FROM THE RESEARCH LABORATORIES AT THE ORTHOPAEDIC CLINIC (CHIEF: DOCENT S. VON ROSEN), MALMÖ, UNIVERSITY OF LUND, SWEDEN, AND THE ORTHOPAEDIC CLINC (CHIEF: PROFESSOR O. SCAGLIETTI) OF UNIVERSITY OF FLORENCE, ITALY

UPTAKE OF Sr^{85} IN NON-MALIGNANT VERTEBRAL LESIONS IN MAN

By

GÖRAN C. H. BAUER and PAOLO SCOCCIANTI

INTRODUCTION

Shortly after intravenous injection of bone seeking tracers like alizarine-sulphonate, lead, certain tetracyclines, radioactive calcium, strontium or barium, high concentrations of tracer will be found in areas where bone formations is active. With the aid of such tracers it is possible to locate areas of active bone metabolism occurring normally during growth and remodeling (for example calcifying metaphyseal cartilage, haversian systems) or pathologically (for example fracture, tumor, infection of bone). The ease of detection make radioactive tracers generally more useful than non-radioactive tracers. This is especially true of γ-emitting radioactive isotopes which may be detected *in vivo* with externally located scintillation detectors. Under clinical conditions this is an advantage over β-emitting isotopes which can usually be detected only in bone obtained at biopsy.

Bauer & Wendeberg (1959) have shown that in man external γ-counting of Ca^{47} and Sr^{85} may be useful for detection and delineation of localized bone lesions like fracture and tumor and for measurements of the rate of bone formation in such lesions. *Gynning et al.* (1961) have recently shown that this method can be used for detection of metastatic cancer in the spine.

This paper describes results of external counting over the spine following administration of Sr^{85} to human subjects with non-malignant vertebral lesions.

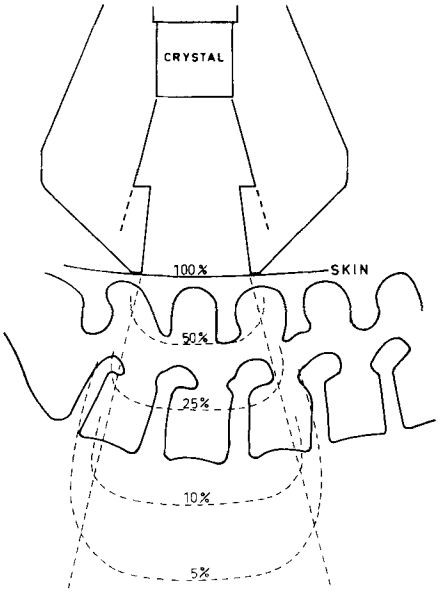

Fig. 1.
Equisensitivity curves (in water) of collimated crystal superimposed on linedrawing of lumbar spine. It is seen how the counter is more sensitive to Sr^{85} located in spinous processes than to Sr^{85} located in vertebral bodies.

MATERIAL

This study comprises 25 patients, 10 males and 15 females, ranging in age from 10 to 73 years (see Table 1).

The patients selected for study either had a localized lesion of the spine or were subjected to tracer studies of their bone metabolism kinetics because of more or less generalized disease. Individual diagnoses are recorded in Table 1.

METHODS

Isotope administration and detection.

In general, the methods for Sr^{85} administration and detection used in this study were those described by *Bauer & Wendeberg* (1959). The carrier-free Sr^{85} was injected intravenously at a dose not exceeding 1 μC per kg. body weight, usually 50 μC total dose. This dose does not exceed the permissible weekly dose of 0.3 rad as recommended by the International Commission of Radiological Protection. The counting

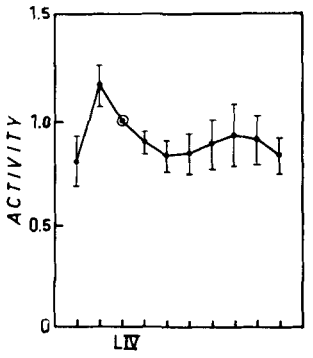

Fig. 2.

Normal pattern of externally recorded counting rate 14 days after intravenous injection of Sr^{85}. This curve was obtained by pooling individual values of 7 patients without localized vertebral lesions (cases 1–7 of Table I).—In each of these subjects each individual activity value recorded over the spinal counting levels on Day 14 was expressed as fraction of that recorded over L–IV. These values were pooled to give a mean value with standard deviation for each level counted over the spine. These mean values were plotted on the ordinate of a linear diagram in which the levels counted formed the abscissa. For comparison with data in individual cases, this curve has been drawn as a broken line in Figs. 3–13 and 15–A.

equipment consisted of a collimated scintillation detector (Fig. 1), a linear amplifier, a single channel pulse analyser and a scaler. External counting was performed over several levels of the spine at 7 and 14 days (Days 7 and 14) following isotope injection. In a few cases measurements over the spineous process of the fourth lumbar vertebra (L–IV), only, were carried out daily.

In each patient L–IV was used as a landmark for positioning the detector. Starting from this point the activity was recorded at equidistant levels 5 cm. apart in line with the spineous processes (see Fig. 2). Usually two levels distal to L–IV and seven proximal to L–IV were counted. No measurements were carried out over the cervical spine. The head of the collimator was kept parallel to the desk on which the patient was lying in the prone position. Owing to the curved configuration of the spine the collimator usually touched the patient's skin only with part of its border. At each measurement 1,000 impulses were recorded. No measurements were accepted in which the probable standard error of the net counting rate was higher than 5 per cent.

In addition to each measurement over the spine, the activities over knees and thighs were recordeed as previously described (2).

Correction for physical decay of the isotope was made by expressing

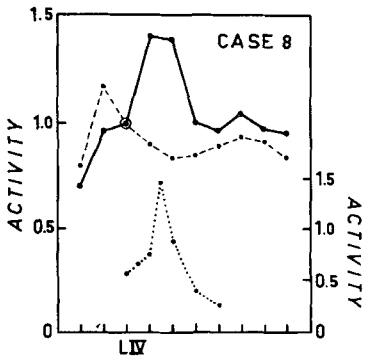

Fig. 3.

Case 8: a 68-year-old man with crush fracture of L–I. The injury occurred one month prior to isotope study. Dotted curve shows activity recordings (in arbitrary values) with narrow (24 mm.) cylindrical collimator. Broken curve represents normal values (see Fig. 2).

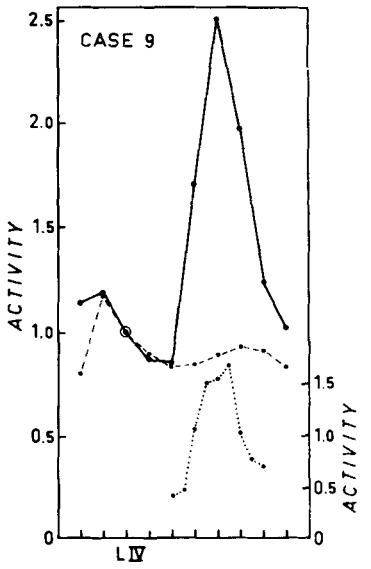

Fig. 4.

Case 9: a 34-year-old woman with crush fractures of Th–VIII, IX and X. The injury occurred one month prior to isotope study. Dotted curve shows activity recordings (in arbitrary values) with narrow (24 mm.) cylindrical collimator. Broken curve represents normal values (see Fig. 2).

all externally recorded activities as percentage of the counting rate of a standard sample of Sr^{85} measured immediately before or after recordings in patients.

A few patients received a second injection after an interval of some months (see Table I).

Representation of results.

The material was divided into two groups according to presence or absence of vertebral lesions. The former group comprised seven subjects in whom radiographic examinations failed to reveal any spinal disease. In each of these subjects each individual activity value recorded over the spinal counting levels on Day 14 was expressed as fraction of that recorded over L–IV. These values were pooled to give a mean value with standard deviation for each level counted over the spine. These mean

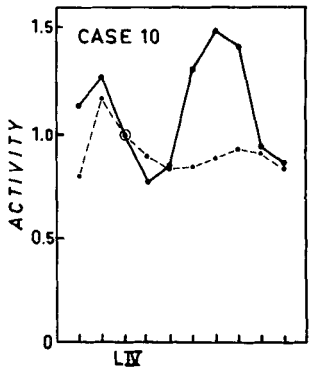

Fig. 5.
Case 10: a 73-year-old woman with crush fracture of Th–IX. The injury occurred 2 months prior to isotope study. Broken curve represents normal values (see Fig. 2).

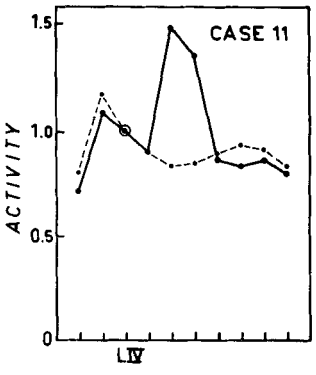

Fig. 6.
Case 11: a 23-year-old man with crush fracture of L–I. The injury occurred 2 months prior to isotope study. Broken curve represents normal values (see Fig. 2).

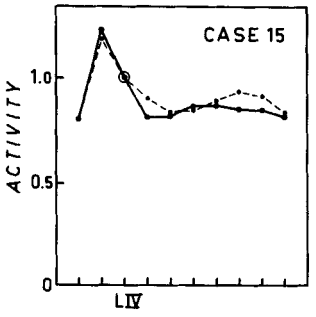

Fig. 7.
Case 15: a 55-year-old woman with crush fracture of Th–XII. The injury occurred 8 months prior to isotope study. Broken curve represents normal values (see Fig. 2). The uptake pattern is considered normal.

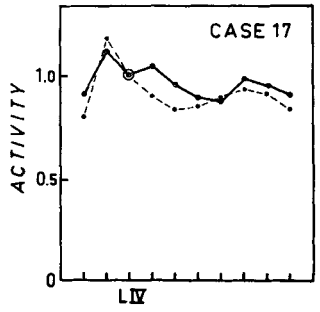

Fig. 8.
Case 17: a 57-year-old woman with crush fracture of L–II. The injury occurred 2 years prior to isotope study. Broken curve represents normal values (see Fig. 2). The uptake pattern is considered normal.

values were plotted on the ordinate of a linear diagram in which the levels counted formed the abscissa. The curve shown in this diagram (Fig. 2) forms the basis for evaluation of the individual spinal activity patterns recorded in cases with vertebral lesions. When the pathological lesion was situated close to L–IV, the spinal activity values were normalized with respect to one of the counting levels over the thoracic spine rather than L–IV (see Figs. 9 and 11).

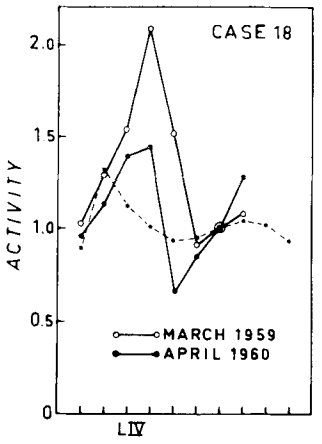

Fig. 9.
Case 18: a 59-year-old woman with a tuberculous spondylitis of L-II, known since 1 year prior to first isotope study. The second isotope study was made when general and local conditions had improved after immobilization in plaster and antibiotic therapy. Broken curve represents normal values (see Fig. 2). All values have been normalized to a counting level over thoracic spine rather than to L IV.

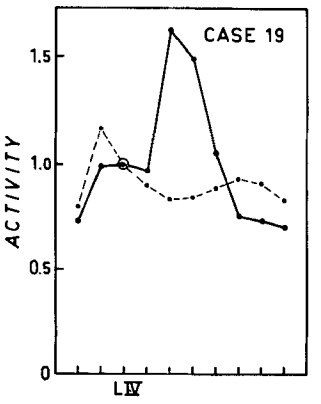

Fig. 10.
Case 19: a 39-year-old woman with a tuberculous spondylitis of Th-XII and L-I known since 1 year prior to isotope study. Broken curve represents normal values (see Fig. 2).

A deviation from the normal pattern in any level counted by more than twice the standard deviation of the normal mean value was used as a criterion for abnormal activity pattern.

When countings were made at several time intervals following isotope administration, time was abscissa instead of the levels counted.

In each case the activity ratio spine (L-IV)/knee was determined on Days 7 and 14. In addition similar ratios were determined for spine (lesion)/knee in cases with vertebral lesions (Table 1).

RESULTS

The results are expressed as detailed above, and are recorded in Table 1 and Figs. 1–13.

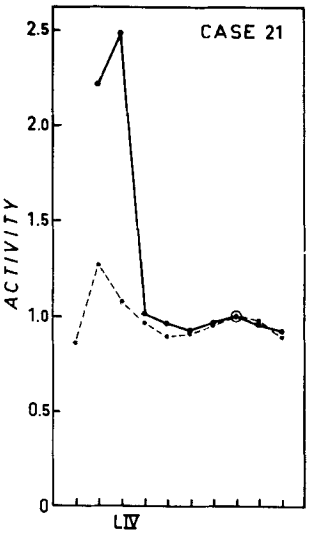

Fig. 11.
Case 21: a 47-year-old woman with non-specific discitis following removal of a disc herniation in the L–V—S–I interspace. The isotope study was made 8 months after operation. Broken curve represents normal values (see Fig. 2). All values have been normalized to a counting level over thoracic spine rather than to L–IV.

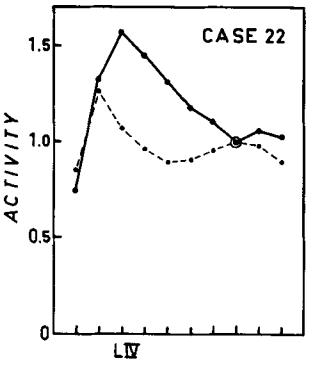

Fig. 12.
Case 22: a 51-year-old woman with spondylarthrotic changes, especially marked in lumbar spine. Broken curve represents normal values (see Fig. 2). All values have been normalized to a counting level over thoracic spine rather than to L–IV.

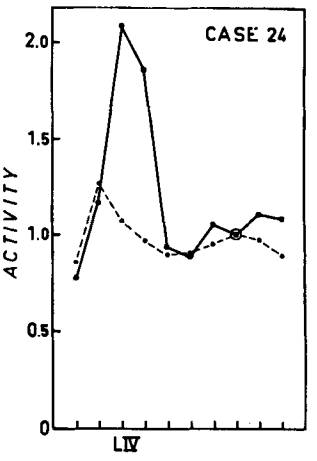

Fig. 13.
Case 24: a 50-year-old woman with spondylolysis of L–III. Broken curve represents normal values (see Fig. 2). All values have been normalized to a counting level over thoracic spine rather than to L–IV.

Cases without vertebral lesions (cases 1–7, Fig. 2).

Data were pooled from measurements on Day 14 in seven individuals without X-ray or other signs of localized vertebral lesions (Fig. 2). Two regions with higher uptake are seen: one over the sacrum and another, less marked, over the thoracic spine.

Cases with localized vertebral lesions.

(a) *Vertebral fracture* (cases 8–17, Figs. 3–8).

In most of the cases studied, a marked activity peak was found over the fractured vertebra(s) and usually also over adjacent vertebras. In one case a wide peak was apparently due to the fact that the fracture was located between two adjacent levels counted (Fig. 3). In two cases, only, the activity pattern did not significantly deviate from the basic pattern (Figs. 7 and 8).

(b) *Spondylitis* (cases 18–21, Figs. 9–11).

A higher uptake was seen over the lesion in two of the three cases with a *tuberculous spondylitis* (Figs. 9 and 10), while in the third patient the uptake pattern did not deviate from normal (case 20). One patient (Fig. 9) was injected twice. The second administration was given after about 1 year of immobilization in plaster and antibiotic therapy. The second activity pattern was similar to the first with the noteable exception that the counting rate over the lesion site was markedly reduced.

In a case of *non-specific discitis* after removal of a disc herniation an activity peak was seen over the lesion (Fig. 11).

(c) *Other localized vertebral lesions* (cases 22–25, Figs. 12 and 13).

Two cases of marked *spondylarthrosis deformans* were studied, one with an abnormal uptake pattern (Fig. 12) and another (case 23) with an uptake pattern which did not deviate from normal.

One case of lumbar *spondylolysis* had a peak uptake over the lesion (Fig. 13).

A normal uptake pattern was found in a case with a *lytic lesion* of unknown origin in the tenth thoracic spinous process (case 25).

DISCUSSION

Evaluation of external counting over localized vertebral lesions is complicated by (a) activity in adjacent tissues, (b) activity in bowel or bladder, and (c) lack of a suitable reference.

(a) Activity in soft tissues and adjacent metabolically active bone tend to "bury" that of a pathological lesion. It is known from earlier studies, however, that the soft tissue/bone activity ratio decreases during the initial 14 days following intravenous injection of Sr^{85}, and this seems to hold also for the normal bone/fractured bone activity ratio (2, 4). It was therefore decided to use the measurements made on Day 14 as a basis for comparison between subjects. The validity of this

decision is emphasized by the finding that the activity ratios spine (L–IV)/knee and spine (lesion)/knee increased from Day 7 to Day 14 in most of the subjects studied (Table 1).

(b) Activity excreted into the bowel or bladder may interfere with measurements over the spine. For example, the effect of slow bowel movements on activity measurements over the spine is illustrated in Fig. 14. For this reason, also, Day 14 will provide more reliable data than would ealier intervals.

(c) Comparison of measurements over the right and left legs or arms may serve as a basis for evaluation of results of external counting over the extremities. It is difficult to provide such a basis for spinal activity measurements. However, the results of this study confirm those of *Gynning et al.* that variation between subjects without X-ray or other evidence of localized spinal lesion is sufficiently small to allow construction of a reasonably reliable basic activity pattern for comparison with individual pathologic cases. It should be emphasized that the shape of this basic pattern is influenced by the detection apparatus used (for example size and shape of crystal and collimator).

A deviation from the basic pattern strongly suggests a pathological process in the spine. In one case studied in this laboratory it was found, however, that a large kidney stone caused a marked rise in the counting rate recorded over the adjacent spinous process (Fig. 15).

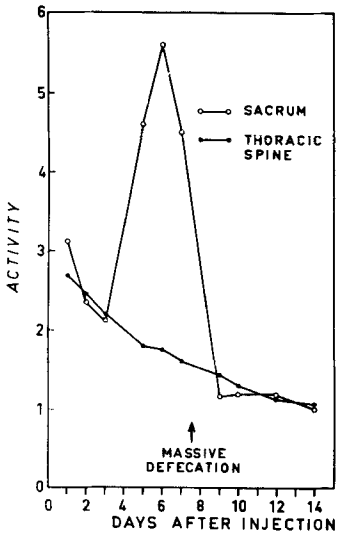

Fig. 14.
An isotope study was made in a 55-year-old man suffering from osteopenia. This graph shows the counting rate over the sacrum and the thoracic spine up to 14 days following intravenous injection of Sr^{85}. The peak counting rate over the sacrum was due to Sr^{85} in the bowel. The activity is expressed as fraction of counting rate over sacrum on Day 14. All values have been corrected for background and decay.

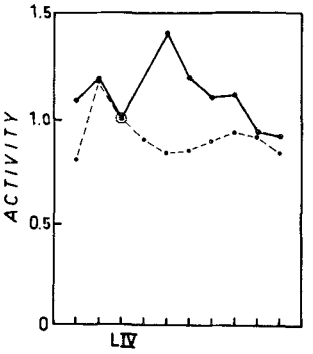

Fig. 15 a.

Fig. 15.
An isotope study was made in a 24-year-old woman with stones in her left kidney. A high counting rate was observed over adjacent spinous processes (Fig. 15 a). The counting rate over the left kidney was higher than over the right kidney (Fig. 15 b). After surgical removal of the stone, its external layers were found to contain Sr^{85}.

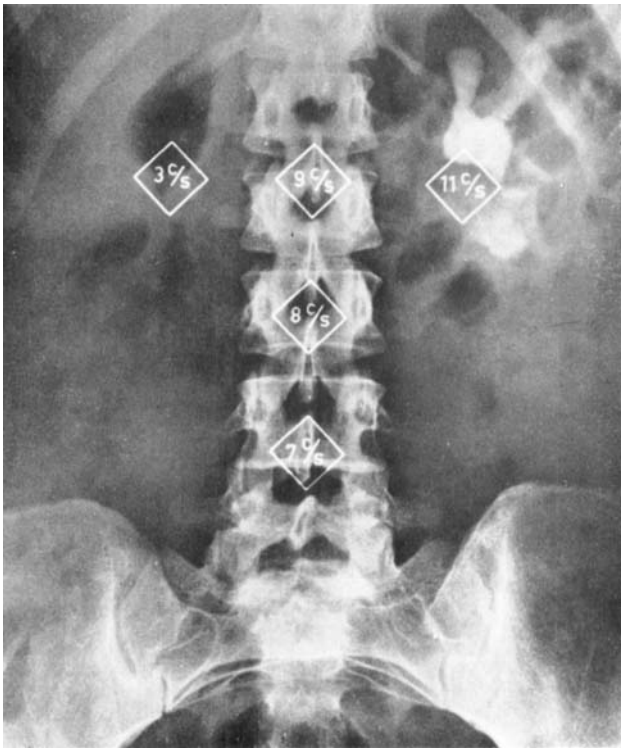

Fig. 15 b.

SUMMARY

With the aid of an externally located scintillation counter it was possible to demonstrate an increased spinal uptake of intravenously injected Sr^{85} in cases of vertebral fracture, spondylitis, and other types of localized vertebral lesions.

RESUME

A l'aide d'un compteur par scintillation placé extérieurement, il a été possible de démontrer une absorption spinale accrue de Sr^{85} injecté intraveineusement dans le cas de fractures vertébrales, de spondylite et d'autres types de lésions vertébrales localisées.

TABLE 1

The pooled Day 14 uptake data of patients 1–7 were used to build up the general pattern (Fig. 2).—In most cases the spine (healthy region)/knee ratios were found to increase from Day 7 to Day 14. This tendency was more marked for the spine (lesion)/knee ratios.—A further analysis of these ratios is in progress.

	Case	Sex	Age (years)	Diagnosis	Spine (normal)/knee ratio			Spine (lesion)/knee ratio		
					Day 7	Day 14	% change from Day 7 to Day 14	Day 7	Day 14	% change from Day 7 to Day 14
1	C-52	M	15	Back insufficience	.44	.50	+13.7			
2	C-132	F	27	Nephrolithiasis	1.41	1.89	+34.0			
3	C-147	M	37	Hypogonadism	.84	.86	+ 2.4			
4	D-4	M	33	Nephrolithiasis	1.78	2.12	+19.1			
5	B-102	F	17	Nephrolithiasis	1.27	1.46	+16.5			
6	C-4	F	53	Nephrolithiasis (clin. normal after parathyroidectomy)	.84	.82	— 2.4			
7	D-56	M	40	Nephrolithiasis after nephrectomy	1.24	1.23	— .8			
8	D-26	M	68	L-1 fracture (1 month after inj.)	1.55	1.76	+13.5	1.87	2.50	+33.7
9	D-57	F	34	Th-VIII, IX and X fractures (1 month after inj.)	1.22	1.45	+18.8	2.87	3.69	+28.6
10	C-153	F	73	Th-IX fracture (2 months after inj.)	1.31	1.48	+13.0	1.41	1.75	+24.1
11	C-114	M	22	L-I fracture (2 months after inj.)	1.16	1.06	— 8.6	1.93	1.91	— 1.04
12	D-55	M	65	L-IV fracture (2 months after inj.)	1.17	1.27	+ 8.5	1.96	2.70	+37.7
13	C-134	F	39	Th-VIII fracture (4 months after inj.)	1.24	1.26	+ 1.6	1.36	1.61	+22.0
14	D-43	F	58	Th-XII and L-IV						

				fractures (6 months after inj.)	1.38	1.31	— 5.6	2.74 4.65	3.13 5.45	+14.2 (over L–IV) +17.2 (over Th–XII)
15	C-22	F	58	Th–XII fracture (8 months after inj.)	1.80	2.22	+23.4	1.50	1.91	+27.3
16	D-23	M	40	Sacrum, L–I and Th–XII fractures (10 months after inj.)	1.48	1.70	+14.8	1.59 1.59	2.56 2.11	+58.5 (over sacrum) +32.7 (over Th–XII and L–I)
17	C-111	F	57	L–II fracture (2 years after inj.)	1.08	1.16	+ 7.4	1.29	1.38	+ 8.5
18	C-48	F	59	L–II tbc spondylitis (1st injection)	1.41	1.55	+ 9.9	2.51	3.29	+31.1
				(2nd injection 13 months later)	1.05	.98	— 6.6	1.25	1.41	+13.6
19	C-122	F	39	L–I and Th–XII tbc spondylitis	1.51	1.38	— 8.6	2.09	2.09	0.0
20	C-16	M	10	L–III tbc spondylitis	.52	.56	+ 7.7	.72	.74	+ 2.8
21	B-66	F	47	L–V, S–I, non-specific discitis after removal of herniated disc	1.72	2.06	+19.8	4.49	5.39	+20.0
22	D-3	F	51	Spondylarthrosis deformans with marked changes in lumbar spine	1.02	1.15	+12.9	1.41	1.81	+28.4
23	D-27	M	55	Spondylarthrosis deformans with marked changes in lumbar spine	1.37	1.83	+33.7	1.40	1.92	+37.0
24	C-152	F	50	L–III spondylolysis	1.30	1.58	+21.5	2.02	2.94	+45.8
25	C-151	F	50	Lytic lesion of unknown origin in the Th–X spinous process	1.35	1.57	+16.3	1.30	1.37	+ 5.4

ZUSAMMENFASSUNG

Mit Hilfe eines ausserhalb aufgesetzten Funkenzählers war es möglich eine erhöhte spinale Aufnahme von intravenös injiziertem Sr^{85} in Fällen von Wirbelbrüchen, Spondylitis und anderen Typen von örtlichen Wirbelsäulenschäden nachzuweisen.

ACKNOWLEDGEMENTS

This study was made while one of the authors (P.S.) held a scholarship awarded by the Swedish Government. Financial support was obtained from grants awarded by the Josiah Macy, Jr. Foundation, New York, and the Wallenberg Foundation, Stockholm.

REFERENCES

1. *Bauer, G. C. H. & Ray, R. D.:* Kinetics of strontium metabolism in man. J. Bone and Joint Surg., *40-A*: 171, 1958.
2. *Bauer, G. C. H. & Wendeberg, B.:* External counting of Ca^{47} and Sr^{85} in studies of localized skeletal lesions in man. J. Bone and Joint Surg., *41-B*: 558, 1959.
3. *Gynning, I., Langeland, P., Lindberg, S. & Waldeskog, B.:* Localization with Sr^{85} of spinal metastases in mammary cancer in uptake after hormone and roentgen therapy. Acta Radiologica, *55*: 120, 1961.
4. *Wendeberg, B.:* Mineral metabolism of fractures of the tibia in man studied with external counting of Sr^{85}. Acta Orthop. Scand., Supplementum 52, 1961.