after fusion and even more so in patients with back pain long after surgery.

In summary, SPECT abnormalities were more commonly related to failure of fusion in patients early after surgery and to late adverse effects induced by apparently solid fusion in patients long after surgery. In addition to the previously established value of SPECT in detecting painful pseudoarthrosis, our results indicate that SPECT is of value in detecting painful late effects of spinal fusion.

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EDITORIAL

SPECT Evaluation of Lumbar Spinal Fusion: Will It Make the Medal Round?

In "The Assessment of Painful Late Effects of Lumbar Spine Fusion with SPECT," Even-Sapir et al. discuss a surgical procedure that is frequently performed, yet provokes a great deal of controversy (*1*).

In industrial countries, low back pain is common; up to 80% of the population is afflicted at some time in their lives. Among chronic conditions, low back problems are the major cause of activity limitations in the population under age 45. Numerous surgical and nonsurgical methods have been proposed to deal with conditions producing low back pain.

In 1911 Russell A. Hibbs and Fred H. Albee introduced lumbar spine fusion. Since that time, fusion of the lumbar spine by a variety of techniques has been proposed to restore stability in a number of congenital, acquired, and developmental spinal disorders. Although the enthusiasm for this procedure has waxed and waned, the operation is still commonly performed. Data from the National Hospital Discharge Survey, based on the Medicare population, reveals that between 1979 and 1987, spinal fusion was one of the fastest growing procedures performed on the lower back. The data shows that there was a 200% increase in the spinal fusion rate between 1979 and 1987 in individuals over age 65. Fusion is frequently performed in association with decompressive procedures; the theory being that laminectomy and discectomy reduce stability of the spine and that fusing the affected vertebral area will assure stability helping to prevent further back problems.

This editorial is not intended to outline the pros and cons of fusion, however, it is fair to say that the discussion of advantages and disadvantages of lumbar fusion remains one of the more heated debates in orthopedic and neurosurgical literature. One of the issues fueling the controversy is lumbar fusion's high rate of failure.

The primary cause of failure is the lack of formation of a solid, bony mass, i.e., pseudoarthrosis. It is thought that this failure to achieve solid fusion may lead to loss of alignment, instability, pain and potential neurological damage. The incidence of failure, or pseudoarthrosis is high and approximately the same whether the anterior, posterior or intratransverse process technique is used. The incidence also varies depending on the number of motion segments fused and the method used to subsequently diagnose pseudoarthrosis.

The reported incidence of failure varies from 9.5% when the diagnosis is based on radiological assessment, to as high as 30% when diagnosis is based on "routine second surgical look." The radiological approach is either a static one where an attempt is made to reveal the actual defect within the fusion mass, or a

Received Nov. 9, 1993; accepted Dec. 13, 1993.
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dynamic one where there is an attempt to establish excessive motion throughout the fused segment during flexion and extension. Given the significant number of false-negative radiologic procedures, surgical re-exploration unfortunately remains, even now, the diagnostic gold standard; with radiology a second, somewhat distant runner-up.

Other modalities proposed to evaluate the fusion mass for pseudoarthrosis include radiographic tomography, discography, computer assisted tomography, biplanar motion roentgenography, stereophotography and stress radiography—MRI has been a late entrant in this race. Based on the number of articles in the literature, each of these modalities has had a relatively small, although at times vocal following. MRI is too late an entrant to be fairly judged as to its efficacy over time.

Radionuclide scanning of the painful fused back was introduced in the late 1970s. However, it was almost immediately sidelined by the publication of two papers. The first, by Hannon in 1977 (*2*), showed an 82% false-negative rate and the second, by McMaster (*3*) in 1988, claimed a high overall diagnostic accuracy, but unfortunately also had a six out of 12 false-positive rate. These two papers are widely and almost singularly quoted throughout the orthopedic and radiological literature, basically sealing the fate of radionuclide scanning as a means of assessing the fused back until the advent of SPECT.

The availability of SPECT has rekindled interest in evaluating the failed back with radionuclide scanning since it was shown that both the area of failed fusion and vertebral levels above and below could provide useful information regarding probable causes of pain. As Even-Sapir et al. point out, successful arthrodesis, i.e., spinal fusion, can alter the biomechanics of the spine and create a compensatory increase in motion and mechanical loading on the free motion segments adjacent to the fusion. A number of authors have previously addressed this issue, but Even-Sapir et al. report the largest series with the most comprehensive and detailed description of the various areas of stress and their radionuclide appearance.

Regardless of how new and interesting that data may be, we are drawn back to the issue of SPECT and failed fusion itself since the Even-Sapir et al. article also has the largest series of patients evaluated with SPECT who have both stable and failed fusion. It is likely that this article will be pivotal in evaluating the relationship between spinal fusion and SPECT. In the overall group of 33 patients, 11 (33%) had failure of fusion. If we break this down further, six of the nine (67%) patients in the early group had failed fusion. We must remember that the failed fusions in this publication were based on roentgenological evaluation and not surgical re-exploration, so the number of failures may be higher. However, assuming that the roentgenographic data is correct, we still have a relatively large population with failed lumbar fusion.

The authors have dealt with failed fusion by dividing the patients into an early or a late group. They have come to the conclusion that in the early group, SPECT did well by identifying five of six failed fusions, and poorly in the late group, missing all five cases of failed fusion. The failure to detect failed fusion in the late group is ascribed to "drop off in activity" with time in the fusion mass.

On the surface, this conclusion appears to be straightforward and reproducible and therefore clinically useful. The thesis propounded is that if a patient with a failed fusion is evaluated before 4 yr, SPECT is useful; after 4 yr another method, probably radiological, is more applicable. A further conclusion is that if it is demonstrated that the fusion mass is intact yet the patient continues to experience pain, then SPECT can be useful in evaluating the changes occurring above and below the fused levels. It is unlikely, however, that the practicing clinicians dealing with patients with spinal fusion will accept the above conclusions without hesitation.

The basis for this hesitation is that the 4-yr cut-off between the early and late cases that the authors propose is not a standard period of time usually present in clinical or imaging literature. It may be a reasonable starting point for discussion, but if we use the more standard period of 2 yr, which appears in the literature as the cut-off between early and late cases, then the data become less certain. The delayed group would not consist of the original five patients with negative scans, as well as two patients with failed fusions and positive scans and a patient with a positive scan, but intact fusion. Similar mixed data would occur if we used a 1-yr period as the cut-off between early and late cases. Many clinicians tend to use the 1-yr period as a time by which a fusion should be stable.

In this era of outcome analysis, an imaging physician is not only required to provide reproducible data, but also to transfer that data into clinically applicable information. Those conclusions that are based on mixed data, particularly if the data are based on a relatively small number of patients, tend to leave the referring physician less than convinced and probably confused. They are more likely to continue an established modality for evaluating their patients.

Although the authors appear to have made excellent progress in providing important data about what seems to occur over a period of time when a normally mobile lumbar spine is restricted, they still have not fully defined the role of SPECT in patients with failed fusion. A large prospective study using SPECT of the lumbar spine needs to be carried out over a number of years on a group of individuals undergoing lumbar spine fusion. Then the "natural history" of both failed and successful patients would be determined. Hopefully, such a project can still be justified in this time of "cost-containment" in medicine.

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Condensed from *30 Years Ago*

A Preliminary Evaluation of Fluorine-18-Labeled Tetrafluoroborate as a Scanning Agent for Intracranial Tumors

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Radioisotopic localization of intracranial space-occupying lesions has become a standard diagnostic procedure in many neurosurgical centers, utilized routinely in patients with suspicion of tumor or other focal intracranial lesions.

Coincidence detection of the annihilation radiation from positron emission has distinct advantages in comparison with simple gamma-emitting isotopes for recording such lesions. Of those positron-emitting isotopes which have been evaluated in man, ^{72}As and ^{74}As as sodium arsenate have been the isotopes of choice from a localization standpoint. However, the long half-life of ^{74}As, 17.5 days, and the fact that it is cyclotron-produced are major disadvantages. Copper-64 chelates have been used to circumvent these two drawbacks of ^{74}As.

The work of Anbar et al. in producing and utilizing ^{18}F as a scanning agent is of great significance in this recent development. Fluorine-18 is a pure positron-emitter with a 112-min half-life. Large single doses may be administered for rapid localization of lesions and repeated tests performed within short time intervals.

The present work is a series of studies with animals and with human patients using potassium fluoroborate labeled with ^{18}F. It corroborates the excellent work of Askenasy et al. in the localization of intracranial lesions using the $B^{18}F_4$ anion.

While the number of scans performed, 10, is limited and allows no generalizations, we do confirm the results obtained by Askenasy et al. In all cases, except the benign intracranial hypertension in which there was no evidence of focal disease, the ^{18}F scan was checked against a scan with arsenic or copper, or both.

The glioblastomas were clearly localized. The fluorine scan was somewhat poorer than the copper, possibly due to the fact that the scan was begun 10 min after injection. This seems to be too short a time for good localization. In one case, an astrocytoma was clearly missed with both isotopes and was seen in another case. This is consistent with the analysis of arsenic scans—that astrocytomas are frequently not seen. In Patients F and I, there was some bony involvement of the neoplasms. In both patients, visualization with fluoroborate was better than with other isotopes. There is a possibility, which is being investigated further, that some fluorine may be split off biologically from the complex ion and appear as a fluoride ion going preferentially to such bone or that the $B^{18}F_4$ was contaminated with ^{18}F and a more rigorous purification of $B^{18}F_4$ is required. Metastatic melanoma in Patient G was missed with fluorine though seen with copper, and metastic carcinoma in Patient H was visualized with all isotopes, but the images were equally poor.

In summary, we think that labeled fluoroborate ion may prove to be a satisfactory scanning agent and should be explored further, as illistruated by these cases.

Although this series of scans reveals no unusual physiological advantages of $B^{18}F_4$ as a conventional scanning agent, its physical properties must be emphasized. Administration of 20 to 40 mCi, giving a whole-body dose of only 1 to 2 rads, would be permissible for routine scanning and even higher doses would be appropriate for patients with known focal lesions. While these higher doses per se do not guarantee better diagnostic accuracy, they would allow greatly refined resolution with currently used scanning times. Alternatively, the scanning time might be appreciably reduced. These improvements could open new avenues for scanning procedures such as transient studies.

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