or planes that offer little resistance to injection. We need to distinguish these spaces from the epidural space.

The needle tilt test dispels this uncertainty. It tells us reliably when a needle has not yet entered the epidural space.

Resistance to injection is tested before and during a firm sideways tilting of the needle, in a direction opposite to the bevel (fig. 1). Tilting compresses the surrounding soft tissue against the side-facing bevel, and creates an unmistakable increase in resistance to injection. This artificially increased resistance can be produced with the bevel facing in any direction, but most noticeably when it is facing the unyielding interspinous ligament. If the test is positive, i.e., when tilting increases resistance, the needle can be confidently advanced further. After the bevel has entered the epidural space, tilting does not affect resistance to injection.

This test for needle position is laughably simple. It requires no devices and is performed in a moment. When there is doubt, it tells unfailingly what we need to know: whether to advance the needle further. In my hands, it has surpassed all other tests for verifying needle position.

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Blood Flow Limits and Signal Detection Comparing Five Different Models of Pulse Oximeters

To the Editor—Lawson et al.1 recently described a protocol that compared relative laser Doppler blood flow and the percent of systolic blood pressure at which a pulse oximeter (Nellcor Inc., Hayward, CA) fails to detect a signal during tourniquet occlusion of a limb. We utilized a similar protocol, to compare five different pulse oximeters during periods of increasing and decreasing tourniquet occlusion using a mercury manometer blood pressure cuff (Nellcor model 200, Hayward, CA; Novametrix 500 and 505, Wallingford, CT; Ohmeda BiX 3700, Boulder, CO; and Criticare Poet, Milwaukee, WI). As in Lawson’s study, we used a laser Doppler flow probe (Laserflo, TSI, St. Paul, MN) to measure relative changes in blood flow during different occlusion pressures. We were interested in comparing different models of pulse oximeters, which utilize different pulse detection algorithms, to determine the percent of systolic blood pressure and relative blood flow at which they fail to detect a pulse and report saturation data. The occlusion pressures and Doppler blood flows at which the pulse oximeters lost and regained a signal in our study are presented in tables 1 and 2.

Lawson et al.1 found that the Nellcor pulse oximeter failed to sense at a mean occlusion pressure which was 96% of control systolic pressure and a relative flow that was 8.6 ± 5.9% of baseline. We found that the five pulse oximeters studied showed failure signals at slightly higher systolic pressures (100–108% of baseline). Furthermore, the pulse oximeters studied were nearly identical in performance, although they have different pulse detection and saturation algorithms. We found no significant difference with Nellcor’s EKG lockout feature or Novametrix 505’s “super bright” LED. The pulse oximeters in this study continued to display saturation data very close to baseline values (98–100%) during progressive tourniquet occlusion until just prior to signal failure. The last saturation obtained before loss of signal detection was 95% or greater in 73% of our trials. We found that when the saturation did decrease below this level, the decrease was rapid and the pulse was inaccurate compared with that from the simultaneously monitored EKG. Furthermore, the oximeters displayed “low signal strength” or other alarm messages at this time. In contrast to Lawson’s findings, we recorded higher percent of baseline flows at the time of signal failure (25 ± 15%). We also observed that the Doppler flows were quite variable at any given blood pressure, although the percent flow at which each pulse oximeter failed to sense was remarkably similar (22–28% of baseline). Unlike Lawson’s protocol,

<table>
<thead>
<tr>
<th>Table 1. Cuff Inflation Phase (12 Subjects)</th>
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<tr>
<td><strong>Pulse Oximeter</strong></td>
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<tr>
<td>Nellcor 200</td>
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<td>CSI–Poet</td>
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<td>Novametrix 505</td>
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<td>Novametrix 600</td>
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<td>Biox 3700</td>
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we did not subtract “noise” from blood flow values. Instead, we used actual laser flow data after calibration in accordance with manufacturers’ recommendations.

After total occlusion of the limb and subsequent slow release of the tourniquet, we found that the pulse oximeter regained pulse and saturation data at 86 ± 7% of systolic blood pressure. The previous study reported an occlusion pressure that was 95% of baseline and a Doppler measurement of 4 ± 3.1% of the baseline flow. We found that the relative blood flow needed to be higher (38 ± 14%) for the five oximeters to sense a pulse during deflation of the occlusion cuff.

In summary, we found the five models of pulse oximeters to be similar in their ability to maintain an accurate pulse and saturation reading in the face of an artificially induced low-flow condition. It is still controversial whether a pulse oximeter can be used in performing an Allen test, to monitor the viability of replanted or revascularized digits or as a measure of adequate tissue perfusion. The pulse oximeter may not be adequate as a monitor of blood flow should not be surprising, since it was engineered to detect pulse absorbance differences and not flow. For example, during nonpulsatile extracorporeal circulation, the pulse oximeter is unable to detect a pulse or give oxygen saturation data, yet blood flow is obviously sufficient to maintain both adequate oxygenation and perfusion.

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REFERENCES
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A Greengrocer’s Model of the Epidural Space

To the Editor—The use of a model for initial instruction in epidural catheterization technique is a recommended practice that benefits the teacher, the pupil, and the pupil’s first patient. However, commercially available models are expensive (e.g., Spinal Tap Simulator, $955, Nasco, Fort Atkinson, WI) and, in my experience, soon lose the resistive feel of the “ligamentum flavum.” An ideal model would realistically duplicate the feel of the loss-of-resistance technique and be simply constructed of inexpensive, readily available materials. Such a model can be constructed with a banana, bread, and a balloon in a suitable frame (figs. 1, 2).

The banana, which represents in turn the skin, subcutaneous tissue, and the ligamentum flavum, is the crucial ingredient. The banana’s viscosity prevents dissipation of the force applied to the syringe plunger through needle tracks from previous attempts. Other common fruits maintain a brisk resistive feel only during the first puncture and are too juicy for this purpose. An average banana can be used for 30 attempts before it becomes mushy (unripe bananas need less frequent replacement). In addition, an average banana’s width (3 cm) is only slightly less than the distance from the skin to the epidural space in the average patient (4 cm).\(^6\)

The use of a thin spacer between the “ligamentum flavum” and the “dura” is not required, although it lowers the incidence of inadvertent “dural puncture” and provides some resistance to catheter threading. I recommend two slices of Wonder\textsuperscript{®} bread, although one thick slice of a denser bread or a ½-inch slice of foam rubber may be substituted. If foam rubber or dense bread with seeds is used, the teacher should try the model first to insure that catheter threading is possible.

The thin skin of an air-filled balloon identifies undue pressure on the “dura” with a loud, dry pop. A bag of intravenous solution may be substituted for the balloon; however, these bags are designed to be puncture resistant and may not portray well the delicacy of the real dura mater. Having once tried water balloons, I cannot recommend this practice unless floor mops are readily available.

A reusable frame can be constructed from a foam surgical headrest (new or used), a disposable clear plastic tray, a plastic bag, and tape (figs. 1, 2). The headrest represents the patient’s back while holding the other elements in place. Trays about three inches deep, such as the trays containing double-decker spinal kits, are ideal, although shallower trays can also be used. A transparent tray allows easy visual inspection. The tray rim should be removed so the model can stand upright on a table. The balloon can be inflated in situ more easily if the top of the tray is removed as well. A rectangle of plastic from a plastic bag lies between the headrest and the tape; it prevents the tape from sticking to the headrest or the disposable components. The lifetime of the headrest, plastic, and tape will depend on use; these elements need replacement in my models every 2 yr. My original 4-yr-old trays are still going strong.

The major drawback of this model is the tendency for the epidural