Intercostal nerve blockade, performed by multiple injections to adjacent intercostal spaces, has an established role in providing analgesia over an extensive field for upper abdominal and thoracic surgery. Recently, a number of authors have reported the successful maintenance of intercostal blockade over a prolonged period by the insertion of a catheter to a single intercostal space and repeated "top-up" injections using large volumes of local anaesthetic. In this way, anaesthesia has been maintained for up to 4 days in a patient with multiple rib fractures (O'Kelly and Garry, 1981), and over a period of 48 h in patients recovering from cholecystectomy (Murphy, 1983).

The interest in this technique has stemmed from the report of Nunn and Slavin (1980) that India ink, injected at the posterior angle of the rib in cadavers, spread through the flimsy substance of the intercostalis intima muscle to gain access to an extrapleural potential space and, hence, to the neurovascular bundles of intercostal spaces adjacent to that injected. This result has been confirmed directly by Murphy (1984), but has been disputed in radiographic studies in patients, and in cadaver studies using both ink and latex to define the space injected (Moore, Bush and Scurlock, 1980; Moore, 1981), and the debate about the route of spread of local anaesthetic solutions in the intercostal space continues (Moore, 1985; Murphy, 1985).

We have attempted to resolve this controversy by performing a radiographic study, in healthy volunteers, of the spread which occurs when a local anaesthetic solution is injected via a catheter to the intercostal space. Some of these results have been presented to the Anaesthetic Research Society (Hosie and Crossley, 1986).

**SUMMARY**

The spread of solutions injected to the intercostal space was studied in 10 healthy volunteers. Up to 20 ml of a 50:50 mixture of local anaesthetic solution and a radiopaque dye was injected through a modified extradural catheter placed in an intercostal space at the posterior angle of the rib. Radiographic films demonstrated spread by an extrapleural route into adjacent intercostal spaces and this was confirmed by the occurrence of analgesia in the corresponding dermatomes. The relevance of these results to clinical practice is discussed.
manner at the posterior angle of the rib, by advancing a 23-gauge needle off the lower border of the rib into the intercostal space perpendicular to the skin, and subsequently injecting 1% lignocaine 2 ml. The muscles and skin overlying the space were anaesthetized by infiltration as the needle was withdrawn. This procedure established a "safe" depth, to which a Tuohy needle was advanced into the space using the same perpendicular approach. The bevel of the Tuohy needle was directed laterally and an 18-gauge radiopaque extradural catheter (Portex Minipack) was inserted to the intercostal space until a 3-5 cm length was beyond the skin. In successfully placed catheters, moderate resistance to insertion was experienced. In some subjects difficulty was encountered in accurately identifying the 7th intercostal space, and the catheter was inadvertently inserted to an adjacent space. The consistency with which the target space was achieved improved as the study progressed.

After insertion of the catheter, the subjects were taken to the radiology department where a total of 20 ml of a 1:1 mixture of iopamidol (Niopam 300) and 2% lignocaine with adrenaline 1:200 000 was injected through the catheter in increments of 5 ml, 5 ml and 10 ml, with the subject standing. Two minutes after each increment, a posteroanterior chest x-ray was obtained, and after the final increment a lateral chest x-ray was taken. In some subjects, a lateral decubitus film was also obtained. No subject required a total of more than five films.

After administration of the final increment of anaesthetic with dye, arterial pressure and heart rate were recorded at regular intervals. The developing analgesia was determined by pin-prick and recorded on a dermatomal map.

A consultant radiologist reviewed the posteroanterior and lateral chest radiographs taken after the final increment and predicted the extent of the analgesia obtained from the observed distribution of the contrast medium. She was unaware of the analgesia obtained in each subject, and was asked to assume that all areas between the upper and lower extents of the dye observed would be analgesic. The radiologist also gave advice on the interpretation of the lateral decubitus films.

RESULTS
The results of the nine successful blocks performed are summarized in table I. Following

<table>
<thead>
<tr>
<th>Subject</th>
<th>Type of spread</th>
<th>Catheter position</th>
<th>Analgesia obtained</th>
<th>Analgesia predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Extrapleural + paravertebral</td>
<td>T8</td>
<td>T8-T10</td>
<td>T8-T10</td>
</tr>
<tr>
<td>2</td>
<td>Extrapleural + paravertebral</td>
<td>T9</td>
<td>T8-T11</td>
<td>T8-T10</td>
</tr>
<tr>
<td>3</td>
<td>Extrapleural + paravertebral</td>
<td>T8</td>
<td>T7-T10</td>
<td>T7-T10</td>
</tr>
<tr>
<td>4</td>
<td>Extrapleural + paravertebral</td>
<td>T7</td>
<td>T6-T10</td>
<td>T6-T10</td>
</tr>
<tr>
<td>5</td>
<td>Extrapleural + paravertebral</td>
<td>T8</td>
<td>T6-T9</td>
<td>T7-T10</td>
</tr>
<tr>
<td>6</td>
<td>Extrapleural alone</td>
<td>T8</td>
<td>T8-T11</td>
<td>T7-T10</td>
</tr>
<tr>
<td>7</td>
<td>Extrapleural alone</td>
<td>T7</td>
<td>T5-T8</td>
<td>T6-T8</td>
</tr>
<tr>
<td>8</td>
<td>Paravertebral alone</td>
<td>T6</td>
<td>T5-T8</td>
<td>T6-T8</td>
</tr>
<tr>
<td>9</td>
<td>Paravertebral alone</td>
<td>T4</td>
<td>T4-T8</td>
<td>T5-T7</td>
</tr>
</tbody>
</table>

Fig. 1. An erect posteroanterior chest radiograph of a female subject following intercostal catheterization and the injection of 5 ml of the local anaesthetic-dye mixture. The catheter can be seen entering the right 9th intercostal space, and contrast is seen around the tip of the catheter and extending horizontally through the intercostal space.
INTERCOSTAL NERVE BLOCKADE

Fig. 2. An erect posteroanterior chest radiograph of the same subject as in figure 1, following the injection of 20 ml of the local anaesthetic–dye mixture. Contrast now extends medially through the 9th intercostal space to the paravertebral space, and further contrast is visible in the right costophrenic angle (arrows). Since the appearance of the accumulation at the costophrenic angle did not change on lateral decubitus films, this appearance was taken as indicating extrapleural spread.

the injection of 5 ml of the local anaesthetic–dye mixture, the dye was confined to the intercostal space catheterized in all nine subjects (fig. 1). Injection of 20 ml of the mixture produced a distinctly different radiographic appearance, as reported below.

Radiological appearance

In five of the nine subjects, evidence was obtained of two routes of spread of the contrast and local anaesthetic mixture. In all five, dye was seen to have spread medially from the catheter tip along the intercostal space injected, reaching the paravertebral space in two subjects. Dye was also seen commonly in adjacent intercostal spaces, spreading in the same horizontal plane. A further accumulation of contrast was seen in the right costophrenic angle in all five subjects (fig. 2).

Fig. 3. An erect posteroanterior chest radiograph of a male subject following intercostal catheterization and injection of 20 ml of the local anaesthetic–dye mixture. The catheter tip is in the right 7th intercostal space, and is surrounded by a discrete mass of contrast medium, overlying the 7th and 8th intercostal spaces. There is no evidence of spread towards the paravertebral space, nor of contrast in the right costophrenic angle.

Lateral decubitus films taken in these subjects demonstrated that the pool of dye in the costophrenic angle was confined in an extrapleural space, since it was unaltered by posture. This appearance was taken as direct evidence of an extrapleural route of spread.

In another two of the nine subjects, contrast was seen around the catheter tip, and in one of these also in the costophrenic angle. In the second, the dye formed a discrete circular mass (fig. 3), and the lateral chest radiograph provided a dramatic demonstration of the extrapleural route of spread (fig. 4). In this film, the bolus of contrast could be clearly seen to be lifting the pleura off a
number of adjacent ribs. Neither of these subjects showed any evidence of lateral or medial spread through the space catheterized.

In the two remaining subjects, contrast was observed only within the intercostal space injected, spreading medially to reach the paravertebral space. In these subjects, no evidence of extrapleural spread was obtained.

In three of our 10 subjects, initial attempts to catheterize the intercostal space failed. In two of these subjects, a subsequent attempt was successful. No attempt was made to repeat the third. All of the misplaced catheters were placed superficially in the muscles of the back, and the radiographic appearance associated with this is distinct (fig. 5). In these films, contrast is seen to be distributed in a vertical plane, with a typical striated appearance. No dye is seen lying horizontally in the intercostal space.

Analgesia

Analgesia typically extended over four adjacent dermatomes, to either side of the intercostal space catheterized. The onset of analgesia occurred within 5–15 min of the final increment, and its duration was 1–2 h.

Table I shows the analgesia obtained compared with that predicted by the radiologist. Calculation of Spearman’s Rank Correlation Coefficient for these data yielded a value of $r_s = 0.91$ ($P < 0.01$).

Complications

No major complications of the technique were observed. One subject suffered a temporary
neuritis within the distribution of the space catheterized, comprising an area of numbness and paraesthesia over the costal margin, and tenderness over the site of injection. This resolved completely and spontaneously over a period of 3 weeks. Two other subjects experienced transient light-headedness following the injection of lignocaine, without cardiovascular disturbance.

**DISCUSSION**

We have shown, using a radiographic method in healthy volunteers, that solutions injected to the intercostal space at the posterior angle of the rib spread by an extrapleural route to reach adjacent intercostal spaces. In most subjects there was also evidence of horizontal spread within the intercostal space towards the paravertebral space. These results clearly support the observations of Nunn and Slavin (1980) and Murphy (1984), who reported that solutions injected to the intercostal space reached an extrapleural space by passing through the flimsy substance of the intercostalis intima muscle.

It has been disputed that extrapleural spread of local anaesthetic solution occurs, on the basis of studies in which small volumes have been injected to the intercostal space (Moore, Bush and Scurlock, 1980; Moore, 1981). In the present study, we observed that, with small volumes such as 5 ml, spread as determined on the posteroanterior chest radiograph, is almost always confined to the intercostal space injected. Without the injection of further increments, our results may have resembled those of Moore, Bush and Scurlock (1980).

Unlike Johansson and Colleagues (1985) and Murphy (1983), who used the technique to provide analgesia after cholecystectomy, we experienced no difficulty in mapping analgesia by pin-prick in those volunteers in whom the catheter was correctly placed. A number of factors may explain this. All our volunteers were medically qualified, and so were familiar with the concept of mapping analgesia, whereas patients undoubtedly experience painful sensations originating from areas not covered by the block, such as the extreme ends of the wound, and visceral afferents. However, we were unable to map analgesia in those in whom the catheter was found to be lying superficial to the intercostal space, suggesting that correct placement of the catheter is a major factor.

The distinct "tug" felt as the tip of the Tuohy needle pierces the posterior intercostal membrane has been suggested to be a sign of successful catheterization of the intercostal space (O’Kelly and Garry, 1981). Our experience would lead us to regard this as an unreliable sign, since a "tug" was felt in each of the unsuccessful attempts, as the Tuohy needle pierced the superficial muscles of the back.

Misplacement of the catheter was the most common complication of this small series. Few other complications were observed and, unlike Moore (1985), we would consider this technique as safe as many other local and regional techniques in routine use. No pneumothorax occurred in any subject. There was no evidence that the catheter tips migrated through the pleura into the pleural cavity, as suggested by Baxter, Flynn and Jennings (1984). The transient lightheadedness that occurred in two subjects might have been caused by the rapid increase in plasma concentrations of local anaesthetic that is known to follow intercostal nerve blockade (Tucker et al., 1972; Moore et al., 1976a, b). However, no other symptoms or signs of lignocaine toxicity occurred, and there was no cardiovascular disturbance. We would agree with Murphy (1985), that the use of repeated intercostal injections for the maintenance of prolonged analgesia is more likely to result in serious complications such as pneumothorax than is the single insertion of an 18-gauge Tuohy needle and catheter. It is our usual practice when performing any local or regional anaesthetic technique to have ready the means for resuscitation, as suggested by Moore (1985).

We believe that this technique is of value for the management of postoperative pain in selected patients, and for pain resulting from multiple rib fractures. The use of an intercostal catheter allows analgesia to be maintained over a wide field for a prolonged period, avoids repeated skin puncture, and deserves further investigation in a clinical setting.

**ACKNOWLEDGEMENTS**

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