Title	NSD vs rad tables
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Citation	日本医学放射線学会雑誌. 1974, 34(4), p. 245-253
Version Type	VoR
URL	https://hdl.handle.net/11094/19078
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NSD VS RAD TABLES

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NSD と ラ ド の 比 較 に つ い て

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　異なる施設における放射線治療の成績を比較する場合，各施設において線量，期間が異なるので，総線量のみでの比較は当を得ていないと思われる．

　これらを客観化するために Ellis はNSDの概念を考え，最近多くの報告がこれを利用する傾向がある．Ellis の考え方は彼自身の論文で不完全なことを述べているが，現在最も許容し得るものとして利用する価値があると思われる．

　この値 (rets) を日常利用する表や図を示すと共に，利用し易くした我々の変法を述べ，更にEllis の正常組織の公式を腫瘍の反応に利用しないように注意をしたい．

　The comparison of the results of radiotherapy among different hospitals is difficult because of the differences of overall time, total dose and fractions. Especially the difference of the number of fractions per week in Japan and that in foreign countries must be discussed, because most of the hospitals in Japan take six fractions per week, and most of foreign papers report five fractions per week.

　To resolve a part of this problem the proposal of nominal standard dose (NSD) of normal tissue and of tumor by Ellis[5][8] is now used in many reports as an acceptable expression at the present[6], although it is not complete as noted in his own reports[4]. In these reports, they use the overall time (days), total dose (rads) and total numbers of fractions as parameters to calculate rets, however, the use of dose per fraction and the fractions per week seem to be better for the parameters than overall time and total

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numbers of fractions, because they are more familiar in routine therapy schedule.

The calculations of NSD are not so difficult by using a computer, but troublesome if manually calculated for medical doctors on daily procedures and the computer is not so easily available for the routine use in most hospitals[3]. To familiate for NSD (rets), we are now using some tables and figures on the relation between NSD (rets) and total dose (rads) calculated by a modified formula for clinical purposes, and we demonstrate some of them in this report.

Because the most of the hospital use fixed daily doses and fractions per week, although the fractionation is not so certain as influenced by patient's condition and irregular holidays, we use "d" (average dose for each fraction by rads) and "n" (average numbers of fraction in a week) instead of original "T" (overall time) and "N" (the number of fractions at the end of treatment).

Naturally $N = D/d$ and $T = 7N/n = 7D/dn$, where D is the total dose in rads and 7 is the number of days in a week. By this modification, the original formula of NSD for normal tissue = $D \cdot N^{-0.24} \cdot T^{-0.11}$ and NSD for tumor (TSD) = $D \cdot N^{-0.24}$ were changed to

NSD for normal tissue = $D \cdot (D/d)^{-0.24} \cdot (7D/dn)^{-0.11}$

NSD for tumor (TSD) = $D \cdot (D/d)^{-0.24}$

By this modification, the NSD (rets) are easily available from D, d and n.

Calculations were performed by Hitachi electronic programmable calculator ELCA P100 (100
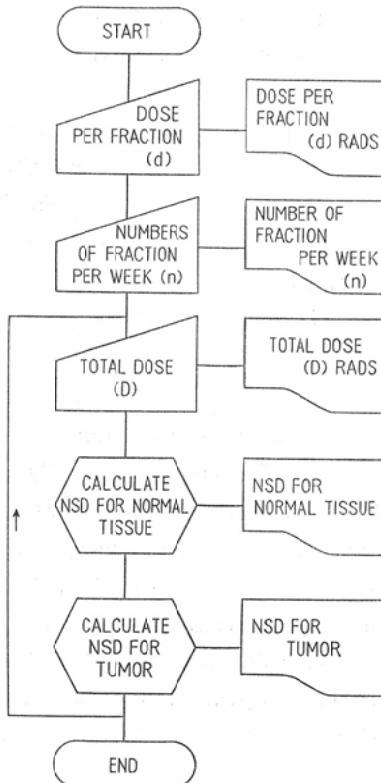

Fig. 1　Flow Chart of Calculation by Calculator (Elca P 100).

steps) which has functional keys for e^x, $1nX$ etc. and 10 numerals between 0 and 9 for memories as one step. Program was constructed by the calculater and memoried by magnetic sheet (83 steps including accessory calculation and program). The flow chart is demonstrated in Figure 1.

The ratios of the values by our modified calculation to those in Ellis's paper[4] are shown in Table 1. The result showed almost complete agreement between Ellis' original results and our modified calculated results as expected, except slight difference among small fractions per week with large dose per fraction. Of course, these formulae could not be applied to the cases which received irregular fractions because of a long term absence.

Table 1. Comparison Between Ellis' Original Calculation and
Our Modified Calculation

No.	Time Days (1)	No. of Frac. (1)	Total Dose (1)	Dose per Frac. (2)	Fract. per Week (3)	Ratio for TSD (4)	Ratio for NSD (4)
1	1	2	2200	1100	14	0.98	0.98
2	2	3	2500	833	10.5	1.00	1.00
3	3	4	2650	663	9.3	0.96	1.00
4	4	5	2750	550	8.8	1.00	1.00
5	6	7	3000	429	8.2	1.00	1.00
6	9	10	3300	330	7.8	0.99	1.00
7	11	12	3500	292	7.6	0.99	1.00
8	14	15	3800	292	7.5	0.99	1.00
9	19	20	4200	210	7.3	1.00	0.99
10	20	21	4250	202	7.4	1.00	1.01
11	24	25	4400	176	7.3	1.00	1.01
12	35	26	7200	277	5.2	1.00	1.00
13	35	26	6500	250	5.2	1.00	1.00
14	21	15	6000	400	5	1.00	1.00
15	21	15	5750	383	5	0.99	1.00
16	21	15	5500	367	5	1.00	1.00
17	21	15	4500	300	5	1.00	1.00
18	20	15	6000	400	5.3	1.00	1.00
19	21	16	5400	338	5.3	1.00	1.00
20	42	20	6000	300	3.3	1.00	1.00
21	28	13	5000	385	3.3	1.00	1.00
22	75	18	6000	333	1.7	1.00	1.00
23	49	13	5200	400	1.9	1.00	1.00
24	33	13	4950	380	2.8	1.00	1.00
25	98	24	6300	263	1.7	1.00	1.00
26	70	9	4500	500	0.9	0.91	0.91
27	40	16	4875	305	2.8	0.91	0.91
28	21	4	3200	800	1.3	0.91	0.91
29	28	21	4200	200	5.3	1.00	1.00
30	84	13	3900	300	1.1	1.00	1.00

(1) from tables 3 and 4 of reference.

(2) from No. 1 to No. 11, from tables 3 and 4 of reference and after No. 12 calculated from the tables of reference.

(3) calculated from tables 3 and 4 of reference as number of fractions divided by time (days) and multiplied seven (days in a week).

(4) results by our modified calculation formula divided by results demonstrated in tables 3 and 4 calculated by Ellis' original formuls.

In Table 2, NSD of normal tissue for weekly dose of 500, 600, 700, 800, 900, 1000, 1200, 1500, 1800, 2000 and 2500 rads by 1, 2, 3, 5 and 6 fractions per week are demonstrated.   In Figure 2, the relation between NSD for normal tissue and total dose are demonstrated from Table 2.   In Table 3 and Fgure 3 the relation between NSD for tumor and total dose are demonstrated, and naturally because NSD for tumor depends only on D and d, the fractionation makes no influence on the relation between NSD and D.   The figures will be useful to know the rough numbers of rets during therapy, and
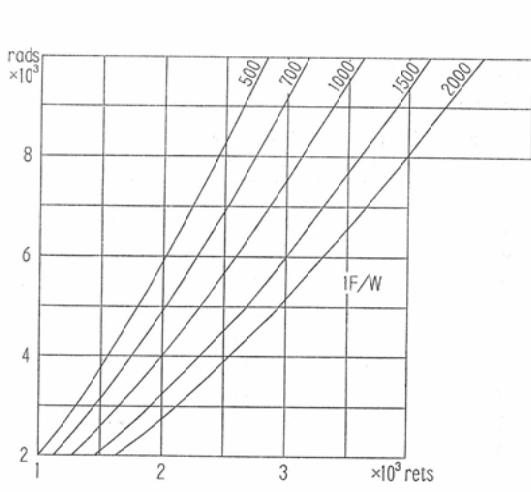
a)   One fraction in a week
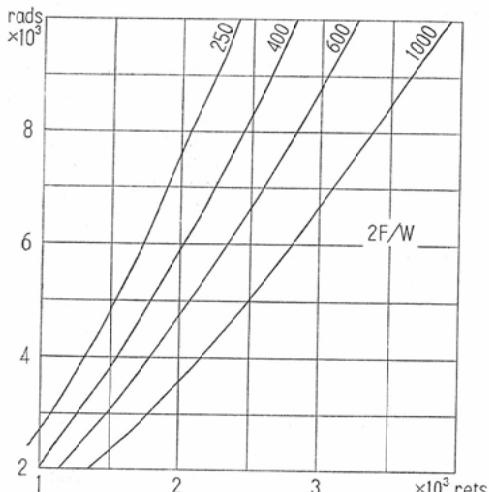
b)   Two fractions in a week
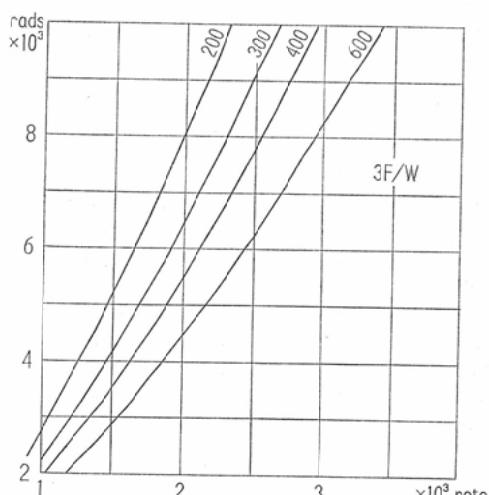
c)   Three fractions in a week
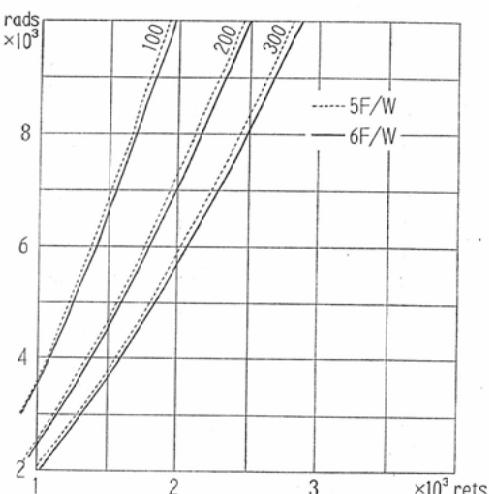
d)   Five (dotted line) and six (solid line) fractions in a week

Numbers on the curves demonstrate the dose (rads) per fraction (d)

Fig. 2   Comparison Between Total Dose (rads) and NSD for Normal Tissue (rets) Calculated by Modified Ellis' Formula

Table 2.　NSD (rets) for Normal Tissue Calculated by Modified Ellis Formula

a)　Accumulated dose for a week 500 rads

Total Dose (D)	Dose per Fraction (d) × Fractions per Week (n)				
	500 × 1	250 × 2	167 × 3	100 × 5	83 × 6
500	404	342	310	274	263
1000	633	536	487	430	412
2000	994	842	764	675	647
3000	1294	1095	994	879	841
4000	1560	1321	1198	1060	1015
5000	1803	1527	1385	1225	1173
6000	2030	1719	1559	1380	1320
7000	2244	1900	1724	1525	1460
8000	2448	2072	1880	1663	1592
9000	2642	2237	2030	1795	1719
10000	2829	2396	2173	1923	1840

b)　Accumulated dose for a week 600 rads

Total Dose (D)	Dose per Fraction (d) × Fractions per Week (n)				
	600 × 1	300 × 2	200 × 3	120 × 5	100 × 6
500	—	364	331	292	280
1000	675	572	517	459	439
2000	1059	897	814	720	689
3000	1379	1168	1059	937	897
4000	1662	1408	1277	1130	1081
5000	1922	1627	1476	1306	1250
6000	2164	1832	1662	1470	1407
7000	2392	2025	1838	1625	1556
8000	2609	2209	2004	1773	1697
9000	2816	2385	2163	1914	1832
10000	3016	2554	2317	2049	1962

c)　Accumulated dose for a week 700 rads

Total Dose (D)	Dose per Fraction (d) × Fractions per Week (n)				
	700 × 1	350 × 2	233 × 3	140 × 5	117 × 6
500	—	385	349	309	295
1000	713	603	547	484	464
2000	1118	947	859	760	727
3000	1455	1232	1118	989	947
4000	1755	1486	1348	1192	1141
5000	2028	1718	1558	1378	1319
6000	2284	1934	1754	1552	1485
7000	2524	2137	1939	1715	1642
8000	2753	2331	2115	1871	1791
9000	2972	2517	2283	2020	1933
10000	3183	2695	2445	2163	2070

d)　Accumulated dose for a week 800 rads

Total Dose	Dose per Fraction (d) × Fractions per Week (n)				
(D)	800 × 1	400 × 2	267 × 3	160 × 5	133 × 6
500	—	403	366	323	310
1000	747	632	574	507	486
2000	1172	992	900	796	762
3000	1525	1291	1171	1036	992
4000	1838	1557	1412	1249	1196
5000	2125	1800	1633	1444	1383
6000	2393	2026	1838	1626	1557
7000	2645	2240	2032	1798	1721
8000	2885	2443	2216	1961	1877
9000	3114	2637	2393	2117	2026
10000	3335	2824	2562	2267	2170

e)　Accumulated dose for a week 900 rads

Total Dose (D)	Dose per Fraction (d) × Fractions per Week (n)				
	900 × 1	450 × 2	300 × 3	180 × 5	150 × 6
500	—	420	381	337	323
1000	778	659	598	529	506
2000	1221	1034	938	830	794
3000	1589	1346	1221	1080	1034
4000	1916	1622	1472	1302	1246
5000	2215	1875	1702	1505	1441
6000	2494	2111	1916	1695	1622
7000	2756	2334	2118	1873	1793
8000	3006	2546	2310	2043	1956
9000	3246	2748	2493	2206	2111
10000	3476	2943	2670	2362	2261

f)　Accumulated dose for a week 1000 rads

Total Dose (D)	Dose per Fraction (d) × Fractions per Week (n)				
	1000 × 1	500 × 2	333 × 3	200 × 5	167 × 6
500	—	436	395	350	335
1000	807	684	620	549	525
2000	1267	1073	973	861	824
3000	1649	1396	1267	1121	1073
4000	1988	1683	1527	1351	1293
5000	2298	1946	1765	1562	1495
6000	2587	2191	1988	1758	1682
7000	2860	2422	2197	1944	1860
8000	3119	2641	2396	2120	2029
9000	3367	2851	2587	2288	2190
10000	3606	3053	2770	2451	2346

g) Accumulated dose for a week 1200 rads

Total Dose (D)	Dose per Fraction (d) × Fractions per Week (n)				
	1200 × 1	600 × 2	400 × 3	240 × 5	200 × 6
500	—	—	421	373	357
1000	861	729	661	585	560
2000	1350	1143	1037	918	878
3000	1757	1488	1350	1194	1143
4000	2119	1794	1628	1440	1378
5000	2450	2074	1882	1665	1593
6000	2758	2335	2119	1874	1794
7000	3048	2581	2342	2072	1983
8000	3325	2815	2554	2259	2163
9000	3589	3039	2757	2439	2335
10000	3844	3255	2953	2612	2500

h) Accumulated dose for a week 1500 rads

Total Dose (D)	Dose per Fraction (d) × Fractions per Week (n)				
	1500 × 1	750 × 2	500 × 3	300 × 5	250 × 6
500	—	—	456	403	386
1000	—	788	715	632	605
2000	1460	1236	1122	992	950
3000	1900	1609	1460	1291	1236
4000	2291	1940	1760	1557	1490
5000	2469	2243	2035	1800	1723
6000	2982	2525	2291	2026	1940
7000	3296	2791	2532	2240	2144
8000	3595	3044	2762	2443	2338
9000	3881	3286	2981	2637	2524
10000	4156	3519	3193	2824	2703

1) Accumulated dose for a week 1800 rads

Total Dose (D)	Dose per Fraction (d) × Fractions per Week (n)				
	1800 × 1	900 × 2	600 × 3	360 × 5	300 × 6
500	—	—	—	429	411
1000	—	840	762	673	643
2000	1556	1318	1195	1058	1012
3000	2025	1715	1556	1376	1308
4000	2442	2068	1876	1659	1589
5000	2823	2390	2169	1919	1836
6000	3178	2691	2442	2160	2067
7000	3513	2975	2699	2388	2285
8000	3832	3244	2944	2604	2493
9000	4137	3503	3178	2811	2691
10000	4430	3751	3403	3010	2882

j)　Accumulated dose for a week 2000 rads

Total Dose (D)	Dose per Fraction (d) × Fractions per Week (n)				
	2000 × 1	1000 × 2	667 × 3	400 × 5	333 × 6
500	—	—	—	446	427
1000	—	871	790	699	669
2000	1615	1367	1240	1097	1050
3000	2101	1779	1614	1428	1367
4000	2534	2145	1946	1722	1649
5000	2929	2480	2250	1991	1905
6000	3298	2792	2533	2241	2145
7000	3645	3086	2800	2477	2371
8000	3976	3366	3054	2702	2586
9000	4292	3634	3297	2917	2792
10000	4596	3892	3531	3124	2990

Table 3.　NSD (rets) for Tumor Calculated by Modified Ellis Formula (TSD)

Total Dose (D)	Dose per Fraction (d)										
	100	200	300	400	500	800	1000	1200	1500	1800	2000
500	340	401	442	474	500	—	—	—	—	—	—
1000	575	680	749	803	847	948	1000	—	—	—	—
2000	975	1151	1267	1359	1434	1605	1693	1769	1867	1950	2000
3000	1326	1566	1726	1850	1951	2185	2305	2408	2540	2654	2722
4000	1650	1949	2148	2302	2428	2718	2868	2996	3161	3302	3387
5000	1955	2309	2545	2727	2877	3221	3398	3550	3745	3913	4013
6000	2246	2652	2924	3132	3305	3699	3903	4078	4302	4494	4609
7000	2525	2982	3287	3522	3716	4159	4388	4584	4837	5053	5182
8000	2795	3301	3638	3898	4112	4604	4857	5074	5353	5593	5736
9000	3056	3610	3977	4263	4498	5035	5312	5549	5854	6116	6273
10000	3311	3911	4310	4618	4873	5454	5754	6012	6343	6626	6796
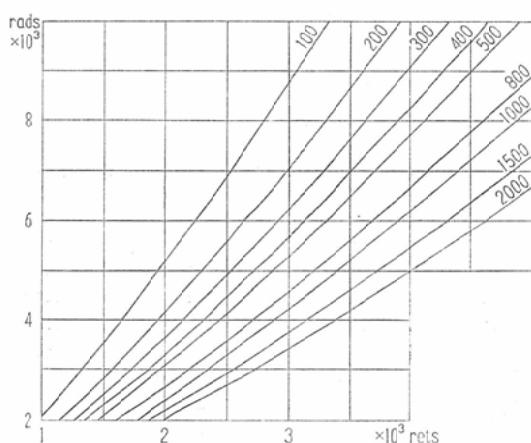
Numbers on the curves demonstrate the dose (rads) per fraction (d)

Fig. 3　Comparison Between Total Dose (rads) and NSD for Tumor (rets) Calculated by Modified Ellis' Formula (TSD)

tables will be useful to know finer numbers of rets. The dose which is not listed on these tables and figures will be estimated by the average number with the proportional law among the nearest points. The difference between NSD for tumor and NSD for normal tissue must be carefully observed because the NSD for normal tissue are frequently used for evaluation of tumor[1][5] instead of clearly different formulae proposed by Ellis[4].

The results suggest that the difference of NSD between six fractions per week and five fractions per week is about 500 rads at the level of total dose of 2000 rets in normal tissue and about 70 rets at the level of 6000 rads for the same weekly doses. In other words, the differences are about 200 rads at 2000 rets and about 40 rets at 6000 rads for the same fractional doses.

Addendum

After we had sent this paper to this Journal, similar report was published in a new issue of British Journal of Radiology by Orton and Ellis[7]. Differences between their report and ours are that their main purpose was based on partial tolerance and they were not concerned with TSD and with six fractions per week, while ours was mainly based on complete course and was concerned also with TSD and six fractions per week, although the need for simplification of formula for routine use by using more familiar parameters was the same.

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