



Title	肺癌の放射線治療による肋骨骨折について
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Rib Fractures Following Radiation Therapy for Cancer of the Lung

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肺癌の放射線治療による肋骨骨折について

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肺癌の放射線治療における正常組織の放射線による障害のうち、肋骨骨折の5症例を経験したので報告する。肋骨線量として、F. Ellis の提唱した NSD (nominal single dose) を用い、発現時間、頻度等の分析を行なつた。照射による肋骨骨

折の頻度は29例の2年生存者のうち5例で17.2%であり、線量が高いほど多くなる傾向がある。線量と発現時間との間には相関関係を認めず、放射線皮膚潰瘍を併発している症例では肋骨骨折がそれに先行していた。

Introduction

The five year survival rate after radiation therapy of cancer of the lung generally does not exceed about 10%. It should be pointed out that these low survival rates are due to the advanced stage of the disease and the age of the patients when admitted to the hospital.¹⁷⁾

It is easy to supply a sufficient tumor lethal dose to the primary tumor by employing high energy irradiation, but the damage of normal tissues of the lung becomes one of the most important factors.

On this subject, there have been many previous papers from our department.¹⁵⁾¹⁷⁾¹⁸⁾¹⁹⁾²²⁾²⁴⁾

Among the side effects of radiation therapy for cancer of the lung¹⁵⁾¹⁸⁾ are skin damage,¹⁷⁾ pneumonitis, pulmonary fibrosis, heart injuries,³²⁾³³⁾³⁵⁾ myelitis,²⁵⁾ and esophagitis.

However, there are only a few reports on rib fracture following radiotherapy for cancer of the lung.²⁾

The purpose of this report is to review long-term survivors with rib fracture following radiotherapy for lung cancer and to study the incidence of rib fracture and the relationship between rib dose and time of appearance of rib fracture.

Materials and Methods

From April to December 1968, 156 patients were treated with X-ray and tele-cobalt-60 γ -ray, mainly with a sieve, in our department.¹⁶⁾¹⁷⁾¹⁹⁾

The tumor dose in all cases was more than 4,000 rads. We usually used a time-dose schedule according to histology as shown below:

Undifferentiated carcinoma	4,000-5,500 rads/5-6W.
Squamous cell carcinoma	6,000-7,000 rads/7W.
Adenocarcinoma	more than 7,000 rads/8W.

The crude survival rates are shown in Table 1. That is,

2 year ... 29 cases(18.6%)

3 year ... 23 cases(16.9%)

5 year ... 10 cases(9.8%)

Table 1. Survival Rates of Cancer of the Lung following Radiotherapy in our Department.

Patients were treated April 1958 to December 1968. Tumor Doses were more than 4,000 rads.

	1/2 Y.	1 Y	2 Y	3 Y	4 Y	5 Y
1958-1965	67/102 (65.7%)	39/102 (38.2%)	17/102 (16.7%)	15/102 (14.7%)	14/102 (13.7%)	10/102 (9.8%)
1966	13/17 (76.5%)	10/17 (58.8%)	7/17 (41.2%)	6/17 (35.3%)	3/17 (17.6%)	/
1967	16/17 (94.1%)	10/17 (58.8%)	2/17 (11.8%)	2/17 (11.8%)	/	/
1968	16/20 (80.0%)	10/20 (50.0%)	3/20 (15.0%)	/	/	/
total	112/156 (71.8%)	69/156 (44.2%)	29/156 (18.6%)	23/136 (16.9%)	17/119 (14.2%)	10/102 (9.8%)

In our experience rib fracture occurred in those who survived more than two years. We reviewed 29 patients who survived more than two years and studied the correlations between rib dose and time of appearance of rib fracture, and between rib dose and incidence of rib fracture. Attempts to correlate the total rib dose in rads with rib fracture did not yield significant results, so we used the NSD (Nominal Single Dose) in our analysis of the complicated dose-time distribution (total dose, fractionation, overall treatment time),⁶⁾⁷⁾ and this resulted in a significant correlation.

So the rib dose was represented by NSD which was recommended by Ellis (Oxford). The NSD is very useful in comparing cases with different dose-time relationships.

The formula of NSD (normal tissue) is given by

$$D = D_0 \times N^{0.24} \times T^{0.11}$$

D = total dose in rads

where, D_0 = NSD (normal tissue) in ret

N = No. of fractions

T = overall treatment time (days)

NSD was calculated by Ellis's slide rule method.

Among the 29 cases studied, five developed rib fractures in the irradiated field. The lowest NSD of these cases was 1,850 ret and the highest was 2,950 ret. The interval between treatment and rib fracture varied two year and three month to five years.

The relationship between the rib dose (ret) in these five patients and that in the 29 patients (two year survivors) is shown in Table 7.

The details of the five cases of radiation-induced rib fracture follow.

Case Report

CASE 1.

Y.S. This 31 year-old man was treated from September 7 to December 24, 1960, with telecobalt-60 irradiation (one portal) and with 200 KVP X-ray radiotherapy (KXC-18: Toshiba) for carcinoma of the right lung.

Since June 10, 1960, he had suffered from attacks of coughing with bloody sputum. His chest roentgenogram showed a lung tumor shadow.

The chief findings upon admission to our clinic were: cervical and axillary lymphnodes not palpable, blood pressure 118/55 mmHg, ECG: within normal limits, Hb 15.8 g/dl, leucocyte count 5,380/mm³, Wassermann reaction: (++), serum protein: total protein 6.1 g/dl, albumin 40.4%, γ -globulin 28.6%, A/G ratio 0.68, sputum: tbc. bacillus (-), malignant cell (-), staphylococcus aureus (+).

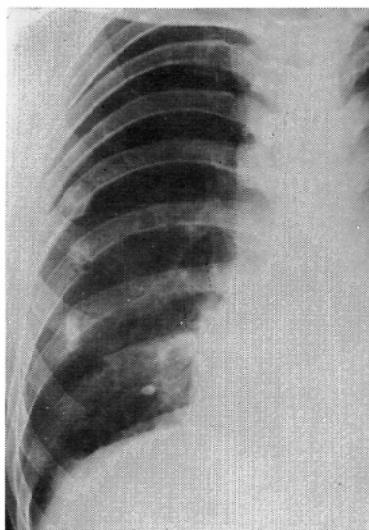


Fig. 1. Y.S. R-ribs 7, 8, 9, 10 (Dec. 6, 1965)

On September 2, 1960, bronchial biopsy was performed and it confirmed malignancy, histologically adenocarcinoma was suspected. On October 13, 1960, pigmentation and oppressive pain were noted in the irradiated field. On December 7, 1960, bronchography showed narrowing and irregularity of the bronchial wall at segment 10a.

His irradiation program was as follows over the period from September 2 to December 24, 1960 (109 days). (1) Co-60 irradiation (irradiation field 10×10 cm, posterior); skin dose: 250 rads/day, tumor dose: 180 rads/day (40 times). (2) 200 KVP X-ray irradiation with sieve (irradiation field 13×13 cm); skin dose: 500 rads/day, tumor dose: 170 rads/day (13 times). The total skin dose was 13,250 rads, and the total tumor dose was 9,610 rads, in 53 fractions. The tumor shadow gradually became smaller on his chest roentgenogram. The overall treatment time was 109 days. The rib dose (about 1 cm beneath the skin surface) was 12,800 rads and 2,950 ret (NSD). Fractures of several ribs (right 7, 8, 9, 10 Fig. 1) appeared on October 1962 (two years and three months after treatment). Skin ulceration appeared in December 1969 (nine years after treatment). He is still living, more than ten years after treatment.

CASE 2.

Y.H. From September 7 to October 22, 1964, this 62 year-old man received telecobalt-sieve therapy for carcinoma of the left lung. On August 26, 1964, his chest roentgenogram showed a tumor shadow (4.3×3.5 cm) in the left middle lung field. The chief findings upon admission to our clinic (July 1, 1964) were: both cervical and supraclavicular lymphnodes not palpable, blood pressure 152/90 mmHg, BSG 3.75 mm/h, urine and feces normal, Hb 14.1 g/dl, leucocyte count 5,000/mm³, icterus index 5.9 (Meulengracht), direct bilirubin 0.51 mg/dl, indirect bilirubin 0.52 mg/dl, alkalinephosphatase 3.9 unit (Bessey-Lowry), ECG: atrial fibrillation and digitalis effect, serum protein within normal limit, sputum: tbc. bacillus (-), malignant cells class III, roentgenogram and sputum analysis confirmed malignancy, pleural effusion showed class V malignancy.

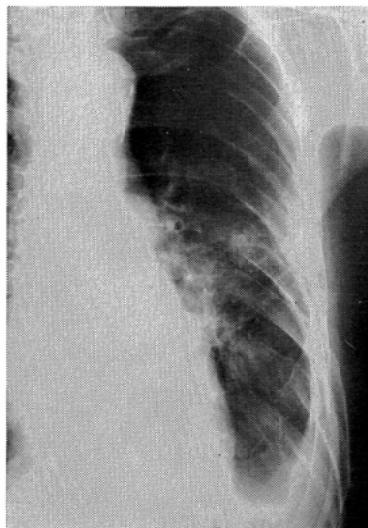


Fig. 2. Y.H. L-ribs 8, 9, 10, 11 (Dec. 21, 1970)

By January 4, 1965, the tumor shadow had completely disappeared on the chest roentgenogram. His irradiation program was as follows: Co-60 γ -ray irradiation with sieve to the left lung, posterior. (1) irradiation field: 8×11 cm, skin dose: 500 rads/day, tumor dose: 145 rads/day (16 times). (2) irradiation field: 5×5 cm, skin dose: 500 rads/day, tumor dose: 130 rads/day (21 times). The total tumor dose was 5,050 rads in 37 fractions, and the overall treatment time was 46 days. The rib dose was 6,700 rads and 1,850 ret (NSD). Rib fracture (left 8, 9, 10, 11) appeared on November 8, 1967 (three years and four months after treatment) (Fig. 2). He is still alive six years after treatment.

CASE 3.

S.S. From May 8 to June 17, 1959, this 57 year-old man received Co-60 and X-ray sieve therapy for carcinoma of the right lung (segment 6). On December 27, 1958, he started having coughing attacks with sputum. He was thought to have pulmonary tuberculosis and was treated with chemotherapy (SM, PAS, INAH). However a tumor shadow was found on his chest roentgenogram, and he was admitted to our clinic.

The chief findings on admission were: cervical lymphnodes not palpable, blood pressure 130/86 mmHg, sputum: tbc. bacillus (-), staphylococcus aureus (+), candida albicans (-), leucocyte count 3,600/mm³, erythrocyte count $340 \times 10^4/\text{mm}^3$, and tomography showed cavity formation in the center of the tumor mass.

On May 22, 1959, he complained of itching and erythema of the irradiated skin. On May 25, roentgenogram showed a smaller tumor shadow than on admission.

His irradiation program was as follows from May 8 to June 17, 1959 (40 days). (1) 200 KVP X-ray irradiation with sieve (irradiation field was 10×15 cm anterior) and skin dose: 1,600 rads/day, tumor dose: 480 rads/day (twice). (2) 200 KVP X-ray irradiation with sieve (irradiation field was 10×15 cm posterior) and skin dose: 800 rads/day, tumor dose: 240 rads/day (15 times). (3) Co-60 γ -ray irradiation (irradiation field was 10×15 cm anterior) skin dose: 300 rads/day, tumor dose: 75

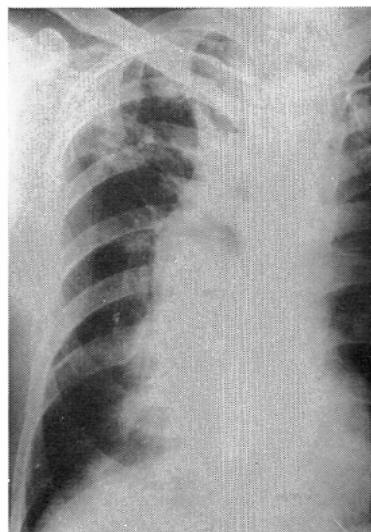


Fig. 3. S.S. R-ribs 3, 4, 5, 6, 7, 8 (Aug. 17, 1967)

rads/day (11 times). The total tumor dose was 5,380 rads in 30 fractions. The treatment period was 40 days, and rib dose was 8,234 rads and 2,850 ret (NSD).

Rib fractures (right 3, 4, 5, 6, 7, 8) appeared in April, 1964 (five years after treatment) (Fig. 3), and skin ulceration appeared in June, 1966 (seven years after treatment). He had skin grafts and is still alive 11.5 years after treatment.

CASE 4.

K.N. From March 23 to May 11, 1964, this 62 year-old woman was treated by telecobalt-60 sieve irradiation for carcinoma of the left lung. In March, 1964, she had a common cold, but cough and sputum continued, and in April, a chest roentgenogram showed a lung tumor shadow.

The chief findings when she was admitted to our clinic were: cervical and supraclavicular lymphnodes not palpable, liver slightly enlarged, blood pressure 150/70 mmHg, BSG 89 mm/h, urine and feces normal, serum protein: total protein 8.4 g/dl, A/G ratio 0.6, alkalinephosphatase 2.8 B.L. units, Hb 9.8 g/dl, leucocyte count 7,600/mm³, sputum: tbc. bacillus (-), ECG: LVH and atrial premature beats, the roentgenogram suggested metastasis to the hilar area, and bronchography showed bronchial stenosis at segment 1, 2, 3. On April 19 to May 1, 1964, she received cyclophosphamide (total 1,300 mg, 100 mg/day). The irradiation program was as follows from March 23 to May 11, 1964 (50 days). (1) Co-60 irradiation therapy with sieve posteriorly, skin dose: 500 rads/day, tumor dose: 140 rads/day (27 times). (2) Co-60 irradiation with sieve anteriorly, skin dose: 500 rads/day, tumor dose: 140 rads/day (14 times). The total tumor dose was 5,740 rads in 41 fractions. The overall treatment time was 50 days, and the rib dose was 7,580 rads and 2,160 ret (NSD). Rib fractures (left 4, 5, 6, 7) appeared in February, 1969 (five years after treatment) (Fig. 4.). She died in

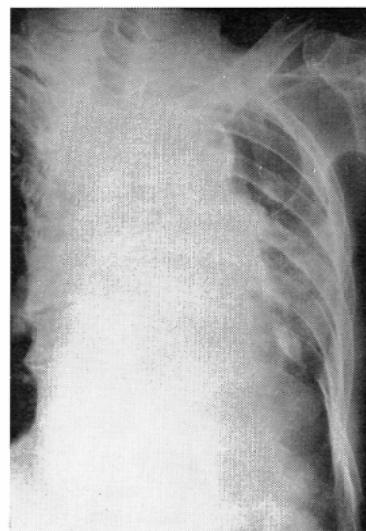


Fig. 4. K.N. L-ribs 4, 5, 6, 7 (Mar. 29, 1969)

September, 1969, with recurrence of tumor.

CASE 5.

T.J. This 61 year-old man was treated from December 28, 1966, to March 15, 1967 with

tele-cobalt-60 irradiation with sieve. In 1958 he had suffered from tuberculosis of the right upper lobe and was treated with SM, PAS, INAH for about two years with arrest of the lesion. On October 20, 1965, he complained of bloody sputum and fever (37.5°C). A tumor shadow was seen in the right lung. He was a heavy smoker (ca. 20 cigarettes/day). The chief findings on admission were: one left cervical lymphnode ca. 1 cm in diameter, supra-infraclavicular and axillary lymphnode not palpable, edema (+) of both feet, clubbed fingers both hands, sputum: tbc. bacillus (-), staphylococcus aureus (+), tumor cell (-), blood pressure 135/75 mmHg, BSG 59.5 mm/h, Hb 12.1 g/dl, leucocyte count 8,500/mm³, liver function, electrolytes, urine, feces: within normal limits, icterus index 8.5, total protein 6.0 g/dl, albumin 43.8%, γ -globulin 16.8%, A/G ratio 0.8, ECG: sinus tachycardia, CRP (+1), ASLO (12 \times), pulmonary function borderline.

On December 16, 1966, a few tumor cells were seen in a bronchial smear. His irradiation program was as follows: (1) Co-60 irradiation with sieve (irradiation field 14×14 cm anterior) skin dose: 1,000 rads/day, tumor dose: 300 rads/day (19 times). (2) Co-60 irradiation with sieve (irradiation field 5×6 cm posterior) skin dose: 1,000 rads/day, tumor dose: 240 rads/day (13 times). The total tumor dose was 8,820 rads in 32 fractions and rib dose was 9,040 rads and 2,460 ret (NSD). The overall treatment time was 77 days. On January 12, 1967, his chest roentgenogram showed a smaller shadow, and frequent sputum examinations showed no tbc. bacilli. On April 22, 1967 lung fibrosis was observed

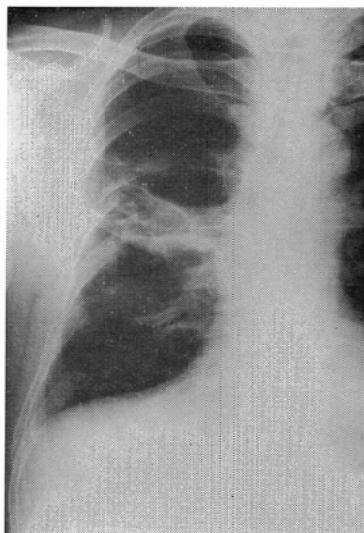


Fig. 5. T.J. R-ribs 4, 5, 6 (Oct. 6, 1970)

in the irradiated lung field and it became increasingly severe. On September 9, 1967, Lhermitte's sign was noted. On January 12, 1970, he complained of right chest pain and a chest roentgenogram showed pneumothorax. On October 16, fractures of the ribs 4, 5, 6, on the right were seen on a chest roentgenogram (three years and four months after treatment). He is still alive 4.5 years after treatment.

Table 2. Details of Five Patients with Rib Fractures following Radiotherapy for Cancer of the Lung.

case No.	case 1	case 2	case 3	case 4	case 5
name and age	Y. S. 31Y.	Y. H. 62Y.	S. S. 57Y.	K. N. 62Y.	T. J. 61Y.
sex	male	male	male	female	male
disease	right-L.C.	left-L.C.	right-L.C.	left-L.C.	right-L.C.
radiation technique	Co-60 X-ray (sieve)	Co-60 (sieve, 2 portals)	Co-60 X-ray (sieve)	Co-60 (sieve, 2 portals)	Co-60 (sieve, 2 portals)
total rib dose	12,800 rads	6,700 rads	8,234 rads	7,580 rads	9,040 rads
No. of fractions	53	37	30	41	32
overall treatment time (days)	109 days	46 days	40 days	50 days	77 days
rib dose (NSD)	2,950 ret	1,850 ret	2,850 ret	2,160 ret	2,460 ret
time of appearance of rib fracture	2 years & 3 months	3 years & 4 months	5 years	5 years	3 years & 4 months
result	skin ulceration (9 years after treatment), and now 10 year survivor	now 6 year survivor	skin ulceration (7 years after treatment), now 11 year and 6 month survivor	5 years and 7 months after treatment and dead with recurrence	now 4 year and 9 month survivor
ribs fractured	R- 7, 8, 9, 10	L- 8, 9, 10, 11	R- 3, 4, 5, 6, 7, 8	L- 4, 5, 6, 7	R- 4, 5, 6

Results

Table 2 shows the details of these five patients with rib fractures following radiation therapy for carcinoma of the lung. There is no clear correlation between rib dose and time of appearance of rib fractures. That is, in cases 1 to 5, the dose was 2,950 ret, 1,850 ret, 2,850 ret, 2,160 ret, 2,460 ret, respectively, and the time of appearance of rib fractures was two years and three months, three years and four months, five years, five years, and three years and four months after treatment, respectively (Table 8.). When the time of appearance of skin ulceration and of rib fractures are compared, it is

Table 7. Incidence of Radiation-induced Rib Fractures according to Rib Dose(ret).

dose (NSD)	incidence
— 1,750 ret	0/4
1,750 — 2,000 ret	1/4
2,000 — 2,250 ret	1/4
2,250 — 2,500 ret	1/8
2,500 ret —	2/9
total	5/29 (17.2%)

Table 8. Relationship between Rib Dose (NSD) and Time of Appearance of Rib Fracture.

No. of case	rib dose(NSD)	time of appearance of rib fracture
case 1	2,950 ret	2 years and 3 months
case 2	1,850 ret	3 years and 4 months
case 3	2,850 ret	5 years
case 4	2,160 ret	5 years
case 5	2,460 ret	3 years and 4 months

clear that rib fractures preceded skin ulcerations; in cases 1 and 3 in which both complications occurred (i.e. rib fracture and skin ulceration), the rib fractures preceded the skin ulceration, by six years and nine months, and two years, respectively.

Table 7 shows the correlation between rib dose (NSD) and incidence of rib fracture; the greater the rib dose, the higher the incidence of fracture. When rib dose was less than 1,750 ret, rib fracture did not occur, but when it was more than 1,750 ret, fractures developed in five cases.

Among the 29 survivors of more than two years with carcinoma of the lung irradiated by our technique, five had rib fractures (17.2%).

Discussion

We usually encounter some severe side effects in the course of radiotherapy for carcinoma of the lung.¹⁵⁾¹⁶⁾ The representative ones which are generally noticed are: skin damage,¹⁷⁾ pneumonitis and fibrosis, myelitis,²⁵⁾ heart injuries,³⁰⁾³²⁾³³⁾³⁵⁾ and esophgitis.³¹⁾ In addition, rib fracture following radiation therapy is an important side effect which should be considered when we plan radiotherapy

Table 3. Lung Cancer (Osteoradiation reported till now).

reporter	case	irradiation	dose	time after irradiation	portion of rib fractures
Birkner ⁽²⁾ (1954)	1) 46 year old man	X-ray	10,200 R (O.D.) 7,000 R (H.D.)	ca. 7 years	cartilage-bone structures of sternal region.
	2) 60 year old man	X-ray	18,300 R (O.D.) 8,300 R (H.D.)	ca. 2.5 years	R-anterior 2, 3, 4

Table 4. Gynecological Cancer (Osteoradiation reported till now).

reporter	case	irradiation	dose	time after irradiation	portion of rib fractures
Dalby ⁽⁴⁾ (1936)	gynecological malignant diseases (40 cases)	X-ray and Radium	1,500 R—2,000 R (\times 2—3 times) Radium 5,000—6,000 mgh	2—35 months	mainly femoral neck
Kalayjian ⁽¹⁴⁾ (1938)	69 year old uterine cancer (squamous cell carcinoma)	X-ray and Radium	1,500 R/one portal (4 portals) Radium 3,000 mgh	1 year	femoral neck
Kropp ⁽²⁴⁾ (1934)	67 year old female	X-ray	1 portal; abdomen, 2 portals; back, (250 R/once) Radium 612 mgEl. Std.	—	femoral neck
Okrainetz ⁽²⁷⁾ (1939)	56 year old female ovarian tumor (papillary adenocarcinoma)	—	2,000 R (3 portals) 3,000 R (1 portal)	8 months	r-femoral neck
Rubin ⁽²⁸⁾ (1961)	uterine cancer (7 cases)	X-ray	1,600 rads (O.D.) (\times 6 times) 2,400—3,000 rads (O.H.) (\times 2 times) 7,000—12,000 rads	1 year and 3 months—5 years (4 years \pm 6 months)	femoral neck (4 cases) pelvic bone (3 cases)

programs. In this report we reviewed long-term survivors with rib fractures following radiotherapy for lung cancer, to analyse the relationship between rib dose and incidence and time of appearance of rib fracture. In general, radiation induced bony disturbances are osteoradionecrosis or radiation osteitis.

There have been several clinical reports on the effects of radiotherapy on bones, but almost all of them concern patients with carcinoma of the breast,¹⁾²⁾⁵⁾⁸⁾⁹⁾¹⁰⁾¹¹⁾¹²⁾¹³⁾²⁰⁾²¹⁾²²⁾²⁶⁾²⁹⁾³⁰⁾³⁵⁾ or various tumors of the female reproductive organs⁴⁾¹⁴⁾²⁴⁾²⁷⁾²⁸⁾ which generally have a much better prognosis than does lung cancer. There have been very few reports on radiation-induced bone lesions in patients with lung cancer. Birkner (1954)²⁾ reported two cases of lung cancer with fractures of ribs and sternum after radiation therapy, together with six cases of breast cancer and one of leiomyosarcoma (Table 3, 6). The rib fractures in these cases appeared one to ten years after irradiation. With the increasing radiocurability of lung cancer, rib fractures appear to be one of the important problems among long-term survivors (Table 1, 2). A review of the many reports published so far indicates that the average incidence of rib fracture is 9-23% in breast cancer, 13% in oral cancer.³⁶⁾³⁷⁾ In lung cancer we find a relatively high incidence of 17.2%. The most important factor contributing to this phenomenon is that the radiation

Table 5. Oral Cancer (Osteoradionecrosis reported till now).

reporter	case	irradiation	dose	time after irradiation	portion of rib fractures
Watson ³⁶⁾ (1938)	oral cancer 235/1819 (13%)	—	—	11 months (average) 8 years & 7 months (longest)	oral bone
Zwerg ³⁷⁾ (1936)	1) oral cancer (58 year old)	Radium puncture	—	1 year	Osteoradionecrosis of the jaw.
	2) oral cancer (37 year old)	Radium puncture	—	1 year	Osteoradionecrosis of the jaw.
	3) oral cancer (60 year old)	Radium puncture	—	1.5 year	Osteoradionecrosis of the jaw.

Table 6. Breast Cancer (Osteoradionecrosis reported till now).

reporter	case	irradiation	dose	time after irradiation	portion of rib fractures
Eggs ⁵⁾ (1941)	breast cancer (3 cases)	X-ray	1,800-2,400 R (T.D.)	6 years and 10 months — 9 years and 4 months	fractures of 3 ribs and osteolysis in 2 cases
Steller ³⁵⁾ (1942)	skin disease (1 case)	X-ray	—	12-15 years	1 ribs
Svab ³⁵⁾ (1947)	breast cancer (3 cases)	X-ray	6,000-10,000 R (O.D.)	2-3 years	3 ribs
Hildebrand ³⁵⁾ (1949)	Hodkin's dis. (1 case)	X-ray	6,500 R (T.D.)	9 years	1 rib
Steingräber ³⁵⁾ (1951)	breast cancer (3 cases, 1.2%)	X-ray	4,600 R (H.D.)	9-10 months	fracture and osteolysis of the ribs
Birkner ²⁾ (1954)	breast cancer (6 cases)	X-ray	4,000-10,500 R (H.D.)	0.5-1— years	7 ribs and 2 ribs and clavicles
Nogimura ²⁷⁾ (1959)	breast cancer (2 cases; 4.3%)	X-ray	2,700-4,500 R (air dose)	8 months — 1 year and 6 months	R-ribs 7, 8, 9 L-ribs 2

Table 6. (continued)

reporter	case	irradiation	dose	time after irradiation	portion of rib fractures
Baudisch ¹⁾ (1960)	breast cancer 4/369	X-ray	3,000R—3,500R (T.D.)	11 months— 3 months and 7 years	rib; 2 rib and clav.; 1 clav.; 1
Kato ¹⁰⁾¹¹⁾ (1960)	breast cancer (1 case)	X-ray	4,550R—5,000R (air dose)	1 year and 6 months to 2 years and 8 months	ribs 2, 3, 4, 5
Kikuchi ²¹⁾²²⁾ (1963)	breast cancer 5/56 (3.9%)	X-ray	2,850R—3,500R	4.5—20 months	2nd rib: 3 3rd rib: 3 4th rib: 1
Kakei ¹³⁾ (1965)	breast cancer 20/128 (X-ray) 12/53(Co-60)	X-ray Co-60	3,000R (X-ray) 3,000—3,500 (Co-60)	5—20 months	ribs 2, 3, 4, 5
Tagaya ⁹⁾ (1967)	breast cancer 15/144 (10.4%)	X-ray	4,000 rads (one portal)	rib... (3 months to 1 year) clav. ... (ca. 3 years)	clav.: 3; 2nd rib: 4; 3rd rib: 8; 4th rib: 5
Fukuda ⁸⁾ (1968)	breast cancer 39/186 (21%)	Co-60	4,500R	1—28 months (mean: 11.8 months)	2nd rib: 39; 3rd rib: 4; 4th rib: 1; 5th rib: 2
Watanabe ³⁵⁾ (1969)	breast cancer 27/263 (10%)	X-ray Co-60	3,000 rads (X-ray) 4,000— 5,000 rads (Co-60)	8 months (X-ray) 9.7 months (Co-60)	2nd rib: 50% 3rd rib; 4th rib.

doses are generally greater than for breast cancer because of the deeper position of the tumor. Most of the rib fractures in lung cancer occurred when the portals of irradiation had been vertical to the chest wall, often posterior.

Fractures of the posterior arcs of the ribs were common. There were no significant differences between Co-60 and X-ray treated patients. There was no significant relationship between rib fracture and age. Often the time of appearance of the fracture was not related to the rib dose, and many other factors contributed, such as trauma, infection, metastasis, osteoporosis due to cachexia and advanced age and sudden strong movements.

Finally, many authors suggested that the cause of rib fractures is the obliteration of endarteries³⁵⁾ which interferes with the blood supply to the bones. From the diagnostic point of view, the differential diagnosis between fracture and metastasis is the most difficult problem, but generally fractures are characterized by the absence of osteolysis and by the destruction of the cortical structure.²⁸⁾ In all our long-term follow-up after the appearance of bony changes has been available, making it possible to determine radiation-induced fractures.

Summary

- 1) The incidence of rib fractures following radiation therapy for cancer of the lung was 5/29 (17.2%).
- 2) A positive correlation was observed between the incidence of rib fractures and the rib dose.
- 3) There was no relationship between the rib dose and time of appearance of rib fractures.
- 4) In the cases in which both rib fracture and skin ulceration occurred, the rib fracture

preceded the skin ulceration.

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