PERIDURAL BLOCK: ANALYSIS OF 3,637 CASES
AND A REVIEW

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The purpose of this paper is to report the results of a survey of 3,637 peridural * blocks performed on 3,554 patients both for surgical and obstetrical anesthesia and as an aid in the diagnosis and therapy of disease. In addition, it is intended to present a discussion of certain aspects of this subject based, in part, upon the data derived from this study and a survey of the literature to evaluate this procedure.

We were prompted to undertake this very detailed study and to publish the results by several motivating factors, not the least important of which was the desire to clarify the status of this method in its various applications and to determine whether or not it merited an important place in the armamentarium of the anesthesiologist. During the past two decades a number of clinicians have shown greater interest in the use of peridural block and much has been written about it including several textbooks (1–6). Many of the reports on this subject are extremely favorable and some even contain enthusiastic acclaim for its many merits. Very few of these reports discuss adequately or emphasize sufficiently the possible hazards, the complications and the technical problems inherent in peridural block. For example, many of the articles (1, 7–27) indicate that hypotension occurs infrequently and that when it does occur it is not as important a problem as the hypotension that follows subarachnoid block. Such incorrect and unjustifiably enthusiastic statements have caused physicians inexperienced in the technique to become prematurely disappointed in their efforts and abandon its use. Moreover, most of the articles deal either with a particular aspect of the technique, or with its application to a certain specific operation; none has reported an over-all objective evaluation of the method for its various applications. In view of these facts, we thought that a critical survey of our results with this procedure would be valuable.

Although this report has been under consideration for the past three years, it has been delayed until a large enough number of cases made it possible for us to gain sufficient experience with the technique in all of

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* "Peridural," "epidural," and "extradural" are synonyms. Although the first of these forms is considered correct by anatomists, they are used interchangeably.
its applications, because correct opinions can be formed only with mature experience. We believe this is particularly important in evaluating methods, techniques and drugs in the clinic, where conditions cannot always be controlled and the value of a survey must necessarily rest on a large amount of data.

Methods

This survey covers all of the peridural blocks that have been performed in four institutions in the Tacoma area during a six and one-half-year period ending June 30, 1956. Although this regional anesthetic procedure was used by one of us (J. J. B.) prior to January 1, 1950, a study of peridural block had not then been considered, nor was the data recorded in sufficient detail to make an analysis possible. Since that time the majority of the cases herein reported have been recorded in detail for this purpose on keysort anesthesia charts, which facilitated the study.

The preliminary preparation in most of the surgical cases was that generally used and included preoperative evaluation and psychologic and pharmacologic preparation of the patient by a member of the anesthesia department. The usual preanesthetic medicaments were administered in individualized doses. Patients who received blocks for diagnostic or prognostic purposes received no preliminary medication, whereas those who received therapeutic blocks received small doses of barbiturates, narcotics, or both, to allay apprehension and decrease the discomfort inherent in the procedure.

The techniques for single and continuous peridural block have been previously described (4, 28, 29) and need not be detailed here. In most instances the procedure was accomplished with the patient in the lateral position, usually lying on the side which required the more intense anesthesia. The site of puncture which was used varied and depended upon the neurotomes which were to be involved. In most instances the intervertebral space which was in the middle of the contemplated band of anesthesia was selected. For reasons given elsewhere (29) and discussed subsequently, in the majority of single blocks executed below the tenth thoracic interspace and above the third thoracic interspace, the needle was introduced in the exact midsagittal plane, whereas in the middle thoracic region the paramedian approach was used. For continuous blocks the paramedian approach was used in the majority of cases. In most instances the method of ascertaining the proper placement of the point of the needle into the peridural space was the “loss-of-resistance” test (1, 30), when the procedure was done below the midthoracic level, and the “hanging-drop” test (12, 13, 17), when done above this site. In a small number of cases various other methods, including the Odom indicator (14) and Macintosh balloon (31), were used.

The fractional technique was employed in all patients in whom a block longer than one and one-half hours was required and also in many
others for purposes of investigating local anesthetic drugs. In about 4 per cent of these patients this technique was accomplished by advancing a 3½ French ureteral catheter with a stilet through a 16-gauge Tuohy needle. In some of these cases a Tuohy needle was used in which the point had been blunted, as suggested by Flowers et al. (32). In the rest of the patients the continuous technique was established by using a special 18-gauge needle with a very short bevel and a thin wall which allows passage of 1 mm. bore vinyl plastic tubing, as recently described (29).†

A test injection of 3 ml. was employed before the full therapeutic dose was administered. The position of the patient immediately after the block was completed varied, depending on the indication. The lateral, Trendelenburg and Fowler's positions were employed whenever it was desired to have the solution gravitate toward a particular region.

After the injection was completed, an intravenous infusion was started and the blood pressure, pulse and respirations were noted and recorded every two to five minutes. Vasopressors were not administered prophylactically except in hypertensive or arteriosclerotic patients in whom an extensive block involving many vasomotor segments was contemplated, but even in these patients they were frequently withheld until hypotension developed. Vasopressors were administered to patients who developed a moderate or severe hypotension unless there was a surgical reason for desiring a lowered blood pressure and the condition of the patient permitted the use of this "hypotensive technique." Five minutes after the injection was completed, the upper and lower limits of cutaneous hypalgesia and analgesia were determined by the pinprick, pinch, and pinseratech methods (4), and thereafter testing was repeated at frequent intervals until complete anesthesia was present.

In surgical patients preparation of the operative site was begun usually 5 to 7 minutes after completion of the injection. By this time hypalgesia was present in most instances and the level of anesthesia could be predicted. In the event analgesia was not complete by the time the surgeon was ready to initiate the operation, the patient would be given thiopental and nitrous oxide-oxygen in sufficient amounts to permit the skin incision. If it was desirable to have the patient awake, these were discontinued when sufficient time had elapsed to have a complete block. Those patients who requested to be asleep were given 0.1 per cent thiopental drip alone or in combination with a mixture of 75 per cent nitrous and 25 per cent oxygen as complementary anesthesia. In those cases in which the surgeon wished to explore the abdomen beyond the confines of the anesthetized region, the patient was given 200 to 300 mg. of thiopental rapidly, thirty to sixty seconds before the maneuver was executed, so that the manipulation occurred during the peak effect of the drug.

† The needle and plastic tubing are manufactured by Beeton, Dickinson & Co. of Rutherford, New Jersey.
TABLE 1

AGE AND PHYSICAL STATUS OF PATIENTS WHO RECEIVED PERIDURAL BLOCK

<table>
<thead>
<tr>
<th>Age in Years</th>
<th>Physical Status Class (A.S.A.)</th>
<th>Total</th>
<th>Number</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
<td>IV</td>
</tr>
<tr>
<td>0-9</td>
<td>28</td>
<td>3</td>
<td>0</td>
<td>0</td>
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<tr>
<td>10-19</td>
<td>86</td>
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<tr>
<td>20-29</td>
<td>255</td>
<td>52</td>
<td>3</td>
<td>0</td>
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<tr>
<td>30-39</td>
<td>468</td>
<td>93</td>
<td>13</td>
<td>0</td>
</tr>
<tr>
<td>40-49</td>
<td>384</td>
<td>142</td>
<td>18</td>
<td>0</td>
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<tr>
<td>50-59</td>
<td>388</td>
<td>192</td>
<td>24</td>
<td>3</td>
</tr>
<tr>
<td>60-69</td>
<td>157</td>
<td>215</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>70-79</td>
<td>50</td>
<td>95</td>
<td>45</td>
<td>2</td>
</tr>
<tr>
<td>80-89</td>
<td>6</td>
<td>28</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>90-99</td>
<td>3</td>
<td>5</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>1,835</td>
<td>836</td>
<td>157</td>
<td>6</td>
</tr>
<tr>
<td>Per Cent</td>
<td>51.6</td>
<td>23.5</td>
<td>4.4</td>
<td>0.2</td>
</tr>
</tbody>
</table>

In surgical patients with a peridural catheter subsequent injections were usually made at intervals of one to one and a half hours, whereas in patients receiving therapeutic blocks injections were given at varying intervals, depending on the circumstances. In patients with severe pain, an attempt was made to maintain uninterrupted comfort by giving injections as frequently as necessary to produce continuous analgesia. On the other hand, in patients in whom the block was being performed for the management of diseases with sympathetic dysfunction, the injections were repeated every 3 to 6 hours. In some of the patients in whom therapeutic blocks were continued for several days, a different drug was used each day, for reasons which will be mentioned subsequently.

In obstetrical patients the technique was executed in the same manner. The single dose technique was employed as anesthesia for the second and third stage of labor and was initiated when the cervix was dilated 8 cm. in multiparous patients and completely dilated in primiparous patients. In such cases the injection was made in the fifth lumbar

TABLE 2

TECHNIQUES EMPLOYED TO PRODUCE PERIDURAL BLOCK

<table>
<thead>
<tr>
<th>Technique</th>
<th>Number of Blocks</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single (Needle) Technique</td>
<td>2,457</td>
<td>67.6</td>
</tr>
<tr>
<td>Midline</td>
<td>1,188</td>
<td>32.7</td>
</tr>
<tr>
<td>Paramedian</td>
<td>1,043</td>
<td>28.7</td>
</tr>
<tr>
<td>Not specified</td>
<td>226</td>
<td>6.2</td>
</tr>
<tr>
<td>Continuous (Catheter) Technique</td>
<td>1,180</td>
<td>32.4</td>
</tr>
<tr>
<td>Midline</td>
<td>264</td>
<td>7.3</td>
</tr>
<tr>
<td>Paramedian</td>
<td>834</td>
<td>22.9</td>
</tr>
<tr>
<td>Not specified</td>
<td>82</td>
<td>2.2</td>
</tr>
<tr>
<td>Total</td>
<td>3,637</td>
<td>100.0</td>
</tr>
</tbody>
</table>
interspace and a total volume of 15 ml. of 1 per cent or 10 ml. of 2 per cent Xylocaine solution was used. In patients in whom peridural block was employed also to provide relief during the first stage of labor, two different fractional techniques were used. In one group of patients the needle was inserted in the second lumbar interspace and the plastic catheter advanced cephalad so that its tip was opposite the body of the twelfth thoracic vertebra. As soon as the patient's cervix was 4 to 5 cm. dilated and uterine contractions were occurring at regular intervals and were associated with moderate to severe discomfort, 3 to 4 cc. of solution were injected every 1 to 2 hours. These injections provided relief from the pain of uterine contractions without interfering with the pelvo-uterine reflex and were continued to within one-half hour of the predicted time of delivery. At this time the patient was made to sit up

**TABLE 3**

<table>
<thead>
<tr>
<th>Agents</th>
<th>Patients Receiving Drugs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number</td>
</tr>
<tr>
<td>Procaïne</td>
<td>122</td>
</tr>
<tr>
<td>Pontocaine</td>
<td>483</td>
</tr>
<tr>
<td>Intracaine</td>
<td>72</td>
</tr>
<tr>
<td>Metycaine</td>
<td>65</td>
</tr>
<tr>
<td>Xylocaine</td>
<td>1,829</td>
</tr>
<tr>
<td>Xylocaine-Pontocaine</td>
<td>506</td>
</tr>
<tr>
<td>Xylocaine-nupercaine</td>
<td>121</td>
</tr>
<tr>
<td>Chloroprocaïne</td>
<td>127</td>
</tr>
<tr>
<td>Chloroprocaïne-Pontocaine</td>
<td>49</td>
</tr>
<tr>
<td>Chloroprocaïne-nupercaine</td>
<td>22</td>
</tr>
<tr>
<td>Nupercaine</td>
<td>63</td>
</tr>
<tr>
<td>Cyclaine</td>
<td>226</td>
</tr>
<tr>
<td>Cyclaine-Pontocaine</td>
<td>87</td>
</tr>
<tr>
<td>Cyclaine-nupercaine</td>
<td>113</td>
</tr>
<tr>
<td>Total</td>
<td>3,885</td>
</tr>
</tbody>
</table>

**TABLE 4**

**Summary of Peridural Blocks for Surgical Operations**

<table>
<thead>
<tr>
<th>Region of Operation</th>
<th>Number of Cases</th>
<th>Mean Site of Injection</th>
<th>Volume of Drug Injected in ml. (Nearest Unit)</th>
<th>Extent of Analgesia (Dermatome)</th>
<th>Results in Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Range</td>
<td>Mean</td>
<td>C2-C6</td>
</tr>
<tr>
<td>Neck</td>
<td>39</td>
<td>C4</td>
<td>5-8</td>
<td>6</td>
<td>C2-C6</td>
</tr>
<tr>
<td>Upper extremity</td>
<td>45</td>
<td>C7</td>
<td>8-12</td>
<td>9</td>
<td>C4-T2</td>
</tr>
<tr>
<td>Chest</td>
<td>179</td>
<td>T5</td>
<td>6-17</td>
<td>12</td>
<td>T2-T8</td>
</tr>
<tr>
<td>Upper abdomen</td>
<td>605</td>
<td>T8</td>
<td>10-18</td>
<td>13</td>
<td>T4-L1</td>
</tr>
<tr>
<td>Lower abdomen</td>
<td>944</td>
<td>L4</td>
<td>15-25</td>
<td>18</td>
<td>T6-S5</td>
</tr>
<tr>
<td>Abdominal wall</td>
<td>549</td>
<td>T12</td>
<td>8-14</td>
<td>10</td>
<td>T8-L5</td>
</tr>
<tr>
<td>Spine and adjacent</td>
<td>142</td>
<td>(T1-L5)</td>
<td>8-20</td>
<td>15</td>
<td>Variable</td>
</tr>
<tr>
<td>structures</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Perineal</td>
<td>105</td>
<td>L5</td>
<td>12-22</td>
<td>14</td>
<td>T10-S5</td>
</tr>
<tr>
<td>Lower extremity</td>
<td>277</td>
<td>L4</td>
<td>10-25</td>
<td>16</td>
<td>T9-S5</td>
</tr>
<tr>
<td>Total</td>
<td>2,885</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
and 15 ml. of solution were injected slowly in order to produce a saddle block type of analgesia for the second and third stage of labor. In the second group of patients the needle was inserted in the fifth lumbar interspace by the paramedian approach and the catheter advanced cephalad for 3 cm. so that its tip was opposite the fourth lumbar vertebra. Ten to 15 ml. of solution were injected every one and one-half to three hours until the delivery was completed. In these patients, like the operative cases, vasopressors were not used prophylactically, but were administered readily if the systolic blood pressure dropped below 100 mm. of mercury. Additional doses of anesthetic solutions were injected as soon as the patient began to experience any discomfort.

The postoperative and postpartum care of the patients was similar to that used with other methods of anesthesia. The great majority of the patients were seen daily by either the resident or the attending anesthesiologist who administered the block, or both. Complications were

<table>
<thead>
<tr>
<th>Operation</th>
<th>Number of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Neck</strong></td>
<td></td>
</tr>
<tr>
<td>Thyroidectomy</td>
<td>14</td>
</tr>
<tr>
<td>Radical neck dissection</td>
<td>5</td>
</tr>
<tr>
<td>Thyroglossal cyst</td>
<td>3</td>
</tr>
<tr>
<td>Esophageal diverticulum</td>
<td>5</td>
</tr>
<tr>
<td>Cervical laminectomy</td>
<td>8</td>
</tr>
<tr>
<td>Plastic operations</td>
<td>3</td>
</tr>
<tr>
<td>Scalenotomy</td>
<td>1</td>
</tr>
<tr>
<td><strong>Upper Extremity</strong></td>
<td></td>
</tr>
<tr>
<td>Open bone</td>
<td>21</td>
</tr>
<tr>
<td>Open soft tissue</td>
<td>16</td>
</tr>
<tr>
<td>Closed operations</td>
<td>8</td>
</tr>
<tr>
<td><strong>Superficial Operations</strong></td>
<td></td>
</tr>
<tr>
<td>Mastectomy</td>
<td>34</td>
</tr>
<tr>
<td>Others</td>
<td>15</td>
</tr>
<tr>
<td><strong>Thoracoabdominal</strong></td>
<td></td>
</tr>
<tr>
<td>Thoracoabdominal*</td>
<td>14</td>
</tr>
<tr>
<td><strong>Intrathoracic</strong></td>
<td></td>
</tr>
<tr>
<td>Exploratory</td>
<td>27</td>
</tr>
<tr>
<td>Pulmonary resection</td>
<td>35</td>
</tr>
<tr>
<td>Heart and great vessels</td>
<td>13</td>
</tr>
<tr>
<td>Esophagus</td>
<td>7</td>
</tr>
<tr>
<td>Diaphragmatic hernia</td>
<td>9</td>
</tr>
<tr>
<td>Others</td>
<td>8</td>
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</table>

*General anesthesia was used in all intrathoracic operations (see text).
TABLE 5—Continued

<table>
<thead>
<tr>
<th>Operation</th>
<th>Number of Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower Abdomen</td>
<td></td>
</tr>
<tr>
<td>Appendectomy</td>
<td>128</td>
</tr>
<tr>
<td>Small intestine</td>
<td>105</td>
</tr>
<tr>
<td>Large intestine</td>
<td>73</td>
</tr>
<tr>
<td>Cesarean section</td>
<td>143</td>
</tr>
<tr>
<td>Gynecologic</td>
<td>395</td>
</tr>
<tr>
<td>Urologic</td>
<td>100</td>
</tr>
<tr>
<td>Abdominal Wall</td>
<td></td>
</tr>
<tr>
<td>Ventral hernia</td>
<td>78</td>
</tr>
<tr>
<td>Inguinal hernia</td>
<td>439</td>
</tr>
<tr>
<td>Others</td>
<td>32</td>
</tr>
<tr>
<td>Herniated disc and/or fusion</td>
<td>66</td>
</tr>
<tr>
<td>Chordotomy (thoracic)</td>
<td>11</td>
</tr>
<tr>
<td>Manipulation of fracture and cast</td>
<td>13</td>
</tr>
<tr>
<td>Thoracolumbar sympathectomy</td>
<td>11</td>
</tr>
<tr>
<td>Lumbar sympathectomy</td>
<td>34</td>
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<tr>
<td>Aortogram</td>
<td>6</td>
</tr>
<tr>
<td>Excision of large fibroma of back</td>
<td>1</td>
</tr>
<tr>
<td>Perineal</td>
<td></td>
</tr>
<tr>
<td>Anorectal</td>
<td>38</td>
</tr>
<tr>
<td>Gynecologic</td>
<td>43</td>
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<tr>
<td>Prostate</td>
<td>15</td>
</tr>
<tr>
<td>Penis and scrotum</td>
<td>9</td>
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<tr>
<td>Lower Extremity</td>
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<td>Open bone operations:</td>
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<tr>
<td>Hip</td>
<td>38</td>
</tr>
<tr>
<td>Knee</td>
<td>70</td>
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<tr>
<td>Ankle</td>
<td>9</td>
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<tr>
<td>Others</td>
<td>19</td>
</tr>
<tr>
<td>Closed bone operations</td>
<td>21</td>
</tr>
<tr>
<td>Vein ligation and stripplings</td>
<td>97</td>
</tr>
<tr>
<td>Other soft tissue operations</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>2,885</td>
</tr>
</tbody>
</table>

TABLE 6

<table>
<thead>
<tr>
<th>Technique</th>
<th>Number of Cases</th>
<th>Site of Injection</th>
<th>Volume of Drug (mL)</th>
<th>Extent of Analgesia</th>
<th>Mean Duration (Minutes)</th>
<th>Excellent</th>
<th>Satisfactory</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single injection</td>
<td>68</td>
<td>L5</td>
<td>15</td>
<td>T9–S5</td>
<td>71</td>
<td>65</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Continuous</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>95.6</td>
<td>2.9</td>
<td>1.5</td>
</tr>
<tr>
<td>Segmental and saddle</td>
<td>26</td>
<td>T12</td>
<td>4</td>
<td>T9–L1</td>
<td>193</td>
<td>20</td>
<td>6</td>
<td>0</td>
</tr>
<tr>
<td>Saddle</td>
<td>95</td>
<td>L4</td>
<td>15</td>
<td>T11–S5</td>
<td></td>
<td>84</td>
<td>23.1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>T9–L5</td>
<td></td>
<td>88.4</td>
<td>9.5</td>
<td>2.1</td>
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<tr>
<td>Total</td>
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<td></td>
<td></td>
<td></td>
<td>169</td>
<td>9.0</td>
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Results

<table>
<thead>
<tr>
<th>No.</th>
<th>Per Cent</th>
<th>No.</th>
<th>Per Cent</th>
<th>No.</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
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<td>Satisfactory</td>
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<td>Poor</td>
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</table>

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noted and recorded in the patient’s chart by the nursing staff and in the copy of the anesthesia chart, which was left in the files of the anesthesiology department.

**RESULTS**

During the six and one half-year period 3,554 patients received 3,637 peridural blocks for surgical or obstetrical anesthesia or for diagnosis, therapy, or both. The great mass of data involved in these cases is summarized in tables 1 to 9.

The blocks were executed by a large number of physicians with a varied amount of training in anesthesiology. Approximately 51 per cent of the blocks were performed by 8 attending anesthesiologists,

**TABLE 7**

**PERIDURAL BLOCKS FOR DIAGNOSIS, PROGNOSIS AND/OR THERAPY**

<table>
<thead>
<tr>
<th>Disorder</th>
<th>Number of Cases</th>
<th>Duration Minutes (M) to Days (D)</th>
<th>Excellent</th>
<th>Satisfactory</th>
<th>Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuralgia or radiculalgia</td>
<td>59</td>
<td>90M–8D</td>
<td>37</td>
<td>62.7</td>
<td>21</td>
</tr>
<tr>
<td>Reflex sympathetic dystrophy</td>
<td>35</td>
<td>150M–12D</td>
<td>17</td>
<td>48.6</td>
<td>16</td>
</tr>
<tr>
<td>Peripheral vascular disease</td>
<td>68</td>
<td>2M–26D</td>
<td>40</td>
<td>58.8</td>
<td>25</td>
</tr>
<tr>
<td>Musculoskeletal disorders</td>
<td>56</td>
<td>130M–29D</td>
<td>38</td>
<td>67.9</td>
<td>16</td>
</tr>
<tr>
<td>Postoperative pain</td>
<td>125</td>
<td>1M–13D</td>
<td>89</td>
<td>71.2</td>
<td>36</td>
</tr>
<tr>
<td>Visceral pain</td>
<td>77</td>
<td>60M–9D</td>
<td>54</td>
<td>70.1</td>
<td>19</td>
</tr>
<tr>
<td>Cancer pain</td>
<td>45</td>
<td>150M–17D</td>
<td>26</td>
<td>57.9</td>
<td>16</td>
</tr>
<tr>
<td>Dermatologic</td>
<td>6</td>
<td>3M–24D</td>
<td>3</td>
<td>30.0</td>
<td>3</td>
</tr>
<tr>
<td>Hypertension</td>
<td>9</td>
<td>60M–5D</td>
<td>3</td>
<td>33.3</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>480</td>
<td>60M–29D</td>
<td>307</td>
<td>64.0</td>
<td>158</td>
</tr>
</tbody>
</table>

approximately 47 per cent were done by 22 residents, and a little over 2 per cent were performed by a number of interns on the anesthesia service. In most instances the residents and interns performed the blocks under the direct supervision of one of the attending physicians.

**Patients.**—Table 1 shows the distribution of the patients according to ages and physical conditions. Although the majority of the patients were adults in good physical condition, it is noted that patients in all age groups and physiologic status were subjected to this procedure. The youngest patient was a 13-month-old infant in whom plastic repair for hypospadias was successfully performed with peridural anesthesia effected by injecting 5 cc. of 1 per cent Xylocaine in the L₄ to S₁ interspace. Eight other infants under three years of age have been operated upon with this type of anesthesia. Approximately 9.4 per cent of the patients were over the age of 70, the oldest being 96 years. Of 6 patients in category IV, 2 required operation which, though elective, was deemed necessary, and 4 needed therapeutic blocks. The
patients in category VII were patients who required emergency surgical intervention which in most cases was for fracture of the hip. Because of the emergency nature of vaginal delivery, all patients who received peridural analgesia for this purpose were placed in class V or VI.

TABLE 8

<table>
<thead>
<tr>
<th>Complications</th>
<th>Number of Cases</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypotension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimal (less than 20 mm. Hg)</td>
<td>721</td>
<td>17.47</td>
</tr>
<tr>
<td>Moderate (20-50 mm. Hg)</td>
<td>956</td>
<td>26.89</td>
</tr>
<tr>
<td>Severe (more than 50 mm. Hg)</td>
<td>121</td>
<td>3.40</td>
</tr>
<tr>
<td>Arrhythmia</td>
<td>4</td>
<td>0.11</td>
</tr>
<tr>
<td>Nausea and vomiting</td>
<td>149</td>
<td>4.22</td>
</tr>
<tr>
<td>Perforation of dura-arachnoid</td>
<td>79</td>
<td>2.23</td>
</tr>
<tr>
<td>Subarachnoid block</td>
<td>35</td>
<td>0.98</td>
</tr>
<tr>
<td>Intended</td>
<td>1</td>
<td>0.05</td>
</tr>
<tr>
<td>Unintended</td>
<td>19</td>
<td>0.53</td>
</tr>
<tr>
<td>Toxic reactions</td>
<td>116</td>
<td>3.24</td>
</tr>
<tr>
<td>Mild</td>
<td>104</td>
<td>2.93</td>
</tr>
<tr>
<td>Moderate</td>
<td>12</td>
<td>0.37</td>
</tr>
<tr>
<td>Deaths</td>
<td>1</td>
<td>0.02</td>
</tr>
<tr>
<td>Primarily due to anesthesia</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Primarily due to surgery</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2,182</td>
<td>61.3</td>
</tr>
</tbody>
</table>

After Block

<table>
<thead>
<tr>
<th>Complications</th>
<th>Number of Cases</th>
<th>Per Cent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atelectasis, pneumonitis</td>
<td>43</td>
<td>1.29</td>
</tr>
<tr>
<td>Nervous system</td>
<td>37</td>
<td>1.04</td>
</tr>
<tr>
<td>Headache</td>
<td>25</td>
<td>.70</td>
</tr>
<tr>
<td>Mild, transient paresthesia</td>
<td>9</td>
<td>0.25</td>
</tr>
<tr>
<td>Neurologic sequelae</td>
<td>3</td>
<td>0.08</td>
</tr>
<tr>
<td>Deaths</td>
<td>21</td>
<td>0.56</td>
</tr>
<tr>
<td>Due to anesthesia</td>
<td>0</td>
<td>0.00*</td>
</tr>
<tr>
<td>Anesthesia major contributing factor</td>
<td>3</td>
<td>14.3*</td>
</tr>
<tr>
<td>Anesthesia minor contributing factor</td>
<td>8</td>
<td>38.1*</td>
</tr>
<tr>
<td>Not related to anesthesia</td>
<td>10</td>
<td>47.6*</td>
</tr>
<tr>
<td>Urinary retention</td>
<td>60</td>
<td>1.12</td>
</tr>
<tr>
<td>Backache</td>
<td>86</td>
<td>2.41</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>0.13</td>
</tr>
<tr>
<td>Total</td>
<td>252</td>
<td>7.1</td>
</tr>
<tr>
<td>Grand Total</td>
<td>2,434</td>
<td>68.4</td>
</tr>
</tbody>
</table>

* Per cent of total deaths.

Techniques.—Table 2 contains data concerning the technique used. The discrepancy between the number of patients as tabulated in table 1 and number of blocks as enumerated in table 2 is due to the fact that 76 surgical patients received a single injection for the operation and some time during the postoperative period a continuous block was instituted to control severe pain. In addition, seven obstetrical patients received a continuous block for the delivery, which was inadvertently discontinued, only to be re instituted later for ligation of the
TABLE 9  
**Summary of Postoperative Deaths**

<table>
<thead>
<tr>
<th>Patient, Initials</th>
<th>Operation, Date and Type</th>
<th>Anesthesia</th>
<th>Intra-Operative Complications Due to Anesthesia</th>
<th>Postoperative Course</th>
<th>Date and Cause of Death</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O. C. 67 Male</td>
<td>9/24/52 Enterostomy</td>
<td>Cont. peridural at T₃ with 10 ml. procaine</td>
<td>Repeated bouts of hypotension. Rx with vasopressors and blood</td>
<td>Peripheral vascular failure → deterioration → Death on 2nd postop. day</td>
<td>9/26/52 Cardiovascular failure *</td>
</tr>
<tr>
<td>2 (Chronic shock)</td>
<td>Herniorrhaphy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W. D. 72 Male</td>
<td>1/29/53 Thoracoabdominal gastrectomy for carcinoma</td>
<td>Cont. peridural at T₄ with 10 ml. Xylocaine N₂O-O₂ (endotracheal)</td>
<td>Marked hypotension for 8 mins. Rx with vasopressors; blood (140/90→50/24→130/70)</td>
<td>Satisfactory until 12 hours postop. Shock due to postop. bleeding</td>
<td>2/1/53 Cardiovascular failure **</td>
</tr>
<tr>
<td>2 (Hypertension 160/100)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>W. G. 51 Male</td>
<td>1/5/54 Mitral commissurotomy</td>
<td>Cont. peridural at T₄ with 6 ml. Xylocaine, Analgesia T₄-T₁, N₂O-O₂ (endotracheal)</td>
<td>Three bouts of moderate hypotension. Rx with vasopressors: 100/70→88/50→110/80, 120/76→60/50→106/72, 100/70→70/50→100/60</td>
<td>Satisfactory for 3 hours → cardiovascular failure → Death 13 hours postop.</td>
<td>1/5/54 Cardiac failure. Large clot found in auricle ***</td>
</tr>
<tr>
<td>3 (Mitril stenosis)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F. L. 44 Female</td>
<td>1/2/52 Exploratory laparotomy for carcinoma of pancreas</td>
<td>Cont. peridural at T₃ with 6 ml. Xylocaine, Analgesia T₂-T₁</td>
<td>Hypotension (70/50→55/40→140/100 with Norepinephrine drip; blood</td>
<td>Blood pressure maintained above 100 systolic, 60 diastolic. Died on 3rd postop. day</td>
<td>1/5/54 Bronchopneumonia, cachexia, shock *</td>
</tr>
<tr>
<td>7 (Pneumonia, distention, cachexia, chronic shock)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>E. M. 69 Male</td>
<td>4/25/52 Laparotomy to control postgastrectomy hemorrhage</td>
<td>Cont. peridural at T₁₀ with 10 ml. Xylocaine N₂O-O₂</td>
<td>Marked hypotension 60/50→0/0→vasopressors; blood. No response for 10 mins. ouabain; 1500 blood→90/55 maintained normal for rest of operation</td>
<td>Immediate postop. period much improved → Satisfactory until 4th postop. day → sudden shock, oliguria → Died on 6th postop. day</td>
<td>5/1/52 Hemorrhage Peritonitis Renal failure **** **</td>
</tr>
<tr>
<td>7 (Shock)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Death due to patient's disease.  
** Operation major contributing factor.  
*** Anesthesia major contributing factor.  
**** Anesthesia minor contributing factor.
<table>
<thead>
<tr>
<th>Patient, Initials</th>
<th>Operation, Date and Type</th>
<th>Anesthesia</th>
<th>Intra-Operative Complications Due to Anesthesia</th>
<th>Postoperative Course</th>
<th>Date and Cause of Death</th>
</tr>
</thead>
<tbody>
<tr>
<td>T. S. 92 Male 2 (Emphysema, mild hypertension 160/70)</td>
<td>Cholecystectomy 12/26/52</td>
<td>Cont. peridural at T₅ with 8 ml. Xylocaine, Analgesia T₂ T₁₁</td>
<td>Mild hypotension 140/60→120/60. Rx with vasopressors. 170/60 and maintained above 160</td>
<td>Satisfactory until 5th postop. day→distention, oliguria. Death on 18th postop. day</td>
<td>1/13/53 Paralytic ileus, Bronchopneumonia, Anuria</td>
</tr>
<tr>
<td>T. H. 73 Female 2 (Mild hypertension 166/90)</td>
<td>Cholecystectomy 2/9/53</td>
<td>Peridural at T₄ with 8 ml. Xylocaine, Analgesia T₂ T₁₁</td>
<td>Hypotension for 3 mins. Rx with vasopressors (130/84→90/60→124/90)</td>
<td>Satisfactory until 6th postop. day→sudden death</td>
<td>2/15/53 Pulmonary embolism</td>
</tr>
<tr>
<td>L. G. 56 Male 3 (Leukemia, distention. Electrolyte fluid imbalance)</td>
<td>Colostomy 9/11/54</td>
<td>Peridural at T₁₂ with 15 ml. Xylocaine. Analgesia T₄-S₁</td>
<td>Severe hypotension treated with vasopressors. 120/78→60/30→treated with vasopressors→maintained normal for operation</td>
<td>Intractable marked electrolyte and fluid imbalance→uremia→Death on 10th postop. day</td>
<td>9/22/54 Uremia</td>
</tr>
<tr>
<td>O. W. 74 Male 6 (Distention, cardiac enlargement, hypertension)</td>
<td>Colostomy 3/31/55</td>
<td>Peridural at L₂ with 15 ml. chlorpromazine. Analgesia T₇-S₂</td>
<td>Moderate hypotension 150/96→110/80. Restored to normal with vasopressors and maintained</td>
<td>Intractable electrolyte imbalance→Anuria→Died on 6th postop. day</td>
<td>4/6/55 Anuria</td>
</tr>
<tr>
<td>M. A. 79 Female 6 (Cardiac disease, intestinal obstruction)</td>
<td>Colostomy 4/6/55</td>
<td>Peridural at L₂ with 10 ml. Cyclaine</td>
<td>Marked hypotension 120/78→70/40. Restored to normal with vasopressors</td>
<td>Satisfactory until 9th postop. day→sudden chest pain→Death</td>
<td>4/16/55 Pulmonary embolism</td>
</tr>
<tr>
<td>M. M. 63 Male</td>
<td>Cystoscopy, Biopsy of bladder, Pelvic exploratory lap.</td>
<td>Cont. peridural at L₃ with 20 ml. Xylocaine, Analgesia T₁ S₁</td>
<td>Marked hypotension 130/80→60/50. Restored to normal with vasopressors</td>
<td>Satisfactory until 28th postop. day→sudden dyspnea and diaphoresis→death in 15 mins.</td>
<td>11/2/55 Coronary thrombosis</td>
</tr>
</tbody>
</table>
fallopian tubes. In such instances it was counted under both categories. As may be noted, peridural block was produced with a single injection in 67.6 per cent of the patients, while in the rest the continuous technique was employed.

**Agents.**—The local anesthetic agents used in this group of patients have been tabulated in table 3. The discrepancy between the total number of cases shown in this table and the actual number of patients treated (table 1) is explained by the fact that in many patients in whom the continuous technique was employed for several days a different local anesthetic drug was used each day. The daily change of drug was done to avoid tachyphylaxis and to investigate the properties of various local anesthetic drugs in the same patient under similar clinical conditions. This work, which is part of a long-term clinical investigation, will be reported in detail in the future (33). In one patient as many as six different drugs were used and in this and other such instances each drug was tabulated as a case. Of course, when the same drug was administered more than once it was still tabulated as one case.

The concentrations of each of the local anesthetics varied according to the purpose of the block. For surgical anesthesia they were as follows: procaine, intracaine, Metycaine, Xylocaine and Cyclaine were used as 2 per cent solutions; chloroprocaine as 3 per cent solution; Pontocaine and nupercaine as 0.2–0.3 per cent solutions. It is to be noted that in 23.1 per cent of patients a combination of two drugs was employed in order to benefit from the short latency of the one and the prolonged effect of the other. In preparing such solutions Pontocaine or nupercaine were added in the form of crystals to 2 per cent Cyclaine or Xylocaine so that the final dilution was 0.2 per cent and 2 per cent respectively. For example, 50 mg. of nupercaine crystals would be added to 25 ml. of 2 per cent Xylocaine. For this and other purposes chloroprocaine was used as 3 per cent concentration. For most diagnostic and therapeutic blocks and in some obstetrical patients one half to one third of these strengths were employed.

Although a detailed analysis of the anesthetic properties of each drug is outside the scope of this paper, a summary of these results in the form of classifications may be deemed in order here. In regard to latency or time necessary to produce the block, 2-chloroprocaine, Xylocaine, and Cyclaine may be classed together as fast-acting; procaine, Metycaine, and intracaine as intermediate-acting; Pontocaine and nupercaine as slow-acting. Xylocaine has the greatest penetration (ability to spread), with Cyclaine and chloroprocaine vying for second place. The remainder of the drugs are significantly less penetrating. In regard to duration of anesthesia, 2-chloroprocaine, procaine, Metycaine, and intracaine can be classed together as drugs producing a block of short duration (approximately 1 hour); nupercaine and Pontocaine effect blocks of long duration (over 2 hours); Cyclaine and Xylocaine are in the intermediate class (1½–2 hours).
Operations.—Table 4 contains a summary of surgical operations performed with peridural anesthesia in various regions of the body. In order to provide information about the technique employed in each corporeal region, data concerning the average site of injection, the volume of drug employed, and the extent of dermatomal analgesia, as well as the results obtained, have also been included in this table.

The site of injection varied only one or two segments from the mean except in a small number of cases in which the lumbar region was used to produce anesthesia for upper abdominal surgery. This group includes those patients in whom pathologic conditions in the thoracic spine (for example, arthritis and abnormal curvature) made it impossible to introduce the needle in the thoracic peridural space and a number of upper abdominal surgical cases in which the lumbar region was selected for teaching purposes. In cases in which a catheter was used the site of injection was recorded as the level at which the point of the tubing or catheter was calculated to be (see Discussion). The low figure in the volume range of drug injected represents Xylocaine, which because of its superior penetration diffuses more extensively than the other drugs.

The extent of dermatome analgesia shown in table 4 represents mean figures. In the thoracic region there was a wide range from five segments in some cardiac cases to fourteen segments in patients undergoing radical mastectomy. In back operations the range varied from six segments for chordotomy to fifteen segments for lumbar laminectomy, for herniated disc or fusion, or both. In the average case for epigastric hernia the injection was made at T₈ interlaminar space and the anesthesia extended from T₅ to T₁₉ or T₁₁; for inguinal hernia the solution was injected at T₁₂, and anesthesia extended from T₅ to L₄ or L₆.

In table 4 the results obtained have been tabulated in per cent only for the sake of clarity. In classifying the results of the anesthesia, each chart was examined and studied carefully. The results were considered “excellent” only if the block provided complete analgesia for the patient and optimal operating conditions for the surgeon. This group included those patients who received no other medication during the operation, and those who received drugs to allay apprehension or induce sleep without producing surgical anesthesia. A block was considered “satisfactory” if it provided adequate anesthesia for the proposed operation for a reasonable period of time. In this group are included all blocks which were successful but required supplementation either because the operative field was extended beyond the limits of anesthesia or because the operation lasted longer than the block, or both. All blocks which failed to provide adequate anesthesia for the proposed operation thirty minutes after the injection was completed were tabulated under the “failure” column. In this group were also included those cases in which hypalgasia but not analgesia of the desired region developed and also those in which unilateral analgesia
developed in patients who underwent operations involving structures with bilateral innervation.

In most intrathoracic operations peridural block was complemented with light general anesthesia which was usually initiated with thiopental and then maintained with nitrous oxide-oxygen administered through an endotracheal or endobronchial tube. These cases have therefore been tabulated under the "satisfactory" column, thus explaining the very low per cent of "excellent" results obtained in this region.

In examining the records of patients who underwent upper abdominal operations it was noted that in a significant per cent it was necessary to supplement the peridural block with general anesthesia in order to relieve discomfort and stop the retching or hiccups, or both, which occurred when the surgeon made traction on the esophagus, stimulated the vagus in some other manner, or explored the inferior surface of the diaphragm. It was also found that in the early phases of this work supplementary anesthesia was necessary in a considerable number of patients who are undergoing intestinal operation, cesarean sections, and certain other procedures of the lower abdomen, because the segmental blocks (T₅₋₆/L₂₋₃), while they provided adequate analgesia for the abdominal wall, small intestine, uterus and part of the large intestine, did not do so for the pelvic viscera. Subsequently, more extensive blocks were produced to include the pelvic viscera.

The numbers of specific surgical operations performed with peridural block are shown in table 5.

Vaginal Deliveries.—Table 6 contains data on 189 patients in whom peridural block was used for vaginal delivery. The different techniques employed have already been described. The low rate of failure can be explained by the fact that where the initial injection failed to produce anesthesia it was repeated. In 3 patients labor was too far advanced to permit reblock, and they had to be given a general anesthetic.

Diagnostic-Therapeutic Blocks.—Table 7 contains data pertaining to those cases for which peridural block was used as a diagnostic, prognostic, or therapeutic procedure. Each of the nine categories is composed of various disorders which have been segregated according to Bonica's classification (4) and will be mentioned in the discussion. As may be noted, in most instances this method was used for a period of days as a therapeutic measure, although in a few cases a single injection was done as a diagnostic-prognostic procedure. Since the block could be repeated or re instituted, no instance of failure to produce a block was recorded. The results in this table indicate the ability of this method to produce the desired effects, which in most instances were relief of pain and sympathetic block. The results were considered excellent if pain relief was complete for the duration of the block, and satisfactory if the block produced partial relief. The failures include those cases in which the intended block was complete but failed
to provide any relief and was not repeated either because the patient refused further blocking or because the side effects (hypotension) deemed it unwise for us to reinstitute the block.

Complications.—The complications which occurred have been tabulated in table 8. As may be noted, hypotension was the most common complication which developed during the anesthetic period, being present in one-half of the cases. Disturbances in cardiac rhythm, which developed after the block was instituted, occurred in 4 patients, all of whom went through the operations without any difficulty. Retching, nausea, and vomiting occurred mostly in patients who were undergoing surgery in the upper abdomen and in those who developed severe hypotension.

In 79, or 2.2 per cent, of the patients the dura-arachnoid was inadvertently perforated during the advance of the needle. In 44 of these patients peridural block was completed at a different segment without incident. In 16 of the other 35 patients the position of the needle was correctly recognized before any drug was injected and a subarachnoid block was produced in the usual manner, whereas in 19 of the patients a subarachnoid block was produced unintentionally. Fortunately, in the majority (17) of these latter cases the spinal block resulted from the test dose and was recognized before the full amount of solution was injected. In 2 cases in which the full therapeutic dose intended for peridural anesthesia was inadvertently injected into the subarachnoid space, the patients developed complete anesthesia with consequent marked hypotension, respiratory paralysis and loss of consciousness. After treatment, consisting of artificial ventilation and support of the blood pressure, was successfully carried out in one patient, the surgeon proceeded with the operation and completed it successfully without incident. In the other patient in whom massive subarachnoid block occurred, serious neurologic sequelae developed; this case warrants a more detailed report.

This was the case of a 76-year-old, white woman who was scheduled for a cholecystectomy for chronic cholecystitis under segmental peridural block. The needle was inserted through the eighth thoracic interlaminar space without apparent difficulty and when it was considered properly placed, 3 ml. of 2 per cent Xylocaine were injected as a test dose. Since there was no evidence of analgesia or anesthesia in five minutes, the resident anesthesiologist attempted to inject the full therapeutic dose, but noted resistance. She therefore advanced the needle slightly while exerting pressure on the plunger of the syringe containing saline. While the needle was being advanced the patient complained bitterly of severe, lancinating pain in the right side of the trunk. The needle was immediately arrested and slightly withdrawn, resulting in complete relief. An attempt to aspirate fluid in the new position was unsuccessful and saline could be injected with minimal resistance. Believing that the paresthesia had been caused by stimulation of the dura, and that now the point of the needle was in the peridural space, the anesthesiologist injected 10 ml. of 2 per cent Xylocaine. As soon as the injection had been completed and the patient placed in the supine position, it was noted that she was extremely pale and was unable to respond to
any stimulus. Within a few seconds she developed apnea; the blood pressure could not be recorded although the carotid pulse was still present. An endotracheal tube was inserted and the patient given artificial ventilation with 100 per cent oxygen, and an intravenous infusion of 500 ml of 5 per cent glucose containing 10 mg of Neosynephrine was started. In addition 1 mg of Neosynephrine was given intravenously. Within a few minutes the blood pressure was restored to normal levels. Thirty minutes after the incidence the patient resumed spontaneous respiration and about one hour later she regained consciousness and had active laryngeal, pharyngeal, corneal and lid reflexes. Of course, the operation was cancelled and the patient was returned to her room.

Soon after the patient regained consciousness she began to complain of severe, lancinating pain in the left side of the trunk involving the sixth to the eleventh thoracic neurotomes. Neurological examination performed that evening revealed that the patient had hypalgesia on the right side of the trunk extending from the fifth thoracic to the first lumbar dermatome and on the left side extending from the first lumbar to the fifth sacral dermatome. There was also loss of proprioception, a decreased patellar reflex and subjective weakness of the left lower extremity. The symptomatology was obviously evidence of damage to the right half of the spinal cord. The pains subsided rapidly and at the time of discharge ten days after the incidence, the patient was pain free, though the sensory and reflex deficits persisted. Electromyographic studies revealed no evidence of denervation. Subsequently she was given conservative treatment consisting of physical therapy and large doses of vitamin B-complex. She has made very slow improvement and at the time of this writing, almost three years after injury, she still has minimal degrees of hypalgesia, though function of the extremity is good. Since that time the symptoms of gallbladder disease, which had disabled her prior to the injection, have never returned and there has been no evidence of gallbladder dysfunction. This beneficial effect on the course of the cholecystitis is probably the result of sensory and sympathetic blockade (4, 34, 35).

Generalized toxic manifestations were noted in 116 patients (3.2 per cent). Of these only 8 (0.2 per cent) developed convulsions, the rest manifesting only mild reactions in the form of apprehension, vertigo, tinnitus and tremors (4). Severe toxic reactions in the form of cardiovascular collapse and depression of the respiratory and central nervous systems due to overdose or rapid absorption, or both, of the drug were not observed. The relatively small incidence of such reactions is probably related to the smaller doses of the local anesthetics used in our clinic than is generally employed.

The only death which occurred during the operation or for the duration of the block was due to surgical error. It occurred in a 27-year-old woman who was undergoing mitral commissurotomy which was being done with a segmental peridural block, limited to 6 thoracic segments, and nitrous oxide-oxygen anesthesia administered through an endotracheal tube. The anesthesia and operation proceeded without incident until the auricular appendage was accidentally torn off, resulting in a sudden massive blood loss. Repeated attempts were made to repair the defect but this was impossible and the patient
deteriorated very rapidly and died twenty-three minutes after the accident.

The complications which occurred after the effects of the block disappeared are shown in the lower part of table 8. All of the pulmonary complications occurred in patients who had been subjected to a surgical operation. In 24 of the 25 patients who developed headache, the dura had been perforated. Mild transient paresthesia in various parts of the body supplied by nerves which had been blocked developed in 9 patients, but fortunately these disappeared in one to three days after the anesthesia.

In 3 patients neurologic sequelae developed. One was the case detailed above. A second patient developed subjective numbness and paresthesia of the right lower extremity involving the fourth and fifth lumbar and first three sacral segments. There was also muscular weakness, a decrease of the patellar reflex and loss of the Achilles reflex. The block had been executed without incident and no cause for this complication could be ascertained. Fortunately, there was progressive improvement and all signs and symptoms disappeared within three weeks. The third patient experienced minimal degrees of subjective numbness, paresthesia and pain of the shoulders and upper extremities for a period of 5 days following an attempt to produce cervical anesthesia of the upper extremities for bilateral shoulder operations. During the advance of the needle in the seventh cervical interspinous space, the patient complained of lancinating pain in the upper extremities. The block was abandoned and the patient was given a general anesthesia. The symptomatology disappeared completely and has not returned for a period of fifteen months.

Backache was the most common complaint noted by the patients, being present in 2.41 per cent of the cases. Although in the majority of these, discomfort was of minor degree, in three patients it was severe and was associated with muscle spasm which persisted for five, seven and nine days respectively. Urinary retention occurred in a relatively small number of patients, being present in 1.2 per cent of the cases. Other postblock complications included 1 case of hysteria, 1 case of persistent hyperemesis, and 3 cases in which the catheter was sheared off. In two of these the end of the catheter was found subeutaneously and was removed, but in the third patient it could not be located in spite of an incision which extended to the tips of the spinous processes. No symptoms or signs have been noted until the date of this writing two years after the incident.

Deaths.—Twenty-two deaths occurred during the first month after operation, including one in the group of patients who received peridural block for diagnosis, prognosis, or therapy. We believe anesthesia played a major role in the death of 3 patients who died of cardiovascular failure within 3 days of the operation. In another 8 patients anesthesia was probably a minor contributing factor. All of these 11 patients sustained moderate to severe hypotension during the course of the operation. These cases are summarized in table 9.
Discussion

The position of peridural block in common anesthesiologic practice is far too uncertain, especially for a procedure which is 35 years old. We believe that this is due to a number of problems and controversies concerning many aspects of this subject which still exist and which require solution or clarification before this method is more widely employed. In this discussion it is our intention to attempt to clarify some of these issues and to try to explain discrepancies between our results and those of some other writers.

It is obvious, that in order to fulfill the purpose of this paper, it is necessary to discuss specifically, albeit briefly, the various technical aspects of peridural block and its clinical applications. To accomplish this the discussion will be divided into three sections: technique, physiopathologic effects (complications), and clinical applications. This order has been decided upon so that the contents of the first two sections will form the basis for the discussion of the clinical use of peridural block.

Technique: Before proceeding with the discussion of various aspects of technique, we deem it essential to emphasize that in our experience peridural block has proved to be technically a difficult procedure to master. Notwithstanding claims of earlier writers (1, 17, 22) to the contrary, it is now generally agreed that the technique of properly inserting the needle into the peridural space is more complicated and requires considerably more precision, skill and practice than does subarachnoid puncture. It is not uncommon to encounter an experienced anesthesiologist, who is very proficient in introducing a needle into the subarachnoid space, having great difficulty in advancing the needle through the same interspinous structures when he begins to learn peridural block. Apprehension of producing a massive subarachnoid block is probably one of the most important factors responsible for this difficulty.

Failures.—The greater difficulty in mastering the technique of peridural blocks is the most important factor responsible for the relatively high rate of failures with this method. As with any other technical procedure the rate of failure decreases with experience, but unfortunately, a point of minimum incidence is reached, below which it seems impossible to progress. This is apparent from a survey of the literature and study of our results. With experience Henninger (36) was able to reduce the rate of failure from 20 per cent to 6 per cent, and Gutierrez (13, 17) from 6 per cent to 1 per cent. Analysis of our cases during a 12-month period revealed that a physician who had had ten years’ experience with this procedure failed to produce peridural block in less than 3 per cent of the cases attempted, that one with three years’ experience failed in 7 per cent of the cases attempted, and that a second year resident produced poor block in 17.5 per cent of the cases. Survey of the subarachnoid blocks done by the same three individuals revealed that the differences in their results were markedly less.
Pathologic curvatures of the spine, arthritic changes which involve the interspinous and interlaminar spaces, the loss of elasticity of the ligaments, and other anatomic abnormalities are other factors which are responsible for the relatively high incidence of failures with peridural block. A partially or completely obstructed intervertebral foramen will impede passage of the injected local anesthetic from the peridural to the paravertebral space, resulting in deficiency of analgesia of the involved segment. The use of local anesthetics which are too weak or lack sufficient penetration also contribute to the number of failures.

Our high rate of failures (6.0 per cent) justifiably prompts one to question the propriety of continuing its routine use, especially in view of the simplicity and effectiveness of modern general anesthetic methods. However, in all fairness to the peridural technique, it should be pointed out that, the majority of failures occurred in the hands of the resident staff which, as a group, also make similar mistakes with general anesthesia. Unfortunately for regional methods, deficiencies in their administration are much more obvious and distinct than is the case with general anesthesia. The slightest mistake in placing the needle or in calculating the dose of the local anesthetics may result in failure with the peridural block, whereas a similar mistake with general anesthesia can be easily disguised or may go unnoticed, even by the anesthesiologist, though it may prove no less deleterious to the physiologic economy of the patient. Moreover, manifestations of such deficiencies in administering general anesthesia, in the form of nausea, vomiting, decreased hepatic and renal function, and even cardiovascular failure, are frequently delayed until the postoperative period, when it is difficult to ascertain which of the many possible factors is responsible.

Frequent changes in the method of identifying the peridural space and in the site of puncture are two of the most important causes of failures with this technique. As with any other method certain techniques of peridural block are more reliable than others, and it is essential to adopt one which provides uniform results with minimal complications. We heartily agree with Bromage (6) who stresses the importance of avoiding variations, either in technique or in anything else, that add to the difficulty of the method.

Preanesthetic Medication.—There are slight differences of opinion regarding the amount and type of premedication. Most writers indicate that they prefer the patient to be lightly premedicated; the patient may then cooperate during the introduction of the needle and the operator may better discern the effects of the test dose. Others (6, 26, 27) prefer the patient to be asleep. Discomfort and psychic trauma may be avoided; these rely on the onset of hypotension and intercostal muscle paralysis, or the marked reaction to injection of distilled water into the peridural space as signs of peridural injection. It is best to use discretion and consider each case individually. The very skilled operator may employ narcosis to advantage in a patient who, while
he agrees to have this type of anesthesia, insists that he or she be asleep even before the block is initiated. On the other hand, if the sitting position is to be employed, or if the operator’s limited experience makes it necessary that he obtain information from the patient following injection of the test dose, it is better to avoid heavy preanesthetic medication. Should the patient insist that he be asleep during the insertion of the needle, thiopental in 100 to 150 mg. doses injected just prior to the puncture will provide temporary amnesia, after which the patient is permitted to awaken and cooperate in testing the effects of the block.

**Position of the Patient.**—There are differences of opinion concerning the optimum position of the patient during the puncture and the injection. Some (37–42) insist on the sitting position. Others (6, 26, 27, 43) use the lateral position exclusively. Some (44–48) use the sitting position to perform the puncture and the lateral position for the injection, while still others (19) perform the puncture with the patient in the prone position. We have found the lateral position more comfortable for the patient than the sitting position, which occasionally causes syncope in premedicated patients. The table should be tilted so that the head of the patient is lower than the site of puncture, in order to decrease the subarachnoid pressure and allow the dura to fall away from the posterior walls of the spinal canal where the point of the needle enters the peridural space, consequently lessening the chance of perforating the dura (6). On the other hand, if the needle is to be inserted in the upper thoracic and cervical region the sitting position provides the best conditions, because the spinous processes are thus made more prominent and the thick elastic ligamentum nuchae is placed at a maximum stretch, rendering passage of the needle less difficult. It is essential that the patient be supported and held securely by an assistant, who keeps his chin over the patient’s occiput to keep the head flexed and holds the patient’s arms crossed in front so as to pull his shoulder girdles away from the site of puncture (38).

**Site of Injection.**—Some controversy exists as to the optimum site for insertion of the needle and injection of the solution. Some of those reporting (6) contend that the puncture should never be made above the second lumbar interspace; others (1, 2, 8–11, 17, 38–42, 49) believe it should be in the center of the zone of anesthesia; while still others (19, 50) compromise by introducing the needle in the lumbar region and advancing the catheter to such an extent that its point reaches the center of the anesthetic zone. The last practice should be abandoned because of the inherent hazard of damaging peridural vessels, dura, and even the cord, especially if the catheter contains a stilet while it is advanced.

Decision as to which is the best site depends upon several factors, including the experience of the anesthesiologist, the purpose of the block and whether or not a continuous technique is to be used. The novice should start learning the technique in the lumbar region below the
level of the first lumbar vertebra, not only because this minimizes the danger of damaging the spinal cord, but also because in this region the interspinous and interlaminar spaces are largest, the posterior peridural space is largest and the ligamentum flavum is thickest, thus facilitating the insertion of the needle. Only after gaining a great deal of experience in this region should an attempt be made at inserting the needle in the thoracic or cervical spine in order to produce a limited segmental block.

In our experience the cervical region presented the greatest difficulties and was where we encountered the highest percentage of failures. This is probably due to several factors: (1) In this region the ligamentum flavum is very thin and thus is much less prominent as a landmark. (2) The peridural space is very narrow owing to the cervical enlargement of the spinal cord. (3) The areolar and fibrous tissue around the exit of the cervical intervertebral foramen and immediately lateral to it are more dense than in the thoracic and lumbar region and not infrequently impede the flow of solution to the paravertebral region (51, 52). (4) The resiliency of the thick, very elastic ligamentum nuchae makes the advance of the blunt needle more difficult, so that there is a tendency to use more force. The consequently greater momentum developed after sudden release from the tissues makes it extremely difficult to arrest the advance of the needle, and its point traverses the narrow peridural space and invades the subarachnoid space before one realizes it.

The midthoracic region is the next most difficult one because of the marked obliquity of the spinous processes, and the frequent presence of bony projections encroaching on the interspinous and interlaminar spaces, especially in elderly patients with arthritis. Anatomic and roentgenographic studies have revealed that in some patients it is impossible to insert the needle in the midline between spinous processes and that osteoblastic processes of adjacent laminae or calcification of the ligamentum flavum, or both, markedly decrease the interlaminar space to a size which hardly permits passage of the needle. For these and other reasons we are of the opinion that the paramedian approach is to be preferred, especially in the midthoracic region and when a continuous technique is to be used. There is evidence which suggests that the use of the paramedian approach is followed by a smaller incidence of postinjection backaches since this method obviates the possibility of damage to the supraspinous and interspinous ligaments (1, 52, 60, 61). Moreover, the paramedian approach in the lumbar region permits insertion of the needle into the peridural space at an angle in excess of 135 degrees and thus facilitates passage of the catheter or plastic tubing (29).

Identification of Peridural Space.—Proper identification of the peridural space is the most important single factor responsible for success with peridural block. It is essential that the operator recognize immediately when the point of the needle penetrates the ligamentum
flavum and enters the space and that the advance be halted instantly, lest the dura-arachnoid be perforated. We have employed almost all of the procedures that have been recommended for this purpose and have found the "lack of resistance test" the most reliable in the lower thoracic and lumbar region, and the "hanging drop" test or Macintosh balloon best in the cervical and upper thoracic region.

The "lack of resistance test," first described by Sicard and Forestier (30) and subsequently popularized by Dogliotti (1, 2, 8–11), of course, entails attaching a large syringe filled with fluid or air to the peridural needle when its point is in the ligamentum flavum and then exerting constant, unremitting pressure as the needle is slowly advanced. As soon as the bevel of the needle penetrates the yellow ligament and enters the peridural space the marked resistance to the injection ceases and the plunger surges forward, giving the operator a characteristic sensation of entering a vacuous space. By experience, we prefer to use a large syringe and saline. The use of air, suggested by some (3) because of its compressibility, decreases the sensitivity of interpreting changes in resistance. The several refinements of this test, which involve accessory apparatus, such as the Brunner-Tkale syringe (62, 63, 64) and the spring-loaded, blunt cannula of Macintosh (65), complicate the procedure and afford no advantages. We agree with Bromage (6) that the Sicard-Dogliotti technique is simpler, positive in all instances and permits the use of tactile as well as visual sensations, providing additional confirmatory evidence other than purely visual signs received from insensate apparatus. Moreover, as first pointed out by Sicard (30), the sudden, forceful ejection of saline from the needle adds to the safety of the procedure by pushing the flexible meninges away from the needle point. The requisites for success with this technique are to have a secure grip on the needle, to advance it with a slow, gradual, well-controlled, smooth movement, and to arrest it instantly when the space is reached (6).

In identifying the peridural space in the upper thoracic and cervical region, the resiliency of the ligamentum nuchae and thinness of the ligamentum flavum make the "loss-of-resistance" test extremely difficult and unreliable. Gutierrez' "hanging-drop" test (12, 13, 17), which entails placing a drop of fluid on the hub of the needle and noting its disappearance into the shaft of the needle as the point of the needle enters the peridural space, is better for this purpose and affords the advantages of simplicity and of permitting the operator to use both hands and concentrate on the puncture. Since the movement of the drop from the hub into the shaft depends upon the presence of negative pressure † in the peridural space, this test is not always positive, especially in the lumbar region when the patient is sitting or straining. Analysis of the data in the small number of patients

† Whether this negative pressure is constantly present, or whether it is created by indentation of the dura by the advancing needle point, or is the result of still other factors remains a controversial issue which need not detain us. Evidence for each theory can be found in many quarters (66–75).
in whom this method was used below the eighth thoracic segment revealed that it was positive in approximately 80 per cent of the instances, whereas in the cervical and upper thoracic region it was present in all but one patient. These data are in agreement with those of Gutierrez (12, 13, 17) and Bromage (6, 74).

Of the many pieces of accessory apparatus to aid visualization of this phenomenon which have been described, including various special manometers (1, 69, 73, 74) and glass indicators (12, 70), none matches the simplicity of Gutierrez’ method and only one, the Macintosh balloon (31), exceeds its reliability. Since the air injected into the balloon is under slight pressure while the point of the needle is within the yellow ligament, collapse of the balloon occurs as soon as the needle enters the peridural space, so theoretically it should be positive in all instances whether the pressure is negative or isometric.

Continuous Technique.—Another controversial issue is whether the continuous technique should be employed routinely or reserved for unusually long blocks (45). We believe that for circumstances which require a block of brief duration the single injection is adequate and has the advantage of producing slightly less trauma. On the other hand, the skillful insertion of the 18-gauge, thin-walled needle and the passage of plastic tubing through it, are inherent with little additional trauma and affords the outstanding advantage of controllability of the intensity, extent and duration of anesthesia. It should be employed whenever there is uncertainty in regard to the magnitude of the operation.

In the event the catheter is used, it is important not to advance it more than 3 to 5 cm. lest it lacerate peridural vessels and thus enhance the possibility of hemorrhage and rapid absorption with consequent increase in incidence of general toxic reaction and the rate of failure. It was noted that those patients who developed signs of toxicity frequently had incomplete or no anesthesia, probably owing to the fact that the drug was rapidly absorbed and not permitted to reach its site of action in sufficient concentrations.

Correlation of clinical data and roentgenographic studies indicate that accurate clinical measurements provide an adequate guide for proper placement of the catheter. Roentgenograms taken to demonstrate the position of the catheter revealed that the level was estimated correctly over 90 per cent of the time. In the rest the catheter tip was found to be one vertebral level higher or to have migrated caudad or laterad through one of the intervertebral foramen into the paravertebral space. In the latter instances the resultant anesthesia was either unilateral or not present. These studies also revealed that the interspinous or interlaminar level was estimated correctly over 90 per cent of the time and the mid-zone of cutaneous anesthesia corresponded to the vertebral level of the tip of the tubing in about 80 per cent of the cases. These findings agree with those of Frumin and Schwartz (50).

Agents.—Many reports on peridural anesthesia attach considerable
importance to the choice of the local anesthetic drug. Some writers (21, 76–81) advocate the use of one specific drug and condemn others on the basis of certain qualities. We believe this is erroneous for there are many drugs which may prove valuable under specific conditions. In selecting the drug to be used various properties of each agent, including activity, latency, penetration, duration, and toxicity, must be considered (33, 82). For short operations or for diagnostic blocks in outpatients, chloroprocaine, with its short latency period and duration of action, affords significant advantages (33, 75). On the other hand, if a short latent period is not necessary and prolonged effect is needed, Pontocaine and unepcaine are the drugs of choice, and even when the continuous technique is employed, the use of these long lasting agents obviates the necessity of frequent injections. In some instances it might be deemed advisable to use a mixture of a drug with a short latent period and one with prolonged action (1, 2, 4, 19, 33).

Optimum Concentration.—There are also differences of opinions as to the optimum concentration and volume of solutions to be used. In our experience 0.5 to 1 per cent Xylocaine or equiactive concentrations of other drugs is necessary to produce complete sympathetic interruption by the peridural route. To assure complete sensory block it is necessary to employ 1 to 1½ per cent Xylocaine or equiactive concentrations of other drugs; and for somatic motor block it has been found necessary to employ at least 2 per cent Xylocaine, and frequently even with this concentration the skeletal muscle paralysis is not complete. We cannot agree with the writers (19, 26, 38) who claim that peridural block produced with such concentrations provides muscular paralysis which is as complete as that provided with subarachnoid block. Many of our patients who had block of the lumbo-sacral segments retained some function of the muscles of the lower extremities. Nor can we reconcile our results with those (6, 52, 78, 99, 100, 101) who report and advocate the use of 1.2 per cent Xylocaine for peridural analgesia for intra-abdominal surgery, on the basis that this concentration is sufficient to interrupt the afferent (sensory) limb of the reflex arc, resulting in reflex relaxation despite the persistence of motor neuron function. When less than 2 per cent Xylocaine or equiactive concentration of other agents were used, we noted that stimuli arising outside of the operative area resulted in causing sufficient increase in the tone of the abdominal muscles that were blocked to interfere with provision of optimum conditions for the surgeon. (This was in addition to the diaphragmatic activity caused by such stimuli.) In some patients who had received maximum concentrations (2 per cent Xylocaine or its equivalent), rebathing of the nerves with an additional dose of the drug was necessary before complete paralysis of the muscles was obtained.

In reviewing the literature we also note a serious discrepancy between our results and those of others concerning the time of onset and duration of anesthesia. Some writers (19, 26, 80) claim that with
Xylocaine anesthesia is complete within 5 to 8 minutes from the time of injection and lasts in excess of two and one-half hours. While some patients develop sufficient sensory anesthesia to permit the incision within ten minutes, in the average case it is necessary to wait fifteen minutes before complete analgesia develops when the rapid acting drugs are employed and, of course, even longer with intermediate and slow acting agents. The duration of the block also varied. Some writers (87) have reported anesthesia of four to six hours with Pontocaine, and others (78) mentioned that with 2 per cent Xylocaine the block lasted six hours. In our patients, the short acting drugs, such as procaine, chloroprocaine, Metycaine and intracaine administered with epinephrine, produced block for not much longer than one hour; with Xylocaine and Cyclaine this block is prolonged to one-half to two hours, Pontocaine, approximately two and one-half to three hours, and nupercaine, two and one-half to four hours. The discrepancy may be due to the fact that the other writers employed larger doses of these drugs and perhaps did not correct the hypotension which occurred. There is experimental and clinical evidence that lowering of the blood pressure, with consequent reduction of blood flow, prolongs the duration of peridural block (6, 33, 102).

Volume.—Careful analysis of our cases indicates that 1 to 1½ ml. of solution are necessary to affect one neurotome. We are at a loss to explain the marked discrepancy between our results and those of many other writers (1, 3, 6, 12, 19, 26, 27, 38–42, 78, 84) who mention and advocate the use of 30, 40 and even 50 ml. of Xylocaine for abdominal surgery, even when the puncture is made in the thoracic spine. The maximum volume of this drug we have employed in order to produce a block which extends from the midthoracic (T₃₋₅) region to the fifth sacral neurotome, has been 20 ml., even when the puncture was done in the lumbar region. As may be noted in table 4, most of the procedures have been done with 10 to 15 ml. of solution injected in the mid-zone of analgesia. Our findings in this regard are similar to those of MacMillan (103, 104) and Moore (105), both of whom have had wide experience with this technique.

Extent of Block.—In predicting the extent of block following peridural injection the following factors must be considered: (1) the site of the puncture, (2) the volume of the solution injected, (3) the concentration and penetration of the local anesthetic drug employed, (4) the speed of injection, (5) the factor of gravity, and (6) the volume capacity of the peridural space. In the course of this work the influence each of these factors has on the spread of peridurally injected solutions has been studied by observing routine clinical cases and by fluoroscopy and roentgenographic examinations following the injection of Diodrast. The following observations have been made.

With the patient in the horizontal position the solution disperses equally in every direction, although this is modified by physiologic and pathologic curvature of the spine (1, 4, 6). Also, the size of the peri-
dural space in the region to be involved effects the spread. In the cervical and upper thoracic region the peridural space is unusually small and, therefore, a given volume of solution will spread more widely than in the lower thoracic, lumbar, and especially the sacral region, where the space has much greater capacity (1, 4, 6, 106). We have also been impressed by the variability in the capacity of the peridural space owing to the age, height, and condition of the patient. The capacity of the peridural space in children is relatively greater than in adults, whereas in elderly patients a given volume will spread to a greater extent than in the average adult, probably because the intervertebral foramina, which constitute the most important escape routes for the injected fluid, are stenosed as a result of age, arthritis, or both (1, 6, 73). The volume of the space is greater in tall individuals than in short ones, so that a given volume of solution will spread to a greater extent in the latter than in the former (6). Pregnancy and intra-abdominal tumors significantly decrease the size of the peridural space, probably as a result of increased venous pressure and consequent engorgement of the internal vertebral venous plexus. Thus, we have noted that in a pregnant patient 10 ml. of 2 per cent Xylocaine will produce a block of the same extent as that produced by 15 ml. on a nonpregnant woman. On the other hand, dehydration and cachexia decrease the density of the contents of epidural space and thus increase the volume of the epidural space.

In addition, to these intrinsic anatomic variations, which cannot be modified, there are a number of extrinsic factors that can be controlled by the operator. The volume of the solution injected is without doubt the most important extrinsic factor affecting the extent of the block; the larger the volume of the injected local anesthetic drug, the greater the extent of the block. In general, the more rapid the injection of the anesthetic solution, the greater the extent of analgesia. This results, however, in a smaller amount of drug distributed to each segment, so that the intensity and duration of analgesia is decreased. Moreover, rapid injection causes paresthesia, referred pain, and other unpleasant symptoms, including vertigo, tinnitus, and headache in the conscious patient and disturbance in respiration and cardiovascular function in the unconscious patient (6, 26, 27). For these reasons it is advisable to inject the solution slowly. Moreover, this will result in a more restricted block which will be more profound and will last longer. The technique should be developed in which this factor is standardized and kept constant. The concentration and penetration of the local anesthetic employed significantly affect the extent of the block. The diffusion of the injected solution is also influenced by the position of the patient during and immediately after the injection and by the specific gravity of a solution (1, 4, 6, 75). Although these factors are not as important in peridural block as in spinal anesthesia, the use of the lateral, Trendelenburg, Fowler, or sitting positions can be employed to advantage when it is desired to have the solution spread predominantly in one direction from the site of injection.
Physiologic Effects and Complications: The anesthetic effects of peridural block are not unlike those of subarachnoid block, except their onset is more delayed, probably because of the greater distance the drug must travel to reach its site of action and there penetrate inert connective tissue before it comes in contact with nerve elements. In about five minutes there is evidence of sympathetic block, loss of temperature sense, and hypalgesia, and subsequently there is progressive loss of the pain, light touch, proprioceptive, and deep touch sensations and motor function. These effects occur first and are most profound near the point of injection, and the farther away from this point, the longer the time for onset and the less the effect.

The exact site at which the block is effected following injection of local anesthetic agents into the peridural space is still a controversial issue. On the basis of early studies by Sicard (30) and others (1, 3, 10), which indicated that solutions injected into the peridural space did not penetrate the dura, it was believed that the site of action of peridural block was outside of the spinal canal on the formed spinal nerve distal to the point where the dura-arachnoid fuses with the epineurium. Improved methods for the quantitative determination of low concentrations of local anesthetics have made possible studies which have demonstrated that following epidural injections these drugs do penetrate the dura and can be present in the cerebrospinal fluids in sufficient quantities to produce block of nerve conduction (53–58). Consequently many writers (56) suggested that the site of action is in the subarachnoid space. However, more recent data (59, 75) together with clinical evidence suggests that, while some of the local anesthetic may penetrate to dura-arachnoid and enter the arachnoid space, the primary site of action is outside of the dura-arachnoid and outside of the spinal canal, and involves the mixed spinal nerve in the paravertebral space.

The effects of peridural anesthesia on the heart, liver, kidneys, and other parenchymatous organs are negligible, provided the blood pressure is maintained within normal limits and there is minimal or no impairment of the intercostal muscles (4, 6, 22, 38–40, 52, 108). Some investigators (6, 109) claim that block of the sympathetic nerves to the kidney prevents or corrects renal cortical reflex vasoconstriction, and block of the nerves to the lungs effects bronchodilatation. The beneficial effects of sympathetic block on the gastrointestinal tract are well known. Moreover, there is electroencephalographic and hematologic evidence that complete sensory blockade produced by peridural (or any other) block shields the central nervous system from noxious operative stimuli until the block is terminated and obviates reflex cardiovascular disturbances (110, 111). Rizzi (22), Crawford (108), and others (52) claim that extensive studies failed to demonstrate occurrence of biochemical changes from peridural block.

However, if the peridural block is accompanied by marked reduction of blood pressure, the situation is considerably changed. It is claimed
that a minimum systolic pressure in the range of 50 to 60 mm. of mercury is needed for perfusion of the brain, heart, liver and kidneys of a normal adult, and below this point there is danger of hypoxia (4, 6, 112, 113). In the presence of arteriosclerosis this critical level is well above this point (70 to 80 mm. of mercury), especially for the brain and heart, since a higher perfusion pressure is required to overcome the increased resistance and to compensate for the inability of the blood vessels to dilate in response to homeostatic mechanisms.

Hypotension.—The incidence and magnitude of hypotension that follows peridural block is one of the most notable controversial issues found in medical literature. Most of the older reports (1, 2, 8–18, 21–25) and a significant number of recent ones (19, 20, 26, 27, 37, 49, 134, 149, 164, 166) contain the claim that epidural analgesia, unlike subarachnoid block, alters the blood pressure very little or none at all. These authors repeatedly state that this is one of the outstanding advantages of peridural block over spinal anesthesia. Since peripheral vascular tone is dependent upon the integrity of the thoracolumbar sympathetic outflow to the blood vessels and the adrenal medulla, it is logical to expect that interruption of sympathetic pathways anywhere along their course would result in a decrease in vascular tone with consequent decrease in peripheral resistance and a resultant fall in blood pressure.

These considerations together with the data herein recorded, as well as those of a number of other writers (4–6, 50, 52, 60, 74–78, 87, 88, 99, 104, 105, 114–118) who report falls of blood pressure comparable with those noted with spinal anesthesia, make it difficult for us to understand the contention of those who claim that peridural block does not affect blood pressure. It is true, of course, that the degree of hypotension is dependent on the number of sympathetic segments involved, and under special circumstances the peridural block can be limited, theoretically, to involve fewer segments than those involved in spinal anesthesia. Such is the case, for example, with a segmental block restricted to 5 or 6 segments in the midthoracic region (T₅₋₁₀) to provide therapeutic or surgical analgesia. In such a case, the lower thoracic and lumbar vasomotor segments theoretically would not be interrupted with peridural block, but included in subarachnoid block. However, since sympathetic fibers are vulnerable to concentrations of local anesthetic which merely produce hypesthesia (4) and since invariably hypesthesia extends beyond the area of anesthesia by 2 or 3 segments, vasomotor block is usually more extensive than the analgesia. Moreover, because for most intra-abdominal operations it is better to include the lower thoracic, the lumbar and the sacral nerves, it is apparent that the resultant block would produce hypotension which would be of the same magnitude as that following subarachnoid block.

Bromage (115) found a linear relationship between the upper limit of the peridural block and the fall of mean arterial pressure. Analysis of our data in this respect reveals a close correlation between degree
of hypotension and the number of segments involved, as well as the location of the segments involved. Thus, it was noted that the greatest drop in blood pressure occurred when the fifth to the twelfth thoracic neurotoines were blocked. Similar observations have been reported by others (52, 74, 78, 103, 105, 116). We also noted a correlation between the rapidity of onset and degree of the hypotension and such factors as the age and physiologic status of the patient. Patients under 30 years of age were apparently able to compensate sufficiently to maintain the blood pressure within normal limits even when the extent of the block reached the critical level (approximately T₅) (119). On the other hand, elderly patients, especially those with marked arteriosclerosis, invariably developed moderate to severe hypotension when the extent of analgesia reached the ninth or eighth thoracic segment. In patients who were dehydrated or had hypovolemia the drop in blood pressure occurred earlier and reached a lower level than would be expected.

In general, the hypotension is slower in onset and more gradual than with subarachnoid block. It begins at about the same time that hypalgesia develops (usually 5 to 12 minutes after injection, depending of course on the local anesthetic used) and reaches its lowest point in a period of 5 to 7 minutes. This gradual pattern is probably the result of epinephrine effect and the progressive diffusion and penetration of the solution through the various neurophysiologically inert tissues. Occasionally the blood pressure rises slightly above normal levels before it begins to fall. This and the slower onset are probably due, in part, to epinephrine effect (4, 26, 90, 91). We do not agree with Blundell et al. (20) and Burstein (119), who claim there is no demonstrable effect of epinephrine on blood pressure and to support this contention have obtained data from patients who received repeated injections with and without epinephrine. We also noted in some instances the blood pressure in patients with extensive peridural block remained at normal levels until the patient received general anesthesia. Bromage (6), who had made the same observation, believes this is probably due to elimination of the pressor action of the brain, and suggests that the belief of lack of effects on blood pressure may have arisen from an observation of a large number of cases in clinics where epidural analgesia is given alone, without general anesthesia. However, since we have observed definite hypotensive effects in many conscious patients, this is unlikely to be the primary reason. Perhaps the misconception arose because earlier writers restricted the use of the peridural block for operation in the lower part of the body (52).

We have emphasized the problem of hypotension because of the importance placed on it by some of the other investigators; who based their argument of the superiority of epidural block over spinal anesthesia, especially for poor risk patients, primarily on this factor. We are of the opinion that death in a number of patients herein reported was due to cardiovascular failure which was initiated, in part, by the hypotension that occurred during the peridural block done in the oper-
ating room several days earlier. Even in those patients who died from pulmonary embolism, coronary thrombosis or anuria many days after the operation, the noted hypotension during the operation cannot be exonerated, but must be considered as an important factor which, together with the effects of the operation and the pre-existing biochemical disorders, initiated a process that ultimately caused death. The obvious conclusion is that while moderate hypotension may be tolerated and may even benefit the patient from the consequent decrease in blood loss, severe hypotension should be prevented and, when it occurs, should be treated immediately, especially in poor risk patients.

Toxic Reactions.—Generalized reaction to injected local anesthetic drug depends in part upon the rapidity of absorption and consequent blood levels. The relatively greater vasculaarity of the peridural space, together with not infrequent laceration of these vessels by the invading needle or catheter, provides favorable conditions for the occurrence of such reactions. For this reason we are not in agreement with some (6, 26, 27) who advocate the use of liberal volumes, which in our experience are far greater than necessary. As we have already indicated, there is no need to employ more than 25 ml. of solution unless a total peridural block is desired. The use of optimum concentrations (1 to 200,000) of epinephrine markedly decreases the rate of absorption and consequently reduces the possibility of reactions (4, 107). Moreover, epinephrine reduces the time of onset and increases the duration of peridural block (102, 107). For these reasons the vasoconstrictor should be employed, unless it is absolutely contraindicated.

Perforation of Dura.—Inadvertent perforation of the dura-arachnoid is a complication which can be minimized with experience. With the continuous technique, care must be taken to withdraw the stilet at least 1 cm. from the end of the catheter and not to use undue force in advancing it beyond the point of the needle, lest the dura be perforated. We had one such accident prior to adopting the paramedian approach.

All possible precautions should be taken to recognize this complication when it occurs and to avoid accidental injection of large volumes of local anesthetic drugs into the subarachnoid space. Although we agree with Bromage (6) that the use of the test dose does not constitute an absolute safeguard against such an accident, it is nevertheless of great value to aid the operator in recognizing inadvertent invasion of the subarachnoid space. In our practice the use of a test dose has proved an invaluable procedure and has obviated inadvertent massive spinal block in 17 patients.

Respiratory Paralysis.—This is one of the most serious complications which can occur during peridural anesthesia and has been one of the factors that has deterred some clinicians from using the method more extensively. It may occur either as a result of extensive extradural block involving the cervical and thoracic region or more likely as a result of accidentally injecting the full therapeutic dose into the
subarachnoid space. Since the amount of local anesthetic employed in peridural block is two to six times the dose usually used for spinal anesthesia, there is certain involvement of the brain stem and brain, if it is accidentally injected into the subarachnoid space, and therefore immediate, intensive resuscitative therapy is required. With care and experience the incidence should be extremely low and certainly should not present any problems if the operator is properly prepared to treat it. The two cases herein reported represent an incidence of 0.05 per cent. Ruiz (120) reported 1 such case in 1,431 blocks, while Dawkins (121) found an incidence of 0.6 per cent in the 6,453 cases of peridural blocks he was able to collect in the literature.

Neurologic Sequelae.—Our experiences with neurologic sequelae following peridural block prompt us to emphasize again that this procedure is not without danger and that for success there are certain requirements which must be carefully observed. The advance of the needle must be very slow and under the complete control of the operator, so that he is able to halt instantly as soon as the needle point enters the peridural space or elicits paresthesia. It bears re-emphasis that the operator must acquire much experience in peridural puncture below the first lumbar interspace before he attempts to insert the needle at higher levels.

Pulmonary Complication.—It would appear that in our cases peridural block anesthesia has been followed by an incidence of pulmonary complications considerably lower than expected. It is important to point out, however, that the entire credit for such a low incidence should not be given to peridural block, because many of the patients operated upon receive antibiotics. On the other hand, the fact that none of the patients who received peridural blocks for diagnosis, prognosis, or therapy developed pulmonary complications emphasizes the significant role that surgery, particularly of the upper abdomen and chest, plays in the etiology of this disorder (4).

Headache.—The almost complete absence of headache in patients who have received peridural block is one of the outstanding attributes of this method and constitutes a very important advantage over subarachnoid block. In the hands of the physician who can perform both procedures with equal dexterity and skill the problem of headache is an important consideration which will prompt him to choose peridural block instead of spinal anesthesia, provided, of course, there are no other contraindications. Also, it might be pointed out that the absence of headache following peridural block lends support to the theory of leakage of cerebrospinal fluid in the causation of so-called postspinal headache (4).

Cardiac Arrest.—The nonoccurrence of cardiac arrest or death attributable to the block during the procedure in this group of 3,554 patients may be considered as a good record and one which is far better than the national average with other forms of anesthesia (122, 123, 124). This could be interpreted to indicate that peridural block
may protect the patient against reflex cardiovascular disturbances and produce less deleterious effects on bodily function than general anesthesia.

However, our data on postoperative deaths certainly indicate that one should not underestimate the malefic effects of severe hypotension or impaired respiratory functions, or both, consequent to peridural block. These complications may not only neutralize the beneficial effects derived from regional anesthesia, but may prove disastrous, unless they are properly managed.

**Clinical Applications**

In discussing the clinical application of any method of anesthesia it is essential to remember that the desired effects are obtained always at a price exacted from the patient in the form of physiologic deviations. It is the primary task of the anesthesiologist to select indicated agents and techniques and employ them in such a manner as to cause the least degree of disturbances of bodily functions. How effectively he discharges such a grave responsibility depends upon his skill, experience and judgment, and is usually measured in terms of results. To select the best method suited he must consider many variable factors. In addition to evaluating his own ability in each method that can be used for the operation on hand, he must take into account the condition of the patient and how this is likely to be altered by the effects of each agent and technique; he must also consider the potential hazards of each method and the risk involved in the particular patient. Finally, he must consider the wishes, ability, skill and behavior of the surgeon. In other words, each circumstance must be dealt with individually and in a specific manner.

These are basic principles of modern anesthesiologic practice which are well-known, but unfortunately they are frequently neglected or overlooked. Such has been the case in considering the clinical application of peridural block in the past. The nonspecific manner in which some clinicians (1, 2, 8-27, 37, 75, 80, 104, 118, 121, 126, 149, 160) have attempted to evaluate this method is one of the most notable shortcomings of some previously published articles and one which we believe has contributed to the delay of its widespread acceptance. It has been stated without qualification that peridural block disturbs the physiology of patients much less than spinal or general anesthesia, as if this rule applied to all circumstances regardless of the patient's condition, the extent of the anesthesia required, and the type and magnitude of the operation. We believe this is a fallacious approach for the evaluation of any method, but particularly for peridural block because its flexibility of application and diversibility of effect prohibit generalities concerning the clinical use of this method. It is true, of course, that in general this method presents certain advantages as well as disadvantages when compared with other forms of anesthesia. For example, the fact that with peridural block the subarachnoid space is
not invaded is a consistent advantage over subarachnoid block, since it obviates the problem of headache and the potential hazards of meningeal irritation, arachnoiditis, and toxic effects on the spinal cord. However, since in some circumstances these and other advantages may not be of sufficient importance to warrant selection of peridural block over spinal anesthesia, it is obvious that each use of peridural block must receive individual consideration. It is our intention here to evaluate and compare for each specific purpose peridural block with other methods in common use. This purpose has provoked what may seem to be tiresome repetition and explicitness.

Age and Condition of the Patient.—Extreme age of the patient in itself need not deter one from using this form of anesthesia, since it has been used successfully in patients ranging in age from one day to a century (52). Schneider (127) reported the use of peridural block in 6,500 children, 25 per cent of whom were infants, with an over-all mortality of 0.3 per cent, which in his practice was considerably less than with general anesthesia. Ruston (128) reported the use of this method in 77 infants, including a 24-hour-old premature infant, for various intra-abdominal, inguinal, and lower extremity operations, with satisfactory anesthesia and without complications. Others (81, 129–131) have reported the use of this technique in infants and children.

We have found this and other regional techniques very useful in infants and children, especially in those with malnutrition and electrolyte imbalance. These patients derive definite benefits from the lack of further biochemical disturbances and apparently tolerate the vasomotor paralysis. In older children we have favored the lumbar peridural route, whereas in small children and infants we have preferred to approach the extradural space via the sacrococcygeal hiatus, using the technique suggested by Pratt (132), because it is simpler and less likely to lead to subarachnoid puncture. Nevertheless, the results in our group of 48 patients under 10 years of age who received spinal peridural block were consistently good.

In order to obtain optimal results with peridural anesthesia in this group of patients it is necessary to observe certain precautions and to modify the usual technique. First of all, only those operators with a great deal of experience with peridural block should attempt it in such young patients. In addition to the usual premedication, we like to induce light basal hypnosis with rectal thiopental (10 mg. per pound of body weight) prior to the block. It is advisable to use an extremely short beveled, 5 cm., 22-gauge needle with a flange on the hub to permit better control. The procedure is best carried out with the patient sitting, since an infant can be held more steadily in this position (128). Because the ligamentous tissues are relatively soft in young children, it is easier to use the hanging drop method or better still the Macintosh balloon in identifying the peridural space. The puncture should be done in the fourth or fifth lumbar interspace, to avoid possible harm to the spinal cord, which in these patients extends as low as the
body of the third lumbar vertebra. In infants and children under 5 years of age, an injection of 4 to 7 ml. of 1 per cent Xylocaine in the fourth or fifth lumbar interspace produces analgesia extending from T₉₋₁₀ to S₂₋₅, whereas in older children it is better to employ 1½ per cent Xylocaine in volumes ranging from 5 to 10 ml.

Geriatric patients will also derive much benefit from peridural anesthesia provided they are selected with care. It is, of course, important to keep in mind the alterations brought about by aging. As previously mentioned, arthritic and other changes in the spine occasionally create difficulties in inserting the needle and may impede adequate diffusion of the anesthetic solution. Even more important to consider in geriatric patients are the physiopathologic changes in the heart, blood vessels, brain, liver and kidney and other organs, which make these patients especially vulnerable to the harmful effects of pronounced hypotension and impaired respiratory function. Therefore, in this group of patients it is better to restrict the use of peridural block to those in whom the operation requires analgesia below the ninth or tenth thoracic segment. Peridural analgesia can be employed with much benefit to the geriatric and poor risk patient who is to have femoral, inguinal or lower abdominal herniorrhaphy, prostatic or vaginal surgery, or any operation of the perineum or lower extremities. On the other hand, an extensive block involving most of the vasomotor fibers supplying the splanchnic area, should be avoided in these patients, as well as in any patient with hypovolemia, shock, electrolyte imbalance, or who for any other reason is considered a poor risk. Admittedly, by using vasopressors an extensive peridural block can be employed in these patients, but a properly administered, light, balanced general anesthesia is better. In this regard we are in disagreement with many clinicians (1, 2, 6, 8–27, 37, 48, 99, 101, 126, 133, 134, 149, 152) who advocate this method as especially suitable for poor risk patients.

Surgical Operations: Neck Operations.—In the early period of this work, at the suggestion of Dogliotti (1, 2), Christmann (85), and Ciocatto (134), we began to use peridural block for various operations on the neck as a substitute for bilateral cervical plexus block, hoping it would be simpler and less time consuming to execute. Moreover, it was thought that since bilateral anesthesia could be accomplished with one puncture there would be less discomfort. However, as previously mentioned, difficulties were encountered in performing the puncture in the upper cervical region and in producing a segmental block limited to the first four or five cervical nerves.

We are now of the opinion that in simple thyroidecomies and thyroglossal cysts, bilateral cervical plexus block can be accomplished with greater facility and safety. In the more extensive radical surgical procedures, regional anesthesia, even when complete, taxes the patient physically and psychologically, and frequently requires supplementation with general anesthesia. In these cases it is far better to employ general anesthesia using an endotracheal tube to assure the
patient a patent airway at all times. Our experience is, of course, limited, but while it is true that cervical peridural block can be successfully accomplished (1, 85, 108, 135), the potential hazards and lack of optimal conditions from the viewpoint of both patient and surgeon are too high a price to pay simply to prove that “it can be done.”

**Operation of Upper Extremities.**—Peridural anesthesia for the upper extremities is a less difficult problem. The puncture is best performed in the first thoracic interspace, and if a catheter is to be employed it is advanced to the level of the seventh cervical vertebra. Our experience with 67 cases, including 45 surgical patients, prompts us to suggest that this procedure be considered only in patients requiring operations of both upper extremities or both shoulders at the same sitting. In patients with multiple injuries of the clavicle, or of the bones of the upper extremity, and of the upper thorax, it may be employed to great advantage to provide not only preoperative and postoperative relief, but surgical anesthesia if operation is indicated. It is especially useful if there is evidence of posttraumatic vasospasm or other signs of reflex sympathetic dystrophy; and it is also useful in the management of severe pain associated with cancer, herniated disc, and other disorders involving both extremities (4). In such cases continuous cervicothoracic (C₃₋₅ to T₁₋₄) peridural block affords obvious advantages over bilateral brachial plexus block or bilateral cervicothoracic sympathetic block, both of which must be repeated, since it is difficult to maintain a catheter in place in either of these two regions.

**Chest.**—In considering the clinical application of peridural block for operations on the chest, it is, of course, especially important to take into account the extent of anesthesia required and the effects of both the anesthesia and operation on the respiratory and cardiovascular functions of the patient because these are frequently already impaired. In order to minimize the extent of the vasomotor paralysis and the degree of intercostal muscle weakness, it is advisable to induce a segmental block which is limited to the operative site and to use dilute solutions of local anesthetic drugs. A mixture of 1 per cent Xylocaine–0.075 per cent Pontocaine with epinephrine 1:200,000 provides analgesia for approximately one and one-half to two and one-half hours with minimal effect on the respiration. By having the patient lie on the side to be operated during and for five minutes after the injection, the effects on the intercostal muscles of the contralateral side will be further minimized while the analgesia on the ipsilateral side is enhanced. It is also important to consider the extent and site of the sympathetic blockade that will result, keeping in mind, of course, that the upper five thoracic sympathetic segments include the cardiac accelerator nerves, as well as the vasomotor supply to the head, neck, upper extremity, and part of the chest, while the lower seven to nine segments contribute most of the splanchnic vasomotor fibers.
For superficial operations which require analgesia limited to a few segments, peridural block affords advantages over general anesthesia, especially if the operative position requires the use of an endotracheal tube. However, peridural block is not as advantageous as intercostal block, if the latter procedure can be used, since it does not interrupt splanchnic vasomotor nerves and does not involve the potential hazards of thoracic peridural puncture. On the other hand, in patients requiring extensive surgery of the chest wall, such as radical mastectomy or thoracoplasty, peridural anesthesia is preferable to intercostal, or the paravertebral-brachial plexus-field block combination, or local infiltration, because it avoids multiple punctures, it offers less risk of providing incomplete block (especially if the operation involves the paravertebral region) and it requires less time to execute. Whether peridural block is preferable to general anesthesia in such cases depends upon the cardiovascular status of the patient. If it is believed that the patient can tolerate hypotension, peridural block may be employed not only to provide analgesia but to help to decrease blood loss (6, 20, 28).

The results in 34 patients who underwent radical mastectomy were highly satisfactory, notwithstanding the fact that in over one-fifth of the cases it was necessary to administer light general anesthesia for short periods because the block did not include the cervical segments. Since this operation requires analgesia of the lower four cervical and upper eight thoracic segments, it is advisable to reserve the use of peridural block for patients with good cardiovascular function who are to undergo a radical resection of the breast. In patients in whom the diagnosis is not certain, in those who may require only a breast biopsy, and in those with symptomatic cardiac disease, severe arteriosclerosis, or who for other reasons are in poor physical condition, light general anesthesia is preferable.

The advantages of regional analgesia for thoracoplasty in tuberculous patients have long been recognized and at present this method is favored in many medical centers (38-42, 85, 136, 143). For reasons previously mentioned the peridural technique is superior to the combination of paravertebral block-brachial plexus block-infiltration. It also affords the advantage over general anesthesia of permitting the patient to retain the cough reflex so that he is able to better control pulmonary secretions and thus reduce the risk of spread (108, 137). In a group of 800 patients who received 1,639 anesthetics for thoracoplasty, Paletto (137) noted excellent results from all aspects. Similarly favorable results have been reported by others (38-42, 47, 52, 84, 85, 131, 138, 145). Although our results in 14 patients have been highly satisfactory, the opportunity to use peridural block has greatly diminished in recent years as a result of the increasing number of pulmonary resections being done for the treatment of tuberculosis.

The use of peridural block as the primary method of anesthesia for intrathoracic operations has been reported by a number of investi-
gators (38-42, 83, 141-146), all of whom claim that this procedure is far superior to general anesthesia for this purpose. Crawford and his associates, who probably have had the widest experience with this method, contend that peridural analgesia is better than general anesthesia because: (1) it does not abolish the cough reflex and thus permits the patient to constantly evacuate bronchopulmonary secretions during the operation, resulting in minimal incidence of spread of infection, (2) it causes less cardiorespiratory embarrassment than general anesthesia and there is consequently better oxygenation and minimal or no hypercarbia,§ (3) the blood loss is considerably less than with general anesthesia, (4) the patient has a better postoperative course, (5) it permits the use of cautery, and (6) it can be employed in extremely poor risk patients and in tuberculous patients with low vital capacity who would not tolerate general analgesia. They deny that this procedure imposes psychologic stress on the patient during the operation because in their institution preoperative patients are informed of the advantages of this form of anesthesia by those who have had the operation.

On the basis of our experience with this and various other types of anesthesia in over 600 patients who have been subjected to intrathoracic operations, we cannot agree with these authors. Although only a few of our cases were done with peridural block alone, experience with these, as well as with patients in whom combination of peridural block and general anesthesia was used, and with over 450 patients in whom general anesthesia alone was employed, permits us to be able to evaluate these methods. After an early, unfavorable experience with peridural block as the sole anesthetic, we abandoned its use in late 1949 because it did not provide as good operating conditions as general anesthesia, from the viewpoint of both the patient and the surgeon. In spite of intensive psychologic preparation, adequate premedication and complete analgesia, the patients become apprehensive when the chest was opened, later became restless and began to move and interfere with the surgeon’s task, and frequently developed paroxysms of cough when the bronchial tree was manipulated. Moreover, many of the patients developed a degree of hypotension which caused concern and required treatment. Although, admittedly, we did not permit the systolic pressure to remain below 90 mm. of mercury, measurement of the blood lost did not demonstrate that the loss was significantly less than had been noted previously with general anesthesia (147, 148).

Subsequently we combined a more limited form of peridural block with general anesthesia administered through an endotracheal or endobronchial tube. Since 1950 this method has been used in 106 cases (table 6). In most instances peridural analgesia of the chest wall and pleura did prove valuable because it greatly diminished the require-

§ Recent studies by Crawford (108) indicate that patients undergoing intrathoracic operations with peridural analgesia without any ventilatory assistance develop hypercarbia and hypoxia which is quickly eliminated by assisted respiration.
ments of general anesthesia. For example, each of 4 patients who underwent esophageal resection lasting over nine hours was maintained with nitrous oxide-oxygen and a maximum total of 1.5 Gm. of thiopental. Similar results were obtained in 17 patients who had thoracoabdominal operations for total gastric resection, in 9 patients who had thoracotomy for repair of diaphragmatic hernia, and in 8 who had various operations. All these 34 procedures were prolonged. In addition to providing surgical analgesia, the block probably obviated abnormal cutaneous, periosteal and pleural reflexes, which occasionally produce serious cardiovascular disturbances (125). In all cases the peridural catheter was left in place for several days after the operation and in many instances it proved useful, since it not only produced unparalleled relief of severe pain but also obviated reflex skeletal muscle spasm, resulted in an increase in the tidal volume and permitted the patient to cough forcefully and eliminate secretions.

In spite of these advantages peridural block as a supplement to general anesthesia has not been adopted as a routine procedure in our practice, but reserved for certain selected patients. The most important reason for this resolution of procedure is that we have been unable to note additional benefits which would warrant using the extra time and effort the block involves or risking its potential complications. Moreover, the problem of hypotension has been sufficiently serious in some patients to constitute the major deterring factor. This complication proved to be serious in all 13 patients who had operations on the heart and great vessels, especially those undergoing mitral commissurotomy, in spite of the fact that the analgesia was limited to the upper seven or eight thoracic segments. Since most of these patients have a fixed cardiac output, interruption of vasmotor and cardiac sympathetic fibers deprives them of one of the most important homeostatic mechanisms, and consequently their cardiovascular system is unable to compensate.

The same problem exists, though to a lesser degree, in patients who require pulmonary surgery for neoplastic disease, since most are elderly and have low cardiac reserve, arteriosclerosis, low blood volume or ventilatory impairment, or combinations of these conditions. These patients do better with balanced general anesthesia. This technique obviates the need for deep general anesthesia and thus minimizes deleterious anesthetic effects, which before the advent of muscle relaxants constituted one of the most important reasons for considering regional anesthesia. Moreover, it affords optimal operating conditions for the surgeon and better control of the patient by the anesthesiologist. Even in patients undergoing pulmonary surgery for tuberculosis, in whom hypotension and cardiovascular dysfunction is not as serious a problem (probably because they are younger and their cardiovascular system can compensate more readily), we have not employed epidural block as a routine because our results with general anesthesia do not warrant a change. In 362 such patients operated upon in two tuber-
culosis sanatoriums there have been no deaths during operation, there were 6 postoperative deaths (1.9 per cent) within the first month after operation, and an incidence of spread of 1.1 per cent. As far as we can determine from their reports our results are superior to those noted by Crawford and his associates, Buchholz, and others who have used peridural anesthesia as the primary anesthetic method. In one of Crawford's series the operative mortality rate was 0.5 per cent and the incidence of spread 1.65 per cent, while the incidence of postoperative death was not reported. It should be noted that Crawford and his associates (108) do not employ this technique on "private" patients. Ciocatto (149) and others (116, 150) from Dogliotti's clinic, and Bromage (6), another outstanding exponent of peridural anesthesia, recognize the superiority of general anesthesia and controlled ventilation over the peridural method for this purpose.

In summary, it may be stated that peridural analgesia may be employed as the sole anesthetic method for intrathoracic operations only by surgical teams, the members of which work together constantly, fully understand the problems that arise from its use (a conscious patient who becomes restless, occasional bouts of paroxysms of cough, bucking, mediastinal flutter, and marked respiratory movements), and are willing to cope with them. We cannot recommend it for routine use by the anesthesiologist who works with different surgeons, some of whom cannot operate under these conditions. To use it under such circumstances may cause far more harm to the patient than its benefits warrant. It should not be employed either alone or in combination with general anesthesia in geriatric patients with notably diminished cardiovascular reserve. It may prove very useful to provide surgical and postoperative analgesia to younger, husky adult patients.

Abdominal Operations.—Many writers (1, 2, 6, 8–27, 37, 44–46, 52, 75, 78, 82, 84, 87, 90, 99, 101, 104, 105, 117, 120, 134, 149–155) have considered peridural anesthesia of special value for operations within the abdomen because it provides optimal operating conditions similar to those of subarachnoid block without many of its disadvantages. Good muscular relaxation, diminished bleeding, contracted intestines, quiet operating field, and minimal or no effects on the liver, kidneys and other parenchymatous organs, and no depression of respiration have been cited as some of the advantages peridural block affords over general anesthesia, especially in poor risk patients and in those with disease of the liver and kidney. Moreover, it may be continued during the postoperative period in a more limited segmental form to provide relief from severe pain and obviate reflex muscle spasm (4, 6).

Bromage (6, 159) found this method of postoperative analgesia far superior to narcotics because it afforded the patient complete pain relief and improved ventilation. Dogliotti (1, 2), and others (53,
87, 95, 156, 157) contend that peristalsis and other functions of the gastrointestinal tract return sooner after peridural block than after general anesthesia, and that ileus rarely occurs after peridural block and is certainly much less frequent than with general anesthesia. While these benefits of peridural anesthesia have been long recognized and may be used as arguments for its use, this method presents certain disadvantages which offset them. In order to evaluate them properly it is necessary to describe briefly the problems peculiar to each technique of peridural block for surgery of the upper and lower abdomen.

Peridural anesthesia for upper abdominal surgery may be produced in the form of segmental or total block. The segmental technique, which requires injection at approximately the eighth thoracic segment and the use of small volumes (10 to 15 ml.) of local anesthetic, affords the advantages of a limited block. Since the lower limits of nerve interruption theoretically reach only the twelfth thoracic segment, the lumbar vasomotor segments are spared, as well as the motor fibers to the skeletal muscles of the lower extremity, to the urinary bladder and other pelvic viscer, with obvious advantages in regard to blood pressure and postoperative complications (such as, urinary retention and thromboembolism). However, the lack of anesthesia in the pelvis may prove disadvantageous if the surgeon wants to explore this region. Moreover, the greater difficulty in performing thoracic peridural puncture may outweigh the aforementioned advantages. Total peridural block for abdominal surgery is usually performed by injecting relatively large doses (20 to 25 ml.) of solution in the upper lumbar region. This usually effects anesthesia from the fourth or fifth thoracic to the fifth sacral segment. In determining which of these two techniques should be used, consideration must be given to the ability of the operator to perform thoracic peridural puncture and the practice of the surgeon in exploring the abdominal cavity.

Regardless of which two of the techniques is employed, there are two problems common to both procedures which occasionally occur and prove disadvantageous: hypotension and stimulation of unanesthetized nerves in the upper abdomen. Since even a limited segmental block produces interruption of most of the vasomotor segments which supply the splanchnic region, a moderate to severe hypotension usually results. This may admittedly be managed successfully with vasopressors, but it is still an important consideration particularly in patients in poor physical condition owing to shock, hypovolemia, intestinal obstruction, and cardiac disease. Moreover, many patients undergoing operation on the stomach or gallbladder frequently experience discomfort and develop retching, vomiting, hiccups and occasionally cardiovascular and respiratory disturbances owing to initiation of the Brewer-Lmekhart or celiac plexus reflex. This is, of course, a result of stimulation of unanesthetized sensory pathways.
associated with the phrenic, vagus, and sympathetic nerves, and it can be obviated, therefore, only by injecting these structures individually with a local anesthetic or by performing an anterior celiac plexus block. Unfortunately many surgeons are not adept with these procedures or do not want to bother with them. It then becomes necessary to give the patient light general anesthesia for varying periods of time. Not infrequently it is necessary to insert an endotracheal tube to assist the respirations, thus neutralizing some of the advantages of regional anesthesia. In our practice peridural analgesia without complete motor block has not proved adequate for upper intra-abdominal operations, so it has been necessary to use the highest therapeutic concentrations of the local anesthetic with consequent paralysis of the lower intercostal muscle segments. Reflex homeostatic mechanisms and the sensitive respiratory center of the conscious patient can compensate for this paralysis by increasing the activity of the unaffected intercostal muscles and diaphragm (39). However, as soon as the functions of these structures are depressed by the general anesthetic, compensation is diminished and it then becomes necessary to assist ventilation. In such instances the use of peridural anesthesia is still advantageous as requiring less general anesthesia than in its absence, and there is retention of spontaneous, albeit depressed, respirations, which obviate the use of controlled ventilation and the associated alterations in cardiopulmonary hemodynamics (158). However, these two disadvantages of peridural anesthesia (hypotension and frequent occurrence of discomfort and retching) considered together with the advantages of the improved techniques of balanced general anesthesia decrease markedly the disparity between regional and general anesthesia which formerly existed. It is no longer the case of comparing the profound depressant effects on the peripheral vascular bed, the kidneys, liver and heart of deep ether anesthesia administered for 2 or 3 hours for a gastrectomy with the effects of 3-hour subarachnoid or peridural block. Admittedly, our results in 605 patients who underwent gastrectomy and cholecystectomy, as well as a number of other upper abdominal operations with peridural block, were highly satisfactory. However, they were not so far superior to those obtained with general anesthesia to warrant recommendation of the routine use of this procedure for upper abdominal surgery.

In trying to select the method best suited, the anesthesiologist must compare the potential hazards inherent in the prolonged use of muscle relaxants with the potential hazards and possible disadvantage of peridural block. Disregarding for a moment the unfavorable report on muscle relaxants recently published by Beecher and Todd (123), all responsible anesthesiologists admit there are undesirable effects and potential hazards to the use of muscle relaxants and of general anesthetics. What must be decided is whether in the problem at hand these are less or more likely to produce harm than are the
undesirable effects and potential hazards of peridural block. Assuming that the anesthesiologist is capable of administering both equally well, then the patient and surgeon are the deciding factors. If the surgeon is gentle in exploring the upper abdomen and in placing traction on the stomach, gallbladder or other visceras, and if the patient's condition does not contraindicate an extensive vasomotor block, peridural anesthesia offers significant advantages and is the procedure of choice. In addition to providing operative analgesia it is of great value in completely relieving postoperative pain, and it thus permits better ventilation (159).

On the other hand, if the habits and behavior of the surgeon are such that the patient is likely to experience physical and mental discomfort during most of the operation, it is far better to use general anesthesia from the beginning. Whether muscular relaxation is to be attained with a peridural block as advocated by some (160) or with muscular relaxants depends on the skill and experience of the anesthesiologist and the status of the cardiovascular system of the patient. Certainly if the patient has shock, hypovolemia, or marked arteriosclerosis, it is best to avoid peridural block because, although by using vasopressors one can control the hypotension which follows the extensive vasomotor paralysis, these patients fare much better with properly administered balanced anesthesia.

If peridural block is selected as the method of anesthesia, it is advisable to insert a "continuous" catheter in case deficiency in the intensity, extent or duration of analgesia should make reinjections necessary. This is especially important in gastric resections, reconstructive biliary surgery and pancreatectomies.

Lower Abdomen.—Although some points made in the preceding paragraph apply to the use of peridural block for surgery of the lower abdomen, there are significant differences that make this method one of the better anesthetic procedures for operations in this region. For one thing, operations in the lower abdomen usually do not entail strong stimulation of the vagus and other unanesthetized sensory nerves. Moreover, it is not necessary to have analgesia extend above the sixth or seventh thoracic neurotome, because the intestinal tract below the duodenum and all other visceras of the abdomen have sensory (pain) fibers which enter the cord not higher than the ninth thoracic segment and the skin incision does not usually involve segments above the seventh or eighth dermatome. Since this is below the critical level for the homeostatic vasomotor apparatus (119, 125), there is significantly less incidence of severe hypotension. Moreover, intercostal muscle paralysis need not extend above the ninth segment so that ventilation of the patient is adequate and spontaneous.

For these and other reasons we consider peridural block a procedure of choice for patients who require appendectomy, operations involving the jejunum, ileum, cecum and colon, hysterectomy and other gynecologic procedures, cesarean section and some urologic opera-
tions. It is preferred over subarachnoid block solely because it does not entail perforation of the dura-arachnoid and the risk of headache and the other rare complications of spinal anesthesia. In our clinic, these advantages have become recognized by surgeons and patients alike and have caused this method to be accepted readily by those who refused subarachnoid block.

As previously mentioned, in the early periods of this study we attempted to perform some of these operations with limited segmental block, but in many instances the discomfort during the exploration of the pelvis (which is, of course, supplied by sacral segments) necessitated supplementary anesthesia. In recent years excellent results have been obtained in over 90 per cent of these cases, by producing blocks which included the sacral as well as the lumbar and lower thoracic segments. Such an extensive block can be produced by injecting not more than 20 ml. of solution in the fourth or fifth lumbar interspace. For operations of the pelvis and lower abdomen this procedure offers two distinct advantages over caudal anesthesia: (1) the amount of solution needed for peridural block is only one-half to two-thirds the amount necessary for caudal and (2) in the hands of the operator who can perform both procedures with equal skill, a higher rate of success will be encountered with the spinal peridural technique because there is a significantly less incidence of anomalies in the lumbar spine than in the sacral and coccygeal region.

We prefer peridural block for cesarean section because, in addition to the well-known advantages of spinal anesthesia in these cases, it obviates the headache problem and other disadvantages inherent in subarachnoid block, and, more important, the extent and degree of anesthesia can be better controlled with peridural analgesia than with the latter. It is well known that occasionally, even when administered by the experienced operator, subarachnoid block "gets away" and extends unduly high in these patients and produces a severe hypotension which endangers the fetus as well as the mother. With our usual technique of peridural block for cesarean section, which entails injecting 15 ml. of solution at the fourth lumbar interspace, analgesia extending from T1 to S5 is produced. Hypotension occurs but is slower in onset than that following spinal anesthesia, and the operator is thus afforded more of an opportunity to control it. Many authors (32, 103, 161–167) have indicated that they consider peridural block superior to most other forms of analgesia for this purpose.

Abdominal gynecologic operations have always constituted one of the most important groups of surgical procedures for which peridural anesthesia is indicated. Favorable reports have been made by many (1, 2, 19, 20, 26, 27, 44–46, 52, 78, 89, 103–105, 149, 160, 168–172). In our practice this technique has proved one of the best methods of anesthesia for gynecologic operations providing adequate results in nearly 95 per cent of the 395 patients. In some cases supplementary anesthesia was needed only for very short periods during exploration of the
upper abdomen. Since complete motor paralysis is not needed above the ninth thoracic segment, there is minimal interference with respiration; and this situation is advantageous in patients in the Trendelenburg position. In four patients who underwent pelvic exenteration, continuous peridural block was employed with excellent results to produce anesthesia and induce "controlled hypotension" to decrease operative bleeding for periods up to 9 hours. It is interesting to note that the Trendelenburg position did not significantly interfere with the caudad spread of the solution from the tip of the catheter at the lumbosacral junction to the sacral canal. This is probably due to the fact that even with the table moderately tilted the sacral canal is at the same level or below the level of the catheter tip (4, 106).

Sigmoid and Rectum.—Peridural block may be used to advantage in prolonged operations of the sigmoid and rectum, such as abdominoperineal resection, in which it has obvious advantages over caudal block. The only advantage it has over subarachnoid block for this purpose is the lack of headache which in this group of patients is not a serious problem.

Urologic Operations.—Urologic surgeons were among the first to recognize the value of segmental peridural block and to employ it for operations on the kidneys, ureters, urinary bladder and prostate (1, 2, 14, 36, 37, 52, 149, 173–177). Our results have been highly satisfactory in this sphere, but several problems have arisen which deserve emphasis.

Theoretically a block involving the eighth thoracic to the fifth lumbar segments inclusive, produced by injecting 10 ml. of solution at T₁₂ or L₁, should provide adequate anesthesia for operations on the kidney and the ureter, thus affording the advantages of a true segmental block without affecting the nerves to the urinary bladder and to the muscles of the lower extremities. However, as is well known, renal operations occasionally develop into complicated, time-consuming procedures, so that one should be prepared to extend the anesthesia and its duration. Even with the continuous technique this is difficult to do because the acutely flexed lateral position diminishes the efficacy of subsequent injections since gravity causes the solution to spread predominantly to the lower, unaffected side and away from the site of operation. For this reason it is best to use a mixture containing a long lasting drug for the initial injection; this is performed with the patient on the affected side, in which position he remains for approximately 10 minutes. If the surgeon needs to excise one or more ribs in order to remove the lesion, there is the risk of pneumothorax which is difficult to manage without an endotracheal tube. Intubation in this operative position is sometimes difficult. It is essential to consider that this position impairs respiratory movements, especially if the patient has a fixed thorax or has pulmonary disease. Not infrequently respiration is further impaired by complementary light anesthesia, often necessary to obviate psychologic
stress and physical discomfort owing to the extreme lateral flexion. In such instances it is preferable to use assisted or controlled respirations with an endotracheal tube.

The results obtained in patients who underwent cystectomy or suprapubic cystotomy with peridural block were satisfactory, since analgesia was effected without complete motor paralysis of the lower extremities. In elderly patients this factor may help to decrease the incidence of thromboembolism. In a few instances the surgeon noted that the capacity of the bladder was less than expected, which circumstance may have been due to the incomplete block of the visceral motor fibers.

**Abdominal Wall Operations.**—Operations on the inguinal and femoral regions constitute one of the most important, if not the most important, application of peridural anesthesia for surgery. Inguinal herniorrhaphies can be done with a limited segmental block involving the tenth thoracic to the third or fourth lumbar segments produced by injecting 8 to 10 ml. of solution at L₄ interspace. This affords the obvious advantage over subarachnoid block of not involving the pelvic viscera or lower extremities. Hypotension may occur, but, except in patients who have marked arteriosclerosis or those in whom the block is more extensive than desired, it is minimal. This procedure is performed easier and more quickly, with less discomfort to the patient, than infiltration, field block or paravertebral block, and provides analgesia which is more certain. This is especially important in patients who are obese, or those who have a large hernia or one that is incarcerated. By using a catheter, repeated injections can be effected to extend the duration of analgesia in patients with difficult hernias or with bilateral lesions.

Peridural block also affords the same advantages for ventral herniorrhaphies, excision of scars, and tumors and other operations of the abdominal wall below the umbilicus. Large hernias above this region, which require anesthesia of more than a few segments, are better done with bilateral intercostal block, since this procedure does not interrupt the splanchnic vasomotor nerves. However, if the operation entails intra-abdominal exploration, peridural block is superior because it also interrupts visceral afferent fibers.

**Spine and Adjacent Structures.**—The advantages of regional anesthesia for operations on the spinal column are well known, and hypobaric subarachnoid block has been considered the procedure of choice for many years because it obviates the many problems inherent in general anesthesia administered to patients in the prone position. Our results with peridural block in a total of 79 patients, including 66 who underwent excision of herniated intervertebral disc or fusion or both, indicate that this procedure is not as satisfactory as subarachnoid block, because sometimes the analgesia was incomplete. This may be due to interference of diffusion of the local anesthetic by the lesion. Junge (178) and Tiwisina (179) have demonstrated
by peridurography that herniation of the disc into the canal encroaches upon and narrows the peridural space. Interference with the diffusion of the local anesthetic and incomplete anesthesia are especially prone to occur in patients who have had a previous laminectomy, probably as a result of obliteration of the space by the postoperative scar tissue (181).

A number of clinicians (52, 97, 178, 179, 181) believe that extradural anesthesia is particularly useful in patients with herniated intervertebral disc because it aids in the diagnosis and in the localization of the involved nerve root. They have noted that during peridural injection there is aggravation of "sciatic" pain and other symptomatology associated with herniated disc. Moreover, they claim that since the irritated nerve root remains sensitive, its manipulation during operation will aggravate the pain whereas touching other nerve roots will not cause any discomfort, and this differentiation aids in localizing the lesion. We have been unable to confirm this.

Others (6, 52) claim that the injection into the peridural space of local anesthetic solutions containing high concentrations of epinephrine results in definite vasoconstriction producing consequently a relatively bloodless field. We attempted to determine whether or not bleeding occurring during operation was less with peridural block than with spinal or general anesthesia, but we were unable to arrive at any definite conclusion. Certainly, if there is any difference it is minimal.

Chordotomy constitutes another very important application of peridural block, since the segmental type of anesthesia provides analgesia for the conscious patient and optimal operating conditions for the surgeon, affording him an unparalleled opportunity for repeatedly testing sensations in the lower portion of the body during the course of the incision of the anterolateral quadrant of the spinal cord. It is acknowledged that chordotomy produces sustained relief with minimal complications only if the surgeon is able to determine the establishment of adequate levels of analgesia at the time of the operation. By having someone examine the patient repeatedly the surgeon can gradually increase the size of the incision until he obtains the desired results. We have found this method far superior to local infiltration and general analgesia for this purpose. Very favorable results have also been reported by Wester and Krumperman (180). Best results are obtained by injecting 12 to 15 ml. of 1.5 percent Xylocaine in the seventh cervical interspace.

Operations of structures adjacent to the spinal column for which peridural anesthesia can be used include lumbar and thoracolumbar sympathectomy. The continuous technique is preferable for this purpose. This method provides optimum operating conditions for lumbar sympathectomy because it interrupts the sympathetic as well as the somatic nerves and helps to predict the effect of the sympathectomy. In some patients who undergo the more extensive operation of thoracolumbar sympathectomy, it is necessary to supplement the block
with general anesthesia with endotracheal intubation, especially if
the surgeon accidentally incises the pleura during the operation.

Lower Extremities.—The significant advantages of regional anes-
thesia for surgery which is limited to the lower extremities are well
known and appreciated by all those who have had sufficient experience
with this method. For this purpose peridural block affords the ad-
vantages of peripheral nerve block and of subarachnoid block without
their disadvantages (1, 4, 6, 19, 26, 52, 130, 155). Certainly, the fact
that this procedure entails only one puncture and is simpler to perform
makes it superior to blocking the sciatic, femoral, obturator, and
lateral femoral cutaneous nerves to produce anesthesia of the lower
extremity. Moreover, the anesthesia is more certain and can be
extended for a long period of time by using the continuous technique.
We have been very pleased with the results obtained with this method
in long operations involving the hip, knee and ankle joints, in various
reconstructive orthopedic procedures, prolonged plastic operations,
and bilateral vein ligation and stripping. Analgesia limited to the
lumbar and sacral segments, obtained by injecting 12 to 15 ml. of
solution in the fifth lumbar interspace, is especially advantageous
in elderly patients in whom it may be better controlled than sub-
arachnoid block. It should be noted that if complete muscular
paralysis is required for orthopedic operations, it is necessary to
employ 2 per cent Xylocaine or equiparalytic concentrations of other
drugs. The continuous technique should be employed (except in very
short, superficial operations) in order to permit reinjection should
the intensity or duration of anesthesia warrant it. The small number
of cases recorded in some of the categories in this group of patients
can be explained by the fact that many of the short closed bone oper-
ations were performed with sciatic-femoral nerve block.

Perineal Operations.—Lumbar peridural block may be used to ad-
vantage in patients who require operation in the perineal region,
especially if the procedure necessitates prolonged analgesia. Ex-
tradural block affords the advantages previously mentioned over sub-
arachnoid block. Whether the analgesia is to be effected by injecting
the solution via the sacrococcygeal hiatus or the lumbar epidural
route depends on the skill of the anesthesiologist with each of these
techniques. Lumbar epidural block offers advantages previously men-
tioned over caudal anesthesia. It is especially useful in patients in
whom extradural anesthesia is desired and in whom caudal blocks can-
not be produced either because of technical difficulties or because of an-
tomic anomalies. On the other hand, peridural block is more difficult
to master and may involve more serious complications since it is
easier to accidentally enter the dura in the lumbar region than when
the needle is inserted through the sacrococcygeal hiatus. Moreover,
patients are more prone to object to a “needle stick” in the lumbar
spine than in the region of the “tail bone.”
OBSTETRICAL ANALGESIA

The superiority of regional anesthesia in obstetrics is well appreciated by all physicians interested in this problem (111, 182, 184). In the hands of one skilled in peridural block this procedure provides all of the benefits of caudal and saddle block without some of their disadvantages. The absence of headache following extradural anesthesia is a significant advantage that this procedure has over saddle block because, as is well known, this problem is especially important in this group of patients.

In recent years we have employed continuous peridural block in many instances in which extradural analgesia was desired, either because the caudal approach could not be used or because for some reason we considered lumbar peridural block a better method. The advantages and disadvantages of the two techniques for this purpose are similar to those previously mentioned. In addition, the lumbar peridural approach offers the very significant advantage of producing subjective relief of labor pains more rapidly than when the solution is injected via the sacrococcygeal hiatus. This is probably related to the fact that the site of injection is nearer to the sensory (pain) fibers of the uterus.

Occasionally the anesthesia is not as intense in the region of the perineum as it should be, probably as a result of inadequate diffusion of the solution in the lower portion of the sacral canal. This problem can be prevented either by having the patient sit up during the injection or merely by placing several pillows under the thoracic spine and shoulders. Cleland (164, 165) has suggested the use of two catheters—one placed in the middle lumbar region and the other through the sacrococcygeal hiatus in order to produce a more specific block. The lumbar catheter is used during the first stage of labor to produce a very limited segmental block of the sensory nerves of the body of the uterus, which, as is well known, involve the lower two thoracic neurotomes. The caudal block is employed to provide perineal analgesia during the actual delivery and for the third stage of labor. We feel that the advantages of these techniques over a single catheter properly placed are not sufficient to warrant the extra procedure.

The successful use of lumbar peridural analgesia for vaginal delivery has been reported by many (28, 32, 103, 161, 163, 164, 165, 169, 170, 185).

DIAGNOSTIC, PROGNOSTIC, AND THERAPEUTIC PERIDURAL BLOCKS

We are firmly convinced that peridural block has its greatest usefulness as a diagnostic, prognostic, and therapeutic measure in the management of various disorders (4). While improvements and advances in general anesthesia have caused regional techniques, including peridural block, to be used less and less for surgical anesthesia, the use of these techniques for medical problems has been increasing. Our results in 480 patients have caused us to agree heartily with
Groenendijk (52), Ciocatto (135, 149, 186), and others (6, 75, 108, 172, 187, 188), who claim that the potentialities of this technique for this purpose have not been fully explored.

Peridural technique offers many advantages in managing disorders involving the body below the neck region. The fact that a catheter inserted into the peridural space can be maintained without displacement for hours, days, and even weeks much more easily and with less risk than a catheter placed in the subarachnoid space, paravertebral region and almost any other part of the body, makes this method superior to almost any other and makes it more useful and applicable in a greater variety of conditions. Since it effects interruption of somatic, visceral and sympathetic fibers, it may be used whenever block of any of these pathways is indicated. In order to obtain all the benefits of this technique it is necessary to carry out a precise segmental block restricted to the neurotomes involved in the disorder and to employ appropriate concentrations of local anesthetics. Frequently this method will permit the patient to ambulate.

It may be employed advantageously as a diagnostic method in problem cases in order to provide information concerning the mechanism of pain or other disturbance and to corroborate data obtained with other block techniques and other diagnostic aids. It is very useful as a prognostic procedure to help predict the probable effects of prolonged nerve interruption. This procedure may provide important information to the neurosurgeon if surgical section of the pathway is contemplated and will afford the patient an opportunity to experience numbness, paresthesia, weakness, and other effects resulting from the operation. A temporary block should always be performed before the injection of neurolytic agents is contemplated. Its value as a therapeutic measure results from the fact that it interrupts pain pathways and abnormal autonomic and skeletal muscle reflexes which frequently take part in the physiopathology of the disorder and not infrequently aid and perpetuate the so-called vicious circle.

It is important to realize that optimal results with this or any other nerve block technique are obtained only with proper application. This has been duly stressed in a number of previous publications from our clinic (4, 189–200) and need not be discussed here except to mention that a correct diagnosis, an understanding of the mechanisms involved in the pain or the disorder under consideration, an adequate knowledge of the anatomy and neurophysiology of these mechanisms, a thorough knowledge of the peridural technique and the agents best suited for this purpose, and an objective assessment of the result are important requirements.

Postoperative Pain.—Segmental peridural block is especially useful in managing severe, postoperative pain which is occasionally seen after any operation, but particularly after those in the chest and the upper abdomen (4, 6, 7, 35, 51, 159, 164, 165, 172, 186). By properly placing a catheter and by using small volumes of dilute solutions of
local anesthetic drugs, a complete sensory and sympathetic blockade may be effected without interfering with the function of the skeletal muscles. Since the sensory block involves somatic and visceral fibers, it not only provides relief of pain but prevents the development of abnormal somato-visceral, viscero-visceral, and viscero-somatic reflexes which result from surgical trauma and from postoperative irritation from the field of operation (4). These abnormal reflex disturbances lead to skeletal muscle spasm, bronchiolar spasm, inhibition of gastrointestinal function and reflex renal, splanchic, and other visceral arteriolar spasm, which in turn lead to such postoperative complications as hypoventilation (and consequent atelectasis, pneumonitis), ileus and abdominal distention and oliguria (4). In dealing with this problem, it is obvious that proper application of segmental peridural block is a method superior to the commonly employed narcotic analgesics which do nothing to prevent or correct these physiopathologic processes but rather aggravate them. Bromage (159) and Cleland (164) have demonstrated the superiority of this method with spirometric studies. We have used peridural block for this purpose in 125 patients with excellent results. We prefer 0.1 per cent Pontocaine or mepereine because these drugs provide analgesia for four to six hours and occasionally longer without significantly affecting the intercostal muscles.

In a number of patients we have employed this method as a prophylactic postoperative measure to prevent vasospasm, dysfunction, edema, and other signs of reflex dystrophy.

Neuritis and Neuralgia.—Segmental peridural block may be used to great advantage to control severe pain associated with segmental or peripheral neuralgia involving the cervical, thoracic, lumbar or sacral nerves. Since neuralgia is usually the symptomatic expression of a mechanical or inflammatory radiculitis or mononeuritis, it is essential to seek the cause and eliminate it. Occasionally the cause is unknown or cannot be eliminated, and it then becomes necessary to provide relief if the severity of the pain warrants it.

We have employed this technique to control the severe pain associated with acute herpes zoster and other infectious processes which involve nerve roots or formed nerves. Although it has been suggested that chemical nerve block mitigates the physiopathologic process of herpes zoster and thus shortens the duration of the disease and the incidence of postherpetic neuralgia (201-203), we are not at all convinced that such is the case and consider peridural block only as a measure to provide symptomatic relief. In a few patients with severe segmental or peripheral nerve pain due to osteoarthritis, herniated intervertebral disc, root-sleeve fibrosis, or other skeletal disorders, we have employed continuous peridural block to provide temporary relief, to obviate the associated skeletal muscle spasm and sympathetic dysfunction, and to permit the use of traction and other physical therapeutic measures which otherwise could not be employed.
Some clinicians (45, 92, 187, 204-207) have employed peridural block as a therapeutic measure in patients with sciatic neuritis, claiming that it effected a cure in a significant percentage of the patients. Some of these authors explain the results on the basis that acute sciatic neuritis is frequently due to infection and is accompanied by reflex muscle spasm. While it is true that nerve block may provide prolonged beneficial effects by relieving muscle spasm and interrupting the so-called vicious circle, it should be noted that the most frequent cause of "sciatica" or lumbosacral neuralgia is herniation of an intervertebral disc (4).

Causalgia and Other Reflex Dystrophies.—This group of disorders is characterized by pain, vasomotor and sudomotor disturbances, delayed functional recovery and trophic changes resulting from accidental or surgical trauma or infection (4). There is apparently an irritative lesion which serves as a chronic focus and constantly bombards the spinal cord, producing dysfunction of internuncial pool and widespread excitation that activate central stations into a frenzy of activity (208). This abnormal activity spreads and implicates the anterolateral horn cells, resulting in sympathetic hyperactivity, skeletal muscle spasm, and other reflex disturbances which, in turn, become new sources of noxious impulses. The vicious circle that results must be interrupted early by chemical blockade in order to preclude irreversible changes. Continuous segmental peridural block is one of the best methods of accomplishing sympathetic interruption because it provides analgesia at the same time. We have employed this method in 35 patients who have had severe forms of reflex dystrophy of the upper or lower extremity with good results. Similar results have been reported by others (52, 75, 135, 188, 207).

Phantom limb pain is a difficult clinical entity which is considered by some authors as a form of reflex dystrophy (4, 209). In most of these cases peridural block may be used as a diagnostic and prognostic aid to predict the effect of neurosurgical operation. Occasionally some of these patients receive prolonged benefit from a block extended for days.

Peripheral Vascular Disease.—One of the most important clinical applications of peridural block is in the management of peripheral vascular disorders, particularly in those cases in which vasospasm is the predominant physiopathologic process. In such instances this method not only effects sympathetic interruption thus alleviating reflex vasospasm of collateral vessels, dilating fully those vessels that can be dilated, and aiding the absorption of edema, but also provides relief of ischemic (somatic) pain.

In our experience this method has been of therapeutic value in patients with traumatic segmentary vasospasm, acute arterial occlusion as a result of embolism or thrombosis, arterial aneurysm, acute thrombophlebitis, and circulatory insufficiency secondary to frostbite, trench foot and immersion foot. In a number of these cases the con-
tinuous technique was used for preoperative relief, to provide surgical anesthesia for embolectomy or other operations, and to effect postoperative analgesia and sympahtetic block.

In patients with Raynaud’s disease and other chronic vasospastic disorders peridural block should be used only to provide temporary relief or as a prognostic measure, because in most instances sympathectomy is necessary if a prolonged sympathetic interruption is indicated. The same comments may be made concerning the use of this method in patients with thromboangiitis obliterans and arteriosclerosis obliterans. In patients with severe pain and trophic changes, continuous peridural block extended over a period of several days or weeks may prove of great benefit in providing both the relief of severe ischemic pain and sympathetic interruption which may halt the process until sympathectomy can be done. Many (6, 37, 45, 91, 135, 164, 165, 181, 186–188, 210, 211) report the use of peridural block for this purpose.

Musculoskeletal Disorders.—Severe, intractable pain owing to fractured ribs, fractured vertebra, and osteoarthritis of the spine or hips, periarthritis, bursitis, tendonitis, and severe muscle spasm may be relieved very effectively with continuous peridural block (4). We have employed this method to great advantage in patients with multiple fractures of the ribs, clavicles and bones of the upper extremity who could not be relieved with large doses of narcotics, which not only failed to provide relief, but also markedly depressed the respiration and endangered the patient with the potential hazard of pulmonary complications.

Visceral Pain.—Many investigators (4, 6, 45, 135, 149, 186, 216) have reported excellent results with this method for the treatment of acute pancreatitis. In addition to providing relief of pain, the sympathetic block is also said to relieve reflex spasm of the visceral vessels, the duodenum, the sphincter of Oddi, and the entire ductal system of the pancreas, so that there is rapid release of the extra-ductal pressure with emptying of the ductal system of its toxic fluids. The block also inhibits reflex ileus which frequently complicates acute pancreatitis. Although this technique has proven to be the best method of providing pain relief, we are not convinced that continuous peridural block significantly improves the physiopathologic process.

We have obtained good results in using peridural block for the management of renal and ureteral colic. In a significant number of these patients the block not only relieved severe pain but relaxed the ureter sufficiently to permit advance of the calculus to a point where it could be removed through a cystoscope, thus obviating an open operation (4). A number of other clinicians (43, 135, 186, 207, 211, 217) have reported similar results.

We have also employed this method in managing severe, intractable pain consequent to ruptured peptic ulcer, acute cholecystitis, and other acute abdominal disorders. In such instances the block was initiated to provide temporary relief during the preoperative period
and then extended for the operation. Evidence has been adduced which suggests that continuous sympathetic interruption effects subsidence or arrest of the inflammatory process of acute cholecystitis (34, 35, 218, 219). Of the many techniques that can be used for this purpose continuous peridural block is the most practical.

Its use has also been suggested as a diagnostic-therapeutic measure for various other abdominal visceral disorders, including congenital megacolon, spasm of the cardia, pylorus, sphincters, biliary dyskinesia, postcholecystectomy syndrome, celiac ganglion syndrome, gastrointestinal pain of undetermined origin, chronic pancreatitis, visceral crises of tabes dorsalis, idiopathic nephralgia, intractable bladder pain, orchitis, salpingitis, and dysmenorrhea (4, 75, 135, 149, 186, 188, 207, 217). Peridural block has also been employed by some clinicians (6, 47, 52, 91, 135, 186, 188) to mitigate ileus and reflex atony of the bladder. While it is true that peridural block produces complete sensory and sympathetic interruption and may thus improve temporarily the physiologic abnormalities and provide relief of pain if this symptom is present, further studies need to be done to clarify the value of this method for these purposes.

The use of peridural block has also been suggested for the treatment of pleuritis, pulmonary embolism and pulmonary edema, and bronchial asthma (4). Bromage (6), Groenendijk (52), and Odom (204) have noted improvement of patients with asthma, pulmonary fibrosis, and emphysema. Bromage suggests that the beneficial effects are due to bronchial dilatation brought about reflexly by hypotension and by reduction of pressure in abnormal anastomotic channels.

**Cardiovascular Disorders.**—Ciocatto (135, 186), Odom (204), and others (52) have suggested the use of limited segmental block in the treatment of intractable cardiac pain. Electrocardiographic studies made by Groenendijk (52) demonstrated that in young patients with a normal heart, high thoracic peridural block produced no changes in the electrocardiogram whereas in older patients with angina pectoris improvement was noted, particularly in the form of a decrease in the depression of the ST segment. He reported similar effects following stellate ganglion block.

Bonica (4), Bromage (6), and Crawford (108) report the use of this technique to provide sustained relief in patients with severe intractable pain owing to dissecting aneurysm of the aorta. Bromage believes that the vascular hypotension consequent to the block not only relieves pain but reduces the force of the blood "wedge" splitting the coats of the aorta and may thus lessen progression of the disease. Moreover, the block obviates reflex renal vasoconstriction and subsequent anuria which often accompany dissection of abdominal aneurysm.

Many reports have been published during the past 35 years on the use of sympathetic block in the management of reflex anuria (4, 6, 109, 135, 149, 186, 217, 220–224). Although the results noted in our
clinic have been variable, we believe that if anuria is on a reflex basis it is worth while to institute continuous segmental peridural block to attempt to initiate diuresis. The interruption should be limited to the involved segments and should be continued for several days.

Many investigators (4, 6, 64, 75, 135, 149, 186, 225–227) have reported dramatic beneficial effects from continuous extradural block in patients with eclampsia and other forms of toxemia of pregnancy. The block should be extended until it produces sufficient lowering of the blood pressure and should be continued until after the delivery. Most of our patients experienced rapid relief of headache and showed an increase in urinary output.

We consider segmental peridural block the procedure of choice for sympathetic interruption either as a prognostic or therapeutic measure in patients with hypertension. This method is superior to subarachnoid block for this purpose since it does not involve the lower extremities and is likely to produce a more complete and more certain sympathetic interruption than the paravertebral method. As previously mentioned, the procedure may be extended to provide surgical anesthesia.

A number of clinicians (4, 6, 75, 135, 186) have reported the use of extensive sympathetic blockade effected by the peridural method in the treatment of hypertensive cardiac failure. Although theoretically the bloodless phlebotomy that accompanies widespread vasomotor paralysis should relieve both the back pressure on the pulmonary vascular bed and the strain on the left side of the heart, our results have been poor in the small number of patients in whom this method has been tried.

Severe, intractable headache which follows lumbar puncture has been treated successfully by many clinicians by injecting saline into the extradural space (4, 6, 228, 229). Although most individuals prefer the sacrococcygeal approach the same effects may be obtained by injecting solution into the lumbar peridural space. Usually 30 to 60 ml. of normal saline are needed to produce the desired effects.

Cancer and Pain.—Segmental analgesia provided with continuous peridural block is of great value as a diagnostic, prognostic and therapeutic measure in patients with severe, intractable pain associated with cancer. This method is particularly useful in providing relief from pain of the trunk and lower extremity for days or weeks, and it also helps predict the effects of alcohol injections or chordotomy.

In our experience injection of alcohol in the peridural space, as recommended by some (52, 187, 204, 230), has failed to produce prolonged effects, and we have, therefore, abandoned this method. We have also been unable to obtain the prolonged effects from continuous peridural block reported by Dogliotti and Ciocatto (231). These clinicians noted that if mixed nerves were subjected to the action of concentrated local anesthetics for several days partial degeneration of
the sensory nerves occurred with consequent prolonged interruption. By using this type of "differential peridural block" they provided relief to 90 per cent of the patients thus treated, some of whom had intractable pain from cancer. After two years the results were considered good in 50 per cent of the patients and fair in another 30 per cent. Although most of our patients received continuous peridural block for a number of days, all had recurrence of pain soon after the block was terminated.

SUMMARY

A detailed analysis of 3,637 peridural blocks performed on 3,554 patients and a review of the literature on the subject have been presented in an attempt to evaluate spinal peridural block for surgical and obstetrical anesthesia, diagnosis, prognosis, and therapy.

The various aspects of the method have been discussed, and emphasis has been placed on the possible hazards. The physiopathologic effects of this form of anesthesia, together with their prevention and treatment, have also been discussed.

Each clinical application of peridural block has been considered, and this method has been compared with other methods generally used. In special circumstances, such as, cordotomy, inguinal herniorrhapsy, and various operations of the lower extremity and perineum, this technique affords certain advantages which are not attained by any other method. It is also of value in operations involving the lower abdomen. It may be employed for surgery of the upper abdomen, but for general use in this region modern balanced general anesthesia is preferable. Peridural block is even less useful for intrathoracic operations and operations about the neck. It may be indicated for patients who have bilateral lesions of the upper extremity and under special circumstances for operations on the chest wall.

Peridural analgesia is valuable in managing the pain of first stage of labor and in providing anesthesia for vaginal delivery and cesarean section.

Peridural anesthesia is most useful in the management of those various medical problems in which it can be employed as an aid in diagnosis, prognosis and therapy.

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