THE SPREAD OF SOLUTIONS INJECTED INTO THE EPIDURAL SPACE

A Study using Epidurograms in Patients with the Lumbosclerotic Syndrome

J. M. BURN, P. B. GUYER AND L. LANGDON

SUMMARY

Radiological evidence of the distribution of solutions in the epidural space indicates that the volume used and the site of injection are the most relevant factors, while the height of the patient is of little importance, and the rate of injection, posture, and age of the patient exert no influence. Even so, there are wide variations in spread with a given volume via the same route, and it is impossible to predict accurately the level which will be attained. Clinical improvement following epidural injection for the lumbosclerotic syndrome does not appear to be correlated with a wide dissemination of the solution used, and large volumes seem to confer no advantage. The caudal route perhaps deserves re-evaluation, though the small number in this series prevents valid conclusions being drawn.

One of the most effective methods of conservative treatment of the lumbosclerotic syndrome is by the epidural injection of a local anaesthetic solution containing steroids. However, the volume of solution used, and the route and rate of injections vary widely in different centres. It was therefore considered desirable to study radiologically the distribution of solutions injected into the epidural space, to determine what factors influence their spread, and to evaluate any correlation between the degree of spread and the clinical improvement produced. Most studies hitherto have investigated spread in terms of the resultant neurological blockade rather than the actual distribution of solutions in epidural space.

METHOD

The selection of patients, regime of treatment, and overall results of 500 cases have been reported previously (Warr et al., 1972). For the radiological investigation of this series of 56 patients, the procedure differed only in detail.

Volume. The solutions injected were either (a) 20 ml of 0.75% lignocaine, containing hydrocortisone acetate 25 mg, methyl prednisolone 80 mg, and sodium iothalamate (Conray 420) 7 ml, or (b) 40 ml of 0.75% lignocaine containing hydrocortisone acetate 25 mg, methyl prednisolone 80 mg and Conray 420, 17 ml.

Route. The lumbar route (usually L3-4) was chosen for 39 patients, in 12 of whom an epidural catheter was passed, while the caudal route was employed in 17 patients.

Position. For the caudal injections, and the lumbar ones made via an epidural catheter, the patient was in the prone position. In the remainder of the lumbar epidural patients the injection was performed in the left lateral position, and the patient turned into the prone position on completion of the injection. In 12 patients the lumbar epidural injection was made when they were 45° (or more) head up.

Rate. In 3 patients the injection was slow (i.e. longer than 90 seconds) and in 9 patients—all in the group given 20 ml via the lumbar route—the injection was divided, with a 2-minute pause between the two halves. Otherwise the injections were given as rapidly as the patients, who were conscious, could tolerate: about 1-2 ml per sec.

The patients were screened in the prone position during the injection, or on its completion, using an image intensifier. Films were taken in the antero-posterior and lateral planes to record the extent of spread.

RESULTS

Of the 56 patients in the series, 46 were men and 10 women, this disparity of the sexes being accounted for by the necessity of avoiding irradiating women of childbearing potential. Ages ranged from 21 to 69 years and heights from 150 to 190 cm. The distribution of the radiopaque solution within the epidural space has been termed the vertical spread.
and the leakage of solution through the intervertebral foramina is described as lateral spread.

Vertical spread. An epidurogram illustrating vertical spread is shown in figures 1 and 2. The extent of spread was measured (in vertebral segments) in the following four groups: 40 ml via lumbar route, 20 ml via lumbar route, 40 ml via caudal route, and 20 ml via caudal route; the results are shown in figure 3.

The introduction of 40 ml via the lumbar route resulted in extensive spread, ascending to the upper thoracic and even cervical levels, although in nearly half this group there was no descent below L5. Similarly, injection of 20 ml via the lumbar route spreads well cephalad to the mid-dorsal segments, though the mean level is low-dorsal; in over half these patients there is no spread below L5. The dotted lines represent those patients who were 45° (or more) head up, and this had no influence on caudad spread or in limiting cephalad extension. Slow or divided injections also had no effect on the degree of spread, in the few cases in which they were employed. Injection through a catheter did not result in any significant variation in the levels achieved, whether the catheter was directed cephalad or caudad. The caudal injection of 40 ml was given in only 4 cases, as it caused considerable discomfort, even if slowly performed; the highest level achieved was D7, in a patient who had had a previous laminectomy. The injection of 20 ml caudally ascended to L1 in all but 6 cases, in 4 of whom laminectomies had been carried out in the past, and in the fifth
patient considerable leakage occurred through the anterior sacral foramina (figs. 4 and 5).

The relation of the height of the patient to the vertical spread, in the 20 ml via lumbar route group, is shown in figure 6. To enable a comparison to be made, when different volumes of solution have been used, vertical spread has been expressed as a ratio obtained by dividing the volume of solution injected by the number of vertebral segments involved as seen on the X-ray. This ratio expressed in millilitres per vertebral segment (ml/seg), varies inversely with the vertical spread, so the lower its value the greater the degree of spread for a given volume. A regression line can be drawn \( y = 161.89 + 4.75x \), indicating greater spread in the shorter patient, but there is considerable scatter.

The bony capacity of the epidural space could not be assessed accurately because the cross-sectional area of the spinal canal cannot be measured. However, the transverse and AP diameters were measured
There is no statistically significant difference between these latter groups. In the 17 patients who had caudal injections 13 (76%) were improved, including 4 postlaminectomy patients; though this figure is better, the difference is not significant ($P>0.2$) compared with the results following lumbar injections.

**Lateral spread.** The lateral spread of the injected solution, shown in figure 8, was measured arbitrarily from the lateral border of the vertebral body along the axis of the nerve. The relationship of spread with age is shown in figure 9, where the number of patients in each decade with a lateral spread of $>1$ cm is compared with those having a spread of $<1$ cm, following the injection of 20 ml via the lumbar route. 80% of young patients (25–35 yr) had $>1$ cm spread; while 75% of older patients (55–
65 yr) had <1 cm lateral spread. When 40 ml was injected in the lumbar region, the lateral spread was >1 cm in every case, irrespective of age.

The 6-month follow-up showed that in the group who received 20 ml via the lumbar route (66%) of the 15 patients in whom the lateral spread had been >1 cm were improved; while 6 (54%) of the 11 patients in whom it was <1 cm showed improvement. There is no statistically significant difference between these two results (P > 0.5). In the group receiving a 40-ml injection via the lumbar route 5 (55%) of the 9 patients were improved; all had had >1 cm lateral spread. There is no statistically significant difference between these results.

![Number of Patients](image)

**FIG. 9.** Lateral spread related to age.

**DISCUSSION**

Before evaluating these results it is essential to underline the subtle but important distinction between the physical spread of a solution in the epidural space and its neuraxial spread. The former can be measured using epidurograms and radioactive tracers, but the latter is only recognized by the extent of anaesthesia resulting from injections of local anaesthetic solutions. The two are only broadly related, and are not synonymous (Shanks, 1968). Hence the effects of certain factors on the spread of solutions may not correspond to clinical experience, but this merely confirms the fact that physical spread alone is not responsible for the extent of neural blockade.

The two most relevant factors determining spread of solutions in the epidural space are the volume used and the route of entry.

**Volume.** Large volumes spread widely: thus cervical or upper dorsal levels were attained in nearly half the patients who were given 40 ml via the lumbar route compared with only one patient who was given 20 ml via the same route. There was also a wide variation in the levels achieved with the same volume, and these differences could not be accounted for by any recognizable factors. It would seem to be impossible to predict accurately the level to which a given volume of solution will ascend in any particular case.

However, injection of a volume of 20 ml at L3-4 should be adequate in the treatment of the lumbosciatic syndrome, since even the smallest ascent recorded reached the L1 level. The value of employing larger volumes in this condition must be questioned, even in the acute cases (Swerdlow and Sayle Creer 1970), as the radiological evidence shows that they do not perform a "fluid dissection" or break down adhesions; indeed, in the presence of the latter the solution merely takes the line of least resistance, i.e. cephalad. Moreover, large volumes are associated with greater arterial hypotension caused by greater sympathetic blockade, and in the conscious patient discomfort, fullness of the head, and even unconsciousness, may ensue. Clinically, too, the incidence of improvement is no higher: in 636 patients in whom 40 ml was injected the relief rate was 65.5%, whilst in 204 patients in whom 20 ml was injected the rate was 71%—not statistically significant (P > 0.2) but certainly no worse. It would therefore seem difficult to justify the use of large volumes, with their attendant risks, in the light of this radiological and clinical evidence. In the same way that large volumes fail to produce superior improvement so for given volumes there is no correlation between the degree of thoracic or lateral spread and the relief of symptoms.

**Site of injection.** The route of the injection obviously has a considerable influence on the distribution of solutions in the epidural space. The choice of site in the treatment of the lumbosciatic syndrome may require reappraisal. Many authors (Cyriax, 1969; Daly, 1970) have preferred the caudal to the lumbar route, and although caudal injections have certain technical disadvantages (inconstant anatomy, infection risk, and greater toxicity from absorption) good spread of solution throughout the sacral and lumbar spaces was obtained in 11 (65%) of these patients; of the remaining 6 (35%), 4 had had previous laminectomies. On the other hand, caudal extension of a lumbar injection below L4 or L5 was quite unpredictable, and occurred in only 19 cases (48%), though cephalad spread into the dorsal region was often extensive, even with the 20-ml injection. Perfusion
of the lumbar (and sacral) roots would seem more relevant than this wide dissemination into the dorsal vertebral segments.

Rate of injection. Rapid injection, like the use of large volumes, causes discomfort to the conscious patient, and may result in loss of consciousness as a result of a pressure wave being transmitted in the cerebrospinal fluid. Nevertheless, the high pressure resulting from rapid injections failed to result in greater spread, contrary to the findings of some authors (Bromage 1954; Usubiaga, Wikinski and Usubiaga, 1967). It also appeared to confer no clinical benefit and has been abandoned. Similarly, unduly slow injections or divided injections did not result in any reduction in the spread of solution, and the conclusion of Nishimura, Kitahara and Kusakabe (1959) that “speed of injection does not affect the spread of the solution” is confirmed.

Posture of patient. The complete absence of any effect of posture on the spread of epidural solutions is of great interest, since it epitomizes the distinction between the influence of a factor on the macroscopic spread of solution as opposed to its influence on the clinical response. It is significant that Nishimura, Kitahara and Kusakabe (1959), who are amongst the few workers to report the same finding, were also actually measuring the spread of solutions in the epidural space by radio-isotope tracers. Clinical experience, especially in obstetrics, has been that posture did alter (dermatome) spread, and indeed it is common practice to sit women up in labour, during the “top up” of a lumbar epidural, in order to obtain perineal anaesthesia. Bromage (1962) also showed that larger volumes had to be injected if the patient was sitting rather than horizontal, to reach the same dermatome level. In both instances, however, it is the clinical effect which is recorded, and this is presumed to be reflected by the physical spread (Morris, 1971), an assumption altogether too facile. Indeed when most authors refer to spread of solutions in the epidural space, they refer to the inferred spread, as indicated by dermatomes blocked (“dermatome spread”), rather than to the actual gross spread as demonstrated by radiopaque dye or radio-isotope detection. As Bromage (1962) says, “our ideas about epidural spread need to be more sophisticated than hitherto”, and clinical spread influenced by posture must be ascribed to other factors than gravitational spread of free fluid.

It might be argued that the findings from a series of patients with the lumbosacral syndrome cannot be extrapolated, because disc pathology, adhesions, and fibrosis could prevent caudad spread by gravity. The epidural space in a pregnant woman, for example, with its congested veins may behave differently. Certainly this must be explored in mothers with anencephalic foetuses and interuterine deaths; so far, in only two such cases have epidurograms in labour been obtained. In both, 8 ml of 0.25% plain bupivacaine with Conray 420 were injected through an epidural catheter at L3-4 whilst the patient was standing (fig. 10). The solution extended from D12 to L3 and showed no descent, though perineal anaesthesia was excellent.

Fig. 10. Epidurogram in labour.

Amongst other factors influencing spread, apart from the obvious one of simple volumetric displacement, might be the negative pressure in the epidural space, transmitted from the pleural cavity. It is not suggested that this “sucks” the solution up, but that
as the pressure is slightly subatmospheric, there is less resistance to spread cephalad than caudad, and hence the solution tends to spread upwards rather than downwards, whatever the posture, and even if the catheter (or cannula bevel) is directed caudad.

**Height of patient.** The relation of the height of the patient to the volume per segment is generally as might be expected: the taller the patient, the greater the volume per segment to attain a given level. There is considerable variation, however, as shown by the scatter. Bromage (1962) who was referring to dermatome segments rather than vertebral segments, also found the height correlation with dose/segment poor, and attributed this to the poor correlation between the length of the spine and the patient’s total height.

**Capacity of epidural space.** The vertical spread of a given volume of solution would be expected to be greater in a spinal canal of small cross-sectional area. The fact that the crudely calculated index of the cross-sectional area bears no such relation to vertical spread suggests that the size of the bony canal does not in fact reflect the capacity of the epidural space, which must be related more to the soft tissue contents. The degree of vertical spread therefore depends upon the extent by which these tissues limit the epidural capacity.

**Age.** There is no correlation in this series between the age of the patient and the extent to which a given volume spreads in the epidural space. The marked reduction in volume that is required clinically in older patients is due to the much greater degree of neuraxial spread and greater permeability of the perineurium (Bromage, 1969). Whilst it is true that the lateral spread, due to leakage through the sclerosed intervertebral foramina, is much less in the older patients, it cannot be argued that there is therefore more solution retained, which can ascend to a higher level. For in those patients in whom the leak was greatest, so too was often the vertical spread (fig. 11). Hence the sclerosis of the intervertebral foramina cannot be of great significance, especially since there was considerable lateral spread through the foramina in all age groups, when 40 ml of solution was injected in the lumbar region.

**ACKNOWLEDGEMENTS**

We wish to thank our orthopaedic and physical medicine colleagues who permitted this investigation on the patients they referred to us, and we are grateful to Dr W. E. Waters for the statistical analysis of the results. The project was supported by a grant from Upjohn Ltd.

**REFERENCES**


LA DISPERSION DE SOLUTIONS INJECTÉES DANS L’ESPACE EPIDURAL: UNE ÉTUDE À L’AIDE D’EPIDUROGRAMMES CHEZ DES PATIENTS AVEC SYNDROME LOMBOSCIATIQUE

Sommaire
L’évidence radiologique de la distribution de solutions dans l’espace épidural indique que le volume injecté et le lieu d’injection sont les facteurs les plus importants, tandis que la taille du malade n’a que peu d’importance et que la vitesse d’injection, la position et l’âge du patient n’exercent aucune influence. Et pourtant, on observe une grande variabilité dans la dispersion d’un volume donné suivant la même voie, et il est impossible de prédire exactement le taux qui sera atteint. L’amélioration clinique consécutive à l’injection épidurale pour le syndrome lumbosciatique ne semble pas être en corrélation avec une large dispersion de la solution utilisée et de grands volumes ne semblent offrir aucun avantage. Il est peut-être utile de réévaluer la route caudale mais le petit nombre dans cette série empêche de tirer des conclusions valables.

ÜBER DIE AUSBREITUNG VON LÖSUNGEN, WELCHE IN DEN EPIDURALRAUM INJIZIERT WERDEN: EINE STUDIE UNTER VERWENDUNG VON EPIDUROGRAMMEN BEI PATIENTEN MIT SYNDROMEN DER LUMBALREGION UND DER HUFTGELENKREGION

Zusammenfassung