong and Murray [42] found that spread of methylene blue into the paravertebral space occurred almost invariably and they believe that it is by this means that analgesia can extend over several dermatomes.

Few investigators have attempted to elucidate the mechanism of action of local anaesthetic agents injected between the parietal and visceral pleura. Studies in dogs [60] using somatosensory evoked potentials indicated that interpleural bupivacaine produces gravity-dependent intercostal nerve block, with no evidence of spinal or extradural block. Studies by Stromskag, Hauge and Steen [78], using computed tomography in patients receiving interpleural analgesia after different types of surgery, are in agreement with these findings. They suggested that interpleural local anaesthetics act by retrograde diffusion to reach the intercostal nerves.

TECHNIQUE OF CONTINUOUS INTERPLEURAL ANALGESIA

The principle of the technique is to deposit the local anaesthetic drug in a tissue plane which allows it to reach several intercostal nerves after a single injection. Two such tissue planes are available for this purpose: the tissue plane deep to the internal intercostal muscle but superficial to the parietal pleura, and that between the parietal and visceral layers of pleura.

Cannulation of the tissue plane deep to the internal intercostal muscle was described first, but this plane is more difficult to locate because of a lack of precise end-point for its determination. In this technique, a Tuohy needle is inserted with the bevel pointed medially within 7–8 cm of the spinous process. Location of the plane relies on insertion of the needle 5–8 mm deep to the rib. A characteristic "pop" may be felt as the aponeurosis is pierced. Passage of an extradural catheter into this space may be facilitated by directing the needle at a slight angle toward the midline. The catheter may be inserted 3–5 cm within this tissue plane with ease.

Cannulation of the tissue plane between the parietal and visceral pleura is accomplished in a similar manner and in a similar location, although the mid-axillary line also has been used [6]. When the posterior intercostal membrane is pierced, the trocar of the Tuohy needle is removed and a freely moving air-filled glass syringe is attached to the hub of the needle. The needle is then advanced using a "loss of resistance to air" technique until the pleural cavity is located. The extradural catheter is then inserted 5–6 cm [59]. Modifications to this technique have been described which aim to reduce the potential for air entrainment into the pleural cavity. These include use of a "hanging drop technique" [76] and use of a fluid-filled syringe to detect negative pleural pressure [71, 89]. The catheter may also be inserted by the surgeon during operation when appropriate [38, 64, 65].

TAXONOMY

Because the techniques of intercostal and interpleural analgesia, as described above, do not differ in their proposed mode of action, the term "interpleural analgesia" is used henceforth to describe both approaches.

The terms "interpleural" and 'intrapleural" have been used interchangeably to describe the space between the parietal and visceral pleura into which local anaesthetic is deposited. Covino [13] suggested that the term "interpleural" be used because "the catheter is located and the local anaesthetic solution deposited between the two layers of pleura rather than within the pleura". As pointed out by other authors, however, "parietal and visceral pleura are continuous around the hilar structures and the right and left pleural sacs are distinct. Therefore, an injection of local anaesthetic through a needle that has penetrated the parietal membrane, but not the visceral membrane, is intrapleural" [39]. It has been suggested that both prefixes be eliminated in the interest of simplicity and that the technique be described as "pleural block" [4]. In the absence of a consensus, the more common term of "interpleural analgesia" is used here.

CLINICAL STUDIES

The indications for which interpleural analgesia has been used are listed on table I. Most clinical studies have been performed in patients recovering from gallbladder or thoracic surgery. Less frequently, this technique has been used for pain relief in patients with multiple fractured ribs. Other indications are uncommon.

Pain relief after cholecystectomy

Studies in patients after cholecystectomy have consistently shown interpleural analgesia to be effective [7, 18, 21, 22, 30, 33, 34, 44, 45, 50, 59, 70, 80, 81, 87]. In a study by Murphy [44] of patients receiving 0.5% bupivacaine 20 ml as required after cholecystectomy, 92% and 76% required no other supplementary analgesia in the first 24 and 48 h after surgery, respectively. Development of tachyphylaxis was the indication for opioid supplementation in

TABLE I. *Indications for interpleural analgesia*

Postoperative analgesia
Cholecystectomy [7, 18, 21, 33, 34, 44, 48, 59, 81, 87]
Thoracic surgery [28, 36, 38, 42, 43, 62, 63, 65, 67]
Renal surgery [32, 45, 55, 59, 82, 85]
Breast surgery [55, 59, 69]
Cardiac surgery [5, 6]
Abdominal surgery [17, 35]
Multiple fractured ribs [25, 45, 49, 61]
Cancer pain management [15, 16, 20, 58]
Acute herpes zoster [27]
Post-herpetic neuralgia [56, 58, 74, 75]
Pain in chronic pancreatitis [1, 58, 75]
Reflex sympathetic dystrophy [57]
Upper limb ischaemia [53]

most subjects. The mean duration of action of bupivacaine in this study was approximately 7 h.

VadeBoncouer and colleagues [87] compared interpleural bupivacaine with interpleural saline in a study of patients also receiving morphine via a patient controlled analgesia (PCA) device. On the first day after operation these patients received a single injection of 0.5% bupivacaine 20 ml with adrenaline or 0.9% saline 20 ml by random allocation. Their PCA morphine requirements were then evaluated over the succeeding 6 h. Patients receiving interpleural bupivacaine required significantly less morphine during this period compared with patients receiving saline. A similar reduction in PCA morphine requirement was found by Lee and colleagues [34], who administered interpleural bupivacaine or saline 4-hourly for 24 h. The mean morphine requirements over this period were 21.6 mg and 72.4 mg, respectively.

In a comparison of 0.25%, 0.375% and 0.5% bupivacaine with adrenaline in patients after cholecystectomy, Stromskag and colleagues [81] found the quality of analgesia to be consistently good in all groups. The mean visual analogue pain score did not exceed 20 mm (0–100 mm scale) for all groups up to 4 h after injection. The duration of action was very variable, however (range 2–18 h). In comparing different volumes of interpleural bupivacaine, Stromskag, Minor and Lindeberg [80] found that 0.5% bupivacaine 20 ml was similar in effect to 0.25% bupivacaine 40 ml.

Laurito and colleagues [33] compared a continuous infusion of interpleural 0.25% bupivacaine 0.125 ml kg^{-1} h^{-1} with intermittent bolus doses of 0.5% bupivacaine 0.4 ml kg^{-1} and found the infusion to provide better pain relief.

Pain relief after thoracotomy

Although the benefits of interpleural analgesia after cholecystectomy have been demonstrated consistently, studies on its use after thoracotomy have been inconclusive. McIlvaine and colleagues [37, 38] reported the use of this technique in 14 children in whom interpleural catheters were inserted before chest closure and a continuous interpleural infusion of 0.25% bupivacaine with adrenaline 0.5–1 ml kg^{-1} h^{-1} was used; opioid analgesia was available as required. These authors found that interpleural analgesia was effective as demonstrated by low observer pain scores and by a lack of requirement for opioid supplementation. Similar benefits were found in adults by several other authors [28, 36, 43, 62, 64, 65, 67, 73, 83]. Variations from the technique of interpleural catheter insertion and local anaesthetic administration were used in these studies, however. Sabanathan and colleagues [65] described insertion of the catheter into the paravertebral space by the surgeon using direct vision, whereas Lee and Abram [36] used the indwelling pleural drainage catheter to instil the local anaesthetic after operation.

Several authors have found that interpleural analgesia is inadequate after thoracotomy. Rosenberg and colleagues [63] administered a bolus of 0.5% plain bupivacaine 15–20 ml followed by a continuous infusion of 0.25% bupivacaine to 14 patients after thoracotomy and prescribed i.m. oxycodone as required. They found that all patients required oxycodone in doses which did not differ significantly from those not receiving interpleural analgesia in their previous studies. Additionally, they found that much of the instilled bupivacaine was lost in the drainage tubing. In a subsequent study of 20 patients [68], this group prevented loss of bupivacaine by clamping the drainage tubes, but found little advantage in comparison with i.m. oxycodone alone. Ferrante and colleagues [19] found that 30–40% of administered bupivacaine was lost via the drainage tube, resulting in inadequate analgesia after thoracotomy.

It is well recognized that regional analgesia techniques may not be completely effective after thoracotomy and some post-thoracotomy pain has been attributed to other causes such as diaphragmatic irritation and scapular retraction [12]. This has been found for extradural analgesia and may also explain the inadequacy of interpleural analgesia in these patients.

Pain relief after renal surgery

Interpleural analgesia has been used successfully for percutaneous nephrostomy and nephrolithotomy, for extracorporeal shock wave lithotripsy (ESWL) and for pain management after open renal surgery. Trivedi, Robalino and Shevde [85] described four patients in whom interpleural analgesia (0.5% bupivacaine 30 ml) was used without the need of supplementary sedative or analgesic drugs for nephrostomy and subsequent nephrolithotomy. Stromskag and Steen [82] reported the use of interpleural analgesia for ESWL in comparison with extradural analgesia. By random sequence 10 patients each received interpleural analgesia (2% lignocaine 20 ml) or lumbar extradural 1.3% mepivacaine 22–25 ml. In addition, both groups received fentanyl and diazepam during operation, as required. Pain was significantly greater in patients receiving interpleural analgesia at 15 and 30 min after the start of ESWL, but not at completion or 2 h later. Patients receiving interpleural analgesia required significantly more fentanyl than the extradural group.

Murphy [45] used interpleural analgesia after nephrectomy, but found that it was inadequate in four of the eight patients studied. It was felt that the posterior extension of the operative scar might have contributed to the inadequacy of the block, in addition to surgical drainage tubes being inserted at some distance from the operative site. No such problems were mentioned by Reiestad and Stromskag [59] in the original description of the technique in 25 renal surgery patients, or in the original abstract by Kvalheim and Reiestad [32] which included results from 10 renal surgery patients. These authors noted, however, that no supplementary analgesia was required in their patients.

Pain relief after other types of surgery

In addition to its use after cholecystectomy, thoracotomy and renal surgery, interpleural analgesia has been used after breast, cardiac and upper

abdominal surgery. Schlesinger and colleagues [69] reported the use of interpleural analgesia as the sole anaesthetic technique for mammography during needle localization and for subsequent breast biopsy. Analgesia using this technique was adequate for surgery and no supplementary analgesia was required. Pain in the non-anaesthetized contralateral breast during its compression from mammography was greater in each case. Reiestad and McIlvaine [55] have also reported unilateral block of intercostal nerves (1st to 9th thoracic nerves), with complete skin anaesthesia sufficient for surgery to the breast. They recommended placing the patient in the lateral decubitus position with the affected side down and with a head-down tilt of 20° for 30 min after injection of the local anaesthetic.

Baxter and colleagues [6] compared interpleural analgesia in patients after cardiac surgery with a similar patient group receiving i.v. opioids. In these patients, interpleural catheters were inserted bilaterally and 0.25 % bupivacaine 20 ml was instilled into each catheter every 6 h as required. Patients receiving interpleural analgesia recorded significantly smaller pain scores throughout the study, although the duration of analgesia was quite variable (requirement for injections ranged from one to four per day). Bilateral interpleural analgesia has also been described for pain relief after midline upper abdominal surgery [17, 35].

Pain relief for multiple fractured ribs

Interpleural analgesia is extremely effective in patients with multiple unilateral fractured ribs [25, 45, 49, 61]. The first use of interpleural analgesia was in a patient with five unilateral fractured ribs who achieved 8 h of pain relief from the first bolus of 0.5 % plain bupivacaine 20 ml [49]. Subsequent injections gave relief of similar duration. Murphy [45] used this technique in 16 patients and found the duration of action was 8–12 h, with some patients requiring "top-ups" as infrequently as 18–24 hourly. Rocco and colleagues [61] achieved complete pain relief in nine patients with four to eight unilateral rib fractures, using either regular top-ups or a continuous infusion of bupivacaine.

Other indications for interpleural analgesia

Interpleural analgesia has been used in several uncommon situations, including management of cancer pain [15, 16, 20, 58], symptomatic management of acute herpes zoster [27] and in post-herpetic neuralgia [56, 58, 74, 75], pain management in chronic pancreatitis [1, 58, 75], reflex sympathetic dystrophy [57] and in the treatment of upper limb ischaemia [52]. In addition, interpleural analgesia has been advocated in situations in which other forms of pain management have been considered less desirable, such as in patients with cystic fibrosis [9] and in a patient with multiple rib fractures and a serious head injury [25].

Comparison of interpleural analgesia with other methods of pain relief

There have been few controlled studies comparing interpleural analgesia with other forms of analgesia. Kastrissios and colleagues [29] compared interpleural analgesia with an i.v. infusion of pethidine in patients after cholecystectomy. Patients receiving interpleural analgesia received 0.5 % bupivacaine 20 ml with adrenaline 1:200000, followed by a continuous infusion of 0.25 % bupivacaine 8 ml h^{-1} without adrenaline and an additional 0.5 % bupivacaine 20 ml with adrenaline after 5 h. The second group received pethidine 20–30 mg h^{-1}. Interpleural analgesia was associated with fewer side effects and with earlier mobilization, although the pain scores were similar for the two groups. Baxter and colleagues [6] used bilateral interpleural analgesia infusions in patients after cardiac surgery and found consistently smaller pain scores compared with patients receiving i.v. opioid. In contrast, Scheinin, Lindgren and Rosenberg [68] found that interpleural analgesia in patients after thoracotomy was no better than i.m. oxycodone.

Comparing interpleural local anaesthesia with interpleural saline after cholecystectomy in patients also receiving PCA morphine, Lee and colleagues [34] found a significant reduction in opioid requirement in the patients receiving local anaesthesia. In similar studies, VadeBoncouer and colleagues [87] and Mozell and colleagues [43] achieved similar results. In comparison with extradural local anaesthetic for pain relief after cholecystectomy, Scott and colleagues [70] found that extradural local anaesthesia was similar to interpleural analgesia for pain relief, pulmonary function and stress response to surgery. Stenseth and colleagues [77] found that extradural local anaesthesia was better than interpleural analgesia in a similar group. Stromskag and Steen [82] found that extradural lignocaine provided better operating conditions than interpleural analgesia for ESWL. Results obtained by Van Kleef, Burm and Vletter [88], who compared interpleural analgesia with multiple intercostal blocks in patients after gallbladder or renal surgery, showed that interpleural analgesia was of shorter duration, less reliable and associated with greater plasma concentrations of bupivacaine for a similar total dose.

Complications of interpleural analgesia

Complications of interpleural analgesia have been reviewed by Stromskag, Minor and Steen [79]. A total of 703 cases were included from 57 original articles and published abstracts. The most commonly registered complication was pneumothorax. This was documented in 14 patients. However, the authors cautioned against attempts to deduce the possible frequency of pneumothorax as, in many studies, chest x-ray findings were not reported, which makes interpretation impossible.

Evidence of unilateral sympathetic block after interpleural analgesia has been reported frequently [8, 38, 41, 51, 57, 74]. In most cases this was evident as a Horner's syndrome, and resolved without treatment. This unilateral sympathetic block has been used therapeutically by several authors [51, 57, 74]. Reiestad and colleagues [57] reported the use of interpleural analgesia in seven patients with reflex sympathetic dystrophy of the upper extremity. Using 0.5 % bupivacaine 30 ml with

adrenaline, these authors reliably induced a profound sympathetic block by positioning the patient in a 20° head-down, lateral decubitus position with the affected side uppermost. Sympathetic block was confirmed by a Horner's syndrome, increase in skin temperature of the affected side and reduced sweating (cobalt blue filter paper test). Sihota and Holmblad [74] used the same technique in the management of post-herpetic neuralgia.

Isolated case reports have been published of other complications, including massive chest wall haematoma in a patient after cardiac surgery (using a modified technique for interpleural analgesia) [5], pleural effusion (which did not require surgical drainage) [47], catheter misplacement [24] and seizure activity in a patient under general anaesthesia [72]. Increased plasma concentrations and systemic toxicity from local anaesthesia have also been reported (see below).

PHARMACOLOGY

Plasma concentrations of local anaesthetic drugs after interpleural analgesia

There is great difficulty in interpreting the significance of plasma concentrations of local anaesthetic drugs after regional anaesthesia [86]. For this reason, many authors have measured plasma concentrations of lignocaine and bupivacaine after interpleural analgesia without any attempt at correlation with clinical response [2, 10, 23, 31, 36, 38, 40, 63, 66, 67, 72, 81, 88]. The estimated threshold plasma concentrations associated with the onset of CNS toxicity for lignocaine and bupivacaine are usually quoted at 5–10 $\mu g\ ml^{-1}$ and 2–4 $\mu g\ ml^{-1}$, respectively [86]. It may be, however, that the rate of change in plasma concentration is more important in determining clinical toxicity than the absolute blood concentrations [50]. For this reason, most authors evaluating interpleural analgesia have concentrated on determination of the peak plasma concentration (*C*max) and the time to reach this concentration (*t*Cmax). Many authors measured plasma concentrations in venous blood. Mogg and colleagues [40] compared arterial with venous plasma concentrations of bupivacaine after interpleural analgesia and showed that a 20% variation occurred between the two routes. *C*max for arterial samples was 1.9 (SD 0.36) $\mu g\ ml^{-1}$ and was attained at 22 (10) min. Venous *C*max was 1.65 (+0.48) $\mu g\ ml^{-1}$ at 25 (10) min. Van Kleef, Burm and Vletter [88] observed a difference of 10% variation between arterial and venous samples.

As might be expected, *C*max increased with increasing dose of local anaesthetic. Stromskag and colleagues [81] compared arterial plasma concentrations in three groups of 10 patients receiving 0.25%, 0.375% or 0.5% bupivacaine 20 ml with adrenaline. *C*max was 0.62 (0.25) $\mu g\ ml^{-1}$, 0.82 (0.4) $\mu g\ ml^{-1}$ and 1.2 (0.44) $\mu g\ ml^{-1}$, respectively, all peak concentrations occurring at approximately 15 min after injection. The influence of volume of a given dose has been studied for lignocaine by Kuhlman and colleagues [31]. These authors administered 2% or 0.5% lignocaine 2 $mg\ kg^{-1}$ with adrenaline. Venous blood samples reached *C*max 0.97 (0.46) $\mu g\ ml^{-1}$ and 0.52 (0.28) $\mu g\ ml^{-1}$; *t*Cmax was 34 (13) min and 48 (14) min for the 2% and 0.5% concentrations, respectively.

Most authors used local anaesthetic with adrenaline, with the expectation of reducing the rate of drug absorption. Gin and colleagues [23] examined the effect of addition of adrenaline to the bupivacaine solution and confirmed that the peak plasma concentration was smaller (venous *C*max 2.57 $\mu g\ ml^{-1}$ compared with 3.22 $\mu g\ ml^{-1}$) and the time to reach this peak, longer (*t*Cmax 25 min compared with 15 min) with addition of adrenaline. There was no difference in total body clearance, apparent volume of distribution or elimination half-life between the two groups. Rademaker and colleagues [53] showed no such difference associated with addition of adrenaline.

After the commonly used dose of 0.5% bupivacaine 20 ml with adrenaline, the maximum arterial concentration of bupivacaine may be expected to be approximately 2 $\mu g\ ml^{-1}$ within 15–20 min of injection and may be expected to increase with administration of repeated doses or with use of a continuous infusion [63, 67]. Despite the large concentrations attained in some patients, clinical toxicity is rarely described in these patients. Only one instance of seizure activity has been reported [72]. This occurred when the first dose of bupivacaine was injected to a patient after cholecystectomy. The extradural catheter was inserted at termination of surgery. Five millilitre of straw-coloured fluid was aspirated through the catheter, but as no further fluid could be obtained, bupivacaine was injected. Within 1 min of the bupivacaine injection (0.5% bupivacaine 30 ml with 1:100000 adrenaline over 2-min), seizure activity was noted in the head and neck region of the patient, who remained under general anaesthesia. Cardiovascular depression did not occur, but awakening was noted to be prolonged. A maximum venous concentration of bupivacaine 4.9 $\mu g\ ml^{-1}$ was found 5 min after injection of bupivacaine. The authors felt that the pleura may have been inflamed after a recent pneumonia and contributed to rapid systemic absorption.

Effect on pulmonary function

Few authors have attempted to determine the effect of interpleural analgesia on postoperative pulmonary function. Murphy [44], using intermittent doses of bupivacaine after cholecystectomy, measured peak expiratory flow (using a Wrights spirometer) on the first day after operation when the patients requested analgesia. Thereafter, the interpleural bupivacaine was administered and peak flow remeasured 30–40 min later. Peak flow after top-up (212 (19) litre min^{-1}) was significantly greater than that before top-up (154 (14) litre min^{-1}) ($P < 0.01$).

VadeBoncouer and colleagues [87] measured FEV_1 and FVC on the first day after operation before and 1 h after an interpleural injection of bupivacaine or saline. FEV_1 and FVC in patients receiving bupivacaine were significantly greater 1 h after administration of bupivacaine. Patients receiving saline showed no significant change in these measurements.

Chan and colleagues [11] achieved similar results comparing 6-hourly bolus doses of bupivacaine or saline. In contrast, Oxorn and Whatley [50] found that i.m. pethidine was better than interpleural analgesia with regard to pulmonary function.

CONCLUSIONS

Interpleural analgesia is clearly effective in patients after open cholecystectomy and in patients with multiple unilateral fractured ribs. In these situations, interpleural analgesia consistently provides high quality analgesia with few adverse effects and may be recommended as a safe alternative to thoracic extradural analgesia. The same consistency of effect has not been found for interpleural analgesia after thoracotomy. It is possible that variations in the technique used may be responsible for the disparity in results. Some authors attempt to place the extradural catheter in the tissue plane superficial to the parietal pleura, close to or in the paravertebral space. In this situation, perhaps less local anaesthetic is lost through thoracic drainage tubes and contributes to a more effective block. Interpleural analgesia has been used in other painful conditions for acute and chronic pain management with good effect, but these indications are relatively rare. Insufficient data are available to allow adequate comparison with other forms of analgesia.

Systemic absorption of bupivacaine from the pleural cavity may be sufficient to produce large plasma concentrations of bupivacaine, especially if given as a continuous infusion over 2 days or more. The correlation between plasma concentration and clinical effect is poor, however, and little useful information can be derived from plasma bupivacaine sampling. Clinical signs of toxicity have rarely been reported for interpleural analgesia.

Several variations on the technique of interpleural analgesia are described, but there appears to be little to choose between them. The effect in each case is thought to be the result of neuronal block at or lateral to the paravertebral space. There is a possibility of some extradural spread. Adverse effects are uncommon; in particular, pneumothorax does not appear to be a significant problem, but the true incidence of this complication is unknown.

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