cardiac function by streptomycin and other antimicrobial agents. Am J Cardiol 26:505–511, 1970
4. Dajee H, Laks H, Miller J, Oren R: Profound hypotension from rapid vancomycin administration during cardiac operation. J Thorac Cardiovasc Surg 87:145–146, 1984
5. Benyon RC, Church MK, Clegg LS, Holgate ST: Dispersion and characterization of mast cell from human skin. Int Arch Allergy Appl Immunol (in press)
6. Faraj BA, Gottlieb GR, Camp VM, Kutner M, Lollies P: Development of a sensitive radioassay of histamine for in vitro allergy testing. J Nucl Med 25:56–63, 1984
7. Shaff RE, Beaven MA: Increased sensitivity of the enzymatic isotopic assay of histamine: Measurement of histamine in plasma and serum. Anal Biochem 94:425–430, 1979
8. Siraganian RP: Refinements in the automated fluorometric histamine analyses system. J Immunol Methods 7:283–289, 1975
9. Newfield P, Roizen MF: Hazards of rapid administration of vancomycin. Ann Intern Med 91:581, 1979
10. Bristow MR, Sageman WS, Scott RH, Billingham ME, Bowden RE, Kernoff RS, Snidow GH, Daniels JE: Acute and chronic cardiovascular effects of doxorubicin in the dog: The cardiovascular pharmacology of drug-induced histamine release. J Cardiovasc Pharmacol 2:487–515, 1980
11. Kaliner M, Sigler R, Summers R, Shelhamer JH: Effects of infused histamine: Analysis of the effects of H-1 and H-2 histamine receptor antagonists on cardiovascular and pulmonary responses. J Allergy Clin Immunol 68:365–371, 1981
12. Owens DAA: Histamine receptors in the cardiovascular system. Gen Pharmacol 8:141–156, 1977
13. Vigorito C, Russo P, Picotti GB, Chiariello M, Poto S, Marone G: Cardiovascular effects of histamine infusion in man. J Cardiovasc Pharmacol 5:531–537, 1983

Anesthesiology
67:125–127, 1987

Assessing the Level of Spinal Anesthesia Using a Neuromuscular Stimulator

RONALD M. MEYER, M.D.,* WILLIAM J. MCCUNE, M.D.†

The response to pinprick is commonly used for defining the area of anesthesia achieved by a subarachnoid blockade (SAB). Unfortunately, there are patients who might benefit from the safety of SAB anesthetic, but are noncommunicative, making it difficult to determine accurately the level of SAB without causing trauma from vigorous needle punctures.

During 2 yr of providing anesthesia for a general hospital with a large group of nursing home patients, we have been routinely using a hand-held neuromuscular stimulator (NMS) to test the level of SAB. The stimulator has been designed to pass a short burst of current through the skin to stimulate motor nerve fibers and activate the neuromuscular junction. The device also produces the sensation of a mild electric shock at the site of application.

A prospective, non-blinded, non-randomized study was undertaken to assess the degree of correlation between SAB levels as determined by NMS, with the pinprick method as a standard for comparison. Unable to elicit useful responses to sensory examinations in noncommunicative nursing home patients, we chose to study a model population of more cooperative patients.

METHODS

Fourteen consecutive, cooperative, English-speaking adult patients, who consented to receive SAB for surgical anesthesia, were examined. The male/female ratio was 4/10, and ages ranged from 19–80 yr. Surgical procedures undertaken included the obstetric (5), gynecologic (4), orthopedic (2), closed urologic (2), and general surgical (1). All SABs were injected with the patient in the lateral position using 5% lidocaine with 7.5% dextrose, or 0.5% tetracaine with 5% dextrose. Patients were then placed in the supine position. Tests of the level of SAB were performed using a sterile hypodermic needle and a "Sparkie" NMS [Dupaco, Oceanside, CA] within 1 min of each other, 5–10 min after the injection of the drug into the cerebrospinal fluid. Patients were instructed to look away from the site of sensory testing. In alternate patients, pinprick was tested first, while, in the other patients, NMS stimulation was first performed.

The patient's deltoid area was touched with the hub and then the point of the hypodermic needle, and the patient was instructed, "This is sharp. Say 'Now!' when

* Assistant Professor of Clinical Anesthesia, Northwestern University School of Medicine.
† Resident in Anesthesia, McGaw Medical Center and Northwestern University School of Medicine.

Received from the McGaw Medical Center and the Northwestern University School of Medicine, Chicago, Illinois. Accepted for publication January 30, 1987. Work was performed at Columbus Hospital, Chicago, Illinois, affiliated with the Northwestern University Medical School.

Address reprint requests to Dr. Meyer: Department of Anesthesia, Columbus Hospital, 2520 North Lakeview Avenue, Chicago, Illinois 60614.

Key words: Anesthetic technique: spinal. Monitoring: nerve; stimulator.

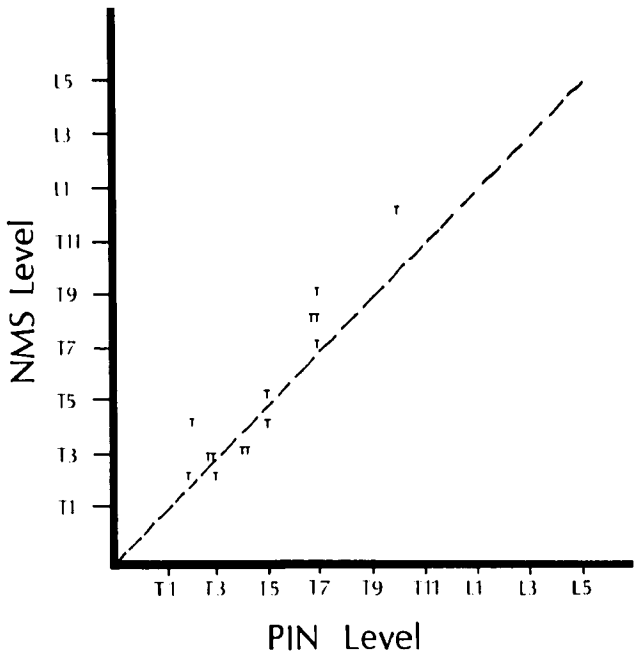

FIG. 1. The highest sensory dermatomal levels of blockade, as determined simultaneously by neuromuscular stimulator (NMS) *versus* the time-honored pinprick. Each T represents this comparison in a single patient. The dashed line of identity is where all Ts would lie were NMS and pinprick fully equivalent.

you feel the same sharpness, not just touching." The point of the needle was then tapped against the patient at roughly 3 cm intervals from the knee upward in the mid-axillary line. With a skin pencil, a mark was made on the skin at the level where the patient first identified the return of pinprick.

The NMS was then touched firmly to the patient's shoulder, and the touch-sensitive switches were activated in this order: low amplitude 2 Hz twitch, high amplitude 2 Hz twitch, low amplitude 50 Hz tetanus, high amplitude 50 Hz tetanus. This sequence produced progressively stronger sensations. The patient was instructed to say "Now!" when a pinch or twinge was felt. Patients responded to either the high amplitude twitch or the low amplitude tetanus. The same intensity of stimulus was then applied along the midaxillary line from the knee upward to the axilla, and then along the ulnar aspect of the upper extremity. A line was drawn at the level indicated by the patient when the sensation of the shock first returned.

We considered "the level" of the SAB to be the sensory dermatomal level immediately below the level at which the patient indicated the return of sensations of pinprick or NMS. The patients' affective and behavioral responses to the test procedures were noted.

The Spearman rank correlation coefficient[1] was determined for the level of SAB as determined by pinprick *versus* NMS. A nonparametric method was chosen because dermatomal levels were considered to be ordinal, not numerical data. A P value less than 0.05 was accepted as indicating statistical significance.

RESULTS

Patients tolerated both pinprick and NMS tests well. There were no complaints about either procedure, in the operating room or at the time of the postoperative visit 24 h later. When patients began to feel the pinprick or the shock-like sensation of the NMS, we noted in their facial expressions a wince or grimace, accompanied by an urgent report of the sensation. The facial expression and voice changes were very reliable indicators of the reappearance of sensation. Particularly in slender patients, it was common for stimulation of intercostal nerves to produce contractions of muscles of the chest and abdominal walls. These movements were never misinterpreted by the patients to be a return of sensation.

Figure 1 demonstrates the location of sensory levels as determined by NMS compared to the standard, pinprick. The correlation coefficient between the levels determined by the two methods was 0.836, with $P < 0.001$ for $n=14$.

DISCUSSION

During SAB, there is a difference between the highest levels of blockade of the various sensory modalities.[2] Anesthesiologists often mean the highest blocked level below the return of the perception of pinprick, when they refer to "the level" of a SAB. The data gathered in this investigation indicate that there is a close correlation in patients between the level of SAB as determined by the NMS *versus* pinprick, when both test modalities are used as described herein.

Previous researchers assessed responses to electrical stimuli to evaluate sensory blockade. Several studies have been published in which SAB was induced in rhesus monkeys.[3-5] The level of sensory anesthesia in the animals was determined by measuring the responses to painful electrical stimuli applied transcutaneously with needle probes. Positive responses included breath holding, facial grimaces, loud screeching, and thrashing about. The level of sensory anesthesia was defined as the most cephalad dermatome that could be stimulated bilaterally with no detectable response.

Andrade and Wikinski[6] developed a sophisticated device to monitor sensory levels in patients during spinal or epidural anesthesia. The device incorporated a NMS connected *via* a crossover box to wires that ended in two groups of bipolar electrodes, one for the right and the

other for the left side of the body. At any time during surgery, the sensory level on either side of the body could be tested by stimulating the appropriate electrodes. They did not publish the correlation between their device and pinprick in assessing levels of SAB.

In contrast to the technique of Andrade and Wilkinski, which may have required several minutes to attach the numerous electrodes to the patient, our NMS testing procedure is simple and takes no longer than the traditional pinprick method. With ease, a hand-held NMS can be pressed to the skin to deliver an atraumatic but unequivocally noxious stimulus. A NMS capable of generating stimuli of progressively greater strengths is well adapted to the application we describe here.

While it may be used to determine the level of SAB in many kinds of patients, the NMS presents special advantages when SAB is the anesthetic of choice in a patient in whom it would be otherwise difficult to determine the extent of the block until the patient evidenced intolerable pain during surgery. Such patients may have a language barrier or suffer from aphasia or dementia. Having a reliable test of the level of the SAB allows the confident application of SAB anesthesia to cases which would otherwise necessitate general anesthesia.

In the non-communicative patient, the objective signs of the extent of SAB may be the decrease in arterial blood pressure and heart rate which begin when the sensory level rises above T9, and the paralysis of the lower extremities and change in abdominal tone that is noticeable with sensory levels above L2. Neither the sympathetic nor the motor signs permit as precise a quantitation of the level of blockade as does application of noxious stimuli. Unfortunately, when using a pin vigorously enough to achieve an unequivocal response in most noncommunicative patients, skin penetration is unavoidable. Puncture wounds appear with particular ease on elderly patients,[2] and they can be plentiful after repeated testing of the level of SAB. Surgeons, fearing infectious complications, may object to skin perforations made over the sites of their incisions.

Of necessity, the population of patients examined in this prospective study consisted of communicative patients who could be relied on to relate sensations. To apply our findings to noncommunicative patients, one must be willing to assume that the noncommunicative patients would respond similarly if they could cooperate with sensory testing. Our experience performing dozens of SABs in a large nursing home population has given us the impression that NMS-determined levels of SAB are clinically valid. (These patients are not presented here because of the retrospective nature and inaccessability of the data.)

It has been our experience that patients unable to respond verbally, still indicate with a grimace, groan, or withdrawal when the electrical stimulus is perceived above the level of a SAB. While this testing procedure may, at first glance, seem cruel, it is less traumatic than using pinprick, and less painful than commonly performed procedures, such as venipuncture or urinary catheterization. Of note, communicative patients have never complained about the shock sensation. The mildest possible shock to which the individual patient responds is determined on a "control" area of skin over the deltoid, above the level of the SAB. When the shock sensation is first felt just above the level of the SAB, its intensity may be moderated by a partial neural blockade.

In summary, we describe a simple technique for testing the level of a SAB with a readily available electronic NMS, and demonstrate that the results of this technique closely duplicate results from the traditional method employing pinprick. The NMS is potentially useful in delineating with precision the extent of SAB in noncommunicative patients.

References

1. Glantz SA: Primer of Biostatistics. New York, McGraw-Hill, 1981, pp 217–221
2. Rocco AG, Raymond SA, Murray E, Dhingra U, Freiberger D: Differential spread of blockade of touch, cold, and pinprick during spinal anesthesia. Anesth Analg 64:917–923, 1985
3. Denson DD, Bridenbaugh PO, Phero JC, Raj PP, Turner PA, Ohlweiler DF: Evaluation of lidocaine spinal anesthesia in the rhesus monkey. Anesth Analg 60:756–759, 1981
4. Denson DD, Bridenbaugh PO, Turner PA, Phero JC, Raj PP: Neural blockade and pharmacokinetics following subarachnoid lidocaine in the rhesus monkey. I. Effects of epinephrine. Anesth Analg 61:746–750, 1982
5. Denson DD, Bridenbaugh PO, Turner PA, Phero JC: Comparison of neural blockade and pharmacokinetics after subarachnoid lidocaine in the rhesus monkey. II. Effects of volume, osmolality, and baricity. Anesth Analg 62:995–1001, 1983
6. Andrade PA, Wikinski JA: Monitor of sensory level during epidural or spinal anesthesia. ANESTHESIOLOGY 52:189–190, 1980