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ESTIMATION OF RADIOTHERAPEUTIC DOSE GIVEN FOR RADIOTHERAPY OF BENIGN DISEASES IN THE PAST JAPAN

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The X-ray treatment has been applied widely to various benign diseases since the early of this century. However, it was difficult to us to know precise radiation dose or conditions in old days particularly before the Second World War, because of destruction of hospitals by war resulting a loss of clinical cards and X-ray records. On the other hand, from the view point of the study of radiation carcinogenesis in man, it is necessary to know radiotherapeutic dose given to patients in former days. As was already described elsewhere[1], a seminational survey on radiation carcinogenesis was performed in Japan during 1961 and 1962 by Takahashi *et al.*

As radiation dose was not clear in majority cases of radiation-induced cancer at that time. In this paper, radiation dose given for various benign diseases in the past Japan was tried as rationally as possible estimated. For this purpose, two methods were taken, that is, a study of exsisting Japanese literatures on radiotherapy of benign diseases, and a survey of hospitals in which senior radiologists or X-ray technicians were employed at the present time.

SURVEY OF LITERATURES

Name and number of Japanese literatures surveyed were listed in Table 1. From each literature of total 98, type of X-ray generator used, kVp, mA, filter, FSD, single dose, total dose, intervals, frequency of irradiation, number of treatment field, etc. were known.

Before 1911, X-ray treatment had been performed in only a few hospitals. In 1912 to 1925, effects of X-ray therapy for various diseases were gradually recognized. The irradiation technique was made, however, in this country,

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TABLE 1. List of Japanese Journals Used in Survey of Radiotherapeutic Dose and Conditions for Benign Diseases

Name of literatures	Volumes available	Volumes surveyed	Number of literatures available
Shimazu X-ray report	Vol. 1 (1925) ↓ Vol. 16 (1941)	Vol. 1 (1925) ↓ Vol. 16 (1941)	13
Jap. J. Dermat.	Vol. 1 (1901) ↓ Vol. 74 (1964)	Vol. 1 (1901) ↓ Vol. 14 (1914)	11
J. Therapy	Vol. 1 (1902) ↓ Vol. 29 (1930)	Vol. 1 (1902) ↓ Vol. 15 (1916)	7
Shimazu X-ray Lectures	Vol. 1 (1923) ↓ Vol. 9 (1931)	Vol. 1 (1923) ↓ Vol. 7 (1930)	7
Jap. J. Roentgenol.	Vol. 1 (1924) ↓ Vol. 17 (1940)	Vol. 1 (1924) ↓ Vol. 17 (1940)	21
Jap. J. Radiol.	Vol. 1 (1934) ↓ Vol. 7 (1940)	Vol. 1 (1934) ↓ Vol. 7 (1940)	10
Nippon Acta Radiol.	Vol. 1 (1940) ↓ Vol. 23 (1963)	Vol. 1 (1940) ↓ Vol. 20 (1960)	8
Other journals	1901–1925		10
Monographs	1928–1960		11
Total			98

TABLE 2. Range of Total Dose and Quality of X-rays Given for Various Benign Diseases Collected from Japanese Old Literatures

Year	1912–1925		1926–1935		1936–1945		1946–1962	
X-ray→ / Diseases irradiated for ↓	Quality (kVp)	Total dose (r) (in air)	Quality (kVp)	Total dose (r) (in air)	Quality (kVp)	Total dose (r) (in air)	Quality (kVp)	Total dose (r) (in air)
Skin disease	100–180	1200– 4000	100–180	1200–4000	80–160	1200–3000	80–140	300–2000
Tuberculous lymphadenitis	120–160	1200– 6000	120–200	1200–6000	120–160	1000–4000	100–160	1000–2000
Gonorrheal lymphadenitis	120–160	3000– 6600	120–160	2000–7000				
Pulmonary tuberculosis	160–200	500	140–200	400–1600	160	1000–1500	160–200	600–1200
Peritoneal tuberculosis	120–160	1200–15000	90–150	1200–7000	140–180	600–3000	180–200	200– 800
Laryngeal tuberculosis			150	1800				
For castration			120–160	600	160–200	400–1500	180–200	200– 300
Basedow's disease			75–150	1800–6600	150–180	2000	180–200	1000–2000
Gonorrheal arthritis			120	600–1800				
Salpingitis					100–200	200–1200		
Vertebral caries					150	600–1800		
Erysipelas					60– 90	100–1000		
Tonsilitis					160	1500–2000	160–200	300–2000
Stomach ulcer					160	800–2000	160–200	400–1800

mostly after the method of Drs. Schultz, Fritz, and Kienböck. In 1926 to 1935 radiation therapy was widely applied to various inflammatory or tuberculous diseases. In 1936 to 1945, radiotherapy was conducted by using Coolidge tube, kenotron tube, and roentgen unit, so far seen in literatures. Indications and

techniques were almost similar to before 1935, although there was a tendency to reduction of both single and total radiation dose. After 1946, radiotherapy did not gradually tend to be used for benign diseases.

The results obtained from these literatures are summarized in Table 2.

SURVEY OF HOSPITALS

Questionnaires were sent to radiology department of hospitals provided with more than 30 beds for in-patients. Questions in the questionnaire requested for were consisted of type of X-ray generator, type of rectification, FSD, kVp, thickness of filter, HVL, mA, time of single irradiation, field size, single dose, total dose, intervals, and treatment period for each benign diseases in every decade. Until after one month 225 hospitals have responded. Results were summarized in Table 3.

TABLE 3. Radiation Data for Cervical Tuberculous Lymphadenitis Collected from Japanese Hospitals

		Number of cases			
		1912–1925	1926–1935	1936–1945	1946–1962
Rectification type	Mechanical	5 (63%)	10 (37%)	9 (18%)	2 (1%)
	Greinacher		6 (22%)	22 (42%)	122 (70%)
	Others	3 (37%)	11 (41%)	21 (40%)	50 (29%)
FSD	Under 29 cm	3 (43%)	4 (15%)	9 (14%)	13 (6%)
	30–40 cm		21 (81%)	50 (80%)	185 (85%)
	Over 41 cm	4 (57%)	1 (4%)	4 (6%)	19 (9%)
kVp	Under 80 kVp	5 (71%)	3 (15%)	9 (18%)	13 (7%)
	90-110 kVp		1 (5%)	7 (14%)	16 (8%)
	120–150 kVp	2 (29%)	12 (60%)	23 (46%)	104 (52%)
	Over 160 kVp		4 (20%)	11 (22%)	65 (33%)
Filter	Under 3 mm Al	5 (63%)	9 (38%)	14 (27%)	23 (11%)
	4 mm Al-0.3 mm Cu	3 (37%)	7 (29%)	16 (30%)	86 (43%)
	Over 0.4 mm Cu		8 (33%)	23 (43%)	94 (46%)
Field size	Under 50 cm^2	1 (25%)	8 (42%)	25 (58%)	108 (61%)
	51–99 cm^2	2 (50%)	8 (42%)	13 (30%)	61 (35%)
	Over 100 cm^2	1 (25%)	3 (16%)	5 (12%)	7 (4%)
Treatment period	Under 10 weeks	3 (50%)	10 (48%)	30 (67%)	107 (59%)
	11–20 weeks	1 (17%)	9 (43%)	9 (20%)	53 (30%)
	Over 20 weeks	2 (33%)	2 (9%)	6 (13%)	19 (11%)
Single dose	Under 90 r	1 (13%)	4 (22%)	21 (41%)	78 (42%)
	91-130 r	2 (25%)	7 (39%)	23 (45%)	88 (47%)
	Over 131 r	5 (62%)	7 (39%)	7 (14%)	20 (11%)
Total dose	Under 1100 r	2 (29%)	12 (63%)	27 (54%)	102 (57%)
	1101–3000 r		4 (21%)	19 (38%)	71 (40%)
	Over 3001 r	5 (71%)	3 (16%)	4 (8%)	6 (3%)

DOSE ESTIMATION

Hospital survey decribed above may have a defect that the majority of answers was made based on radiologists' memories. In this instance, a memory bias may tend to respond as to be less dose. On the other hand, radiation techniques collected from literatures may be instructive pattern in radiotherapeutics in those days. Therefore it is doubtful that whether or not all hospitals had adopted these representative techniques. However we have no positive or negative proof on these two problems.

To give a solution the embrrassment, comparison of total dose and quality of X-ray used for tuberculous cervical lymphadenitis was done between obtained from literatures and from hospital survey, as is shown in Fig. 1. The data collected from literatures and from hospitals were completely coincided. Therefore data collected from hospitals was mainly used for dose estimation, and those from literature are additionally utilized.

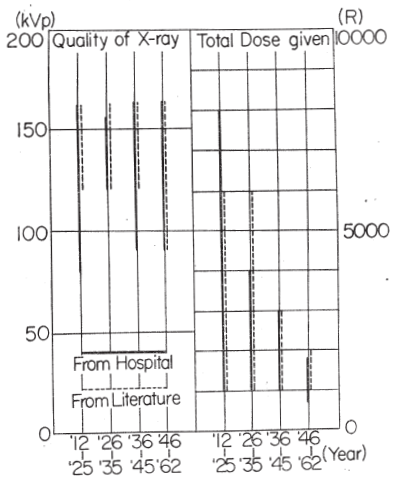

FIG. 1. Comparison of total dose and quality of X-rays given for cervical tuberculous lymphadenitis between collected from existing Japanese literatures and from hospital survey. In each decade both appeared to be well coincided.

For example, the authors interprete here calculation procedure of the deep tissue doses in treatment for cervical tuberculous lymphadenitis during 1936 to 1945 in Japan.

First, the lower and upper limits of most frequently used range in irradiation conditions were collected and summarized from literature survey as is shown in Table 4. According to the depth dose table repersented by F. Wachsmann[11], the depth dose-rate is appreciated as 115% at 0 cm (where skin cancer may occur), 58% at 2 cm (where thyroid cancer may occur), and 31% at 4 cm (where pharyngeal or laryngeal cancer may occur), under the conditions of lower limits in Table 4. Secondly, the deep dose distribution thus obtained was checked by phantom experiment using Siemens Universal Dosismesser. Descrepancy of depth dose distribution between obtained from Wachsmann's table and from phantom experiments was within 5%. Now, if we adopted the radiation conditions of lower limits, total skin dose given by treatment of cervical lymphadenitis was 1150 r, and if the upper limits were utilized total skin dose became 3900 r. Namely, in this decade, total skin dose is considered to be 1150 to 3900 r by radiotherapy for cervical lymphadenitis. On the same way, the thyroid might have received

TABLE 4. The Lower and Upper Limits of Most Frequently Used Range in Irradiation Conditions for Radiotherapy of Cervical Tuberculous Lymphadenitis During 1936 to 1945 in Japan

		Lower limits	Upper limits	Average
Quality (kVp)		80	160	125
Filter used		1 mm Al	0.5 mm Cu	2 mm Al
HVL		1.6 mm Al	0.7 mm Cu	0.2 mm Cu
FSD (cm)		23	40	31
Field size (cm^2)		50	100	100
Single dose (r)		60	120	100
Total dose (r)		1000	3000	2000
Depth dose percentage	0 cm (Skin surface)	I15%	130%	125%
	2 cm (Thyroid gland)	58%	92%	90%
	4 cm (Larynx and pharynx)	31%	77%	64%
Depth dose (single)	0 cm	69 r	156 r	125 r
	2 cm	35 r	110 r	90 r
	4 cm	19 r	92 r	64 r

TABLE 5. Depth Tissue Dose in Radiotherapy of Cervical Tuberculous Lymphadenitis

Year	HVL	Air dose (r)	Field size (50 cm^2)			Field size (100 cm^2)		
			Skin dose (r)	Thyroid dose (r)	Larynx dose (r)	Skin dose (r)	Thyroid dose (r)	Larynx dose (r)
1912 -1925	1.6 Al -0.3 Cu (0.2 Cu)	3000–10000 (5700)	3450–12700 (7150)	1740–9400 (5160)	930–6700 (3650)	3510–13400 (7520)	1800–10000 (5480)	1050–7600 (4170)
1926 -1935	0.2 Cu -0.3 Cu (0.2 Cu)	500– 4000 (1860)	625– 5080 (2320)	450–3760 (1750)	320–2700 (1190)	660– 5750 (2460)	480– 4000 (1790)	370–3080 (1360)
1936 -1945	1.9 Al -0.7 Cu (0.2 Cu)	1000– 3000 (1500)	1150– 3900 (1870)	580–2770 (1250)	310–2300 (975)	1170– 4140 (1980)	610– 3450 (1435)	350–2730 (1095)
1946 -1962	0.3 Cu -0.9 Cu (0.5 Cu)	500– 2000 (1340)	635– 2600 (1740)	457–2260 (1220)	335–1760 (1030)	670– 2760 (1850)	500– 2500 (1540)	380–2000 (1210)

Values in the parenthesis indicate an average of each range.

TABLE 6. Depth Tissue Dose in Radiotherapy of Non-malignant Goitre

Year	HVL	Air dose (r)	Field size (50 cm^2)			Field size (100 cm^2)		
			Skin dose (r)	Thyroid dose (r)	Larynx dose (r)	Skin dose (r)	Thyroid dose (r)	Larynx dose (r)
1912 -1925	Unknown							
1926 -1935	2.0 Al -0.8 Cu (0.5 Cu)	1800–6600 (4000)	2090–8600 (5100)	1060–6600 (3860)	550–5410 (2880)	2160–9110 (5500)	1115–7780 (4410)	630–6280 (3320)
1936 -1945	0.8 Cu -1.1 Cu (0.9 Cu)	2000–4500 (3000)	2600–5850 (3900)	2000–5120 (3210)	1640–3960 (2550)	2760–6220 (4140)	2360–5185 (3660)	1900–4500 (2940)
1946 -1962	1.1 Cu -1,5 Cu (1.1 Cu)	1000–3000 (2500)	1300–3840 (3250)	1140–3360 (2850)	880–2600 (2200)	1380–4080 (3450)	1260–3600 (3150)	1000–3030 (2500)

TABLE 7. Depth Tissue Dose in Radiotherapy of Various Skin Diseases

Year	HVL	Air dose (r)	Field size (50 cm²)			Field size (100 cm²)		
			Dose at 0 cm (r)	Dose at 2 cm (r)	Dose at 4 cm (r)	Dose at 0 cm (r)	Dose at 2 cm (r)	Dose at 4 cm (r)
Before 1911	1.8 Al -0.3 Cu (0.2 Cu)	1000–5000 (4000)	1150–6300 (4500)	580–4700 (3600)	310–3350 (2560)	1170–6850 (5210)	610–5000 (3800)	350–3800 (2900)
1912 –1925	0.6 Al -3.2 Al (2.0 Al)	1000–4000 (2090)	1060–4800 (2440)	420–2920 (1310)	200–1920 (756)	1070–5000 (2510)	460–3240 (1420)	240–2120 (835)
1926 –1935	0.6 Al -0.2 Cu (1.8 Al)	500–3000 (1040)	530–3750 (1260)	210–2700 (626)	100–1920 (328)	535–3960 (1250)	230–2880 (645)	120–2200 (370)
1936 –1945	1.1 Al -0.2 Cu (2.0 Al)	300–2000 (870)	333–2500 (990)	150–1800 (545)	78–1280 (313)	336–2640 (1210)	156–1992 (592)	87–1460 (348)
1946 –1962	1.1 Al -0.25 Cu (3.0 Al)	300–1500 (950)	333–1890 (1140)	150–1380 (695)	76– 950 (456)	336–2000 (1190)	159–1470 (770)	87–1160 (504)

radiation dose of 580 to 2800 r by treatment of cervical lymphadenitis. The estimated total doses are tabulated in Table 5, 6 and 7.

DISCUSSION

It is generally difficult to know radiation dose given for various diseases in the past days. This is partially due to a loss of prior radiotherapeutic records by war, and may be partially due to the juniority of radiology in Japan. However, in the study of radiation effects in man, we cannot consider the dose-response relationship if prior radiation dose was not clear. So long as radiation dose in each case cannot be clarified, dose given in former days should be estimated rationally by the second best method, as detailed in this paper.

In our estimation, radiation dose was expressed with a relatively wide range. At the present time we could not make small this dose range. We believe that the real dose value is within these ranges.

However we do not consider that all of real exposure dose can be obtained by the application of this method to each case with unknown prior radiation therapeutic dose. When a patient had exposed to a great amount of X-rays accidentally or after mistaken controlling in X-ray generation, a correct and real dose could not be clarified forever, unless the technical record is available. Our results may be able to apply to cases with unknown radiation dose given by normally controlled technique.

SUMMARY AND CONCLUSIONS

An estimation of radiation dose given for radiotherapy of benign diseases in the past Japan was described, by means of both surveys of existing radiotherapeutic literatures and hospital survey method. Radiation conditions in-

cluding X-ray quality, time. FSD, type of rectification, filter, dose, etc. were collected from 98 old Japanese literatures classified according to disease and decade. On the other hand, the questionnaires were sent to senior radiologists and X-ray technicians in big hospitals in Japan, which requested to answer the radiation conditions for various benign diseases according to decade. From these data the lower and upper limits and average radiation doses given for benign diseases were calculated and tabulated.

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(Ninty-eight Japanese literatures quoted in this calculation are omitted. The list of these references may be distributed from the author if required.)