THE USE OF DOSES FROM PERSONAL MONITORING SERVICES FOR EPIDEMIOLOGICAL PURPOSES

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Introduction

Epidemiological studies of groups of workers who are occupationally exposed to radiation may offer direct evidence on the effects of low doses of ionising radiation on human populations. Information on the doses to which these workers have been exposed will usually come from programmes of personal monitoring. One of the main aims of personal monitoring is to demonstrate compliance with dose limits and dose recording conventions are sometimes used which can seriously distort dose histories. This paper discusses some of these problems and describes ways in which estimates of dose can be improved.

The conventions which can distort dose histories are given below

Notional Doses If a dosemeter is lost or cannot be assessed for some other reason many dosimetry services assign a pro-rata notional dose. This is the fraction of the dose limit appropriate to the period for which the missing dosemeter should have been worn. The effect is to reduce the dose limit pro-rata to the period for which measured doses are available. Notional doses should not be confused with "estimated doses" which are realistic estimates of missing doses based, for example, on the experience of other workers.

Threshold Doses When the dosemeter assessment process does not indicate a dose above the threshold of detection, some personal monitoring services enter this "threshold dose" into the dose record.

Recording Levels It has been suggested, for example in ICRP publication 26, that it is unnecessary to record doses below some prespecified recording level. ICRP now suggest that the recording level should be 10% of the fraction of the dose limit for the period in question. 30% had also been suggested.

Illustration

The effect of notional doses, threshold doses and recording levels are illustrated in Table 1. The data refer to a group of 513 classified workers on the National Radiological Protection Board's dose record keeping service for the whole of 1980. More details of this group, will be found in Kendall et al, 1982, and Darby et al, 1982. The importance of the three dose recording conventions will of course depend on the particular group involved. Nevertheless we believe that data presented here are not atypical.

The importance of notional dose depends on the frequency with which dosemeters are lost or cannot be assessed for some other reason. Unless the loss rate is very small, it is likely that notional doses will be important. The data in Table 1 indicates that notional doses increased the recorded annual average dose by about 50%. In fact this underestimates the problem since one criterion for inclusion in the group was that the individual had lost no more than two dosemeters in the year. For classified workers as a whole, notional dose increased the annual dose by almost 80%.

	Number of individuals in each dose group (doses in mSv)								average dose mSv
	0.0-5.0	5.01-10.0	10.01-15.0	15.01-20.0	20.01-30.0	30.01-40.0	40.01-50.0	50.0+	
measured doses only	413	49	20	10	14	4	2	1	3.6
measured doses and notional doses	354	74	39	13	22	8	0	3	5.5
Threshold doses									
set to 0.1 mSv	391	59	30	9	16	5	1	1	5.7
set to 0.2 mSv	0	434	35	18	18	5	1	2	8.1
Recording level									
set to 0.2 mSv	421	43	18	13	11	4	2	1	3.3
set to 0.6 mSv	433	36	18	11	8	4	2	1	2.9

Table 1: The effect of notional doses, threshold doses and recording levels on the doses incurred by a group of 513 workers on two-weekly monitoirng.

Table 1 shows the effect of simulating threshold doses of 0.1 and 0.2 mSv. Even these low thresholds increase the recorded annual doses greatly. Most workers are in the lowest dose category and it is here that the effect is the greatest. Those individuals with large doses are relatively little affected. There will be a minimum recorded annual dose, in this case twenty-six times the dose threshold.

Table 1 also shows the effect of simulating recording levels by setting to zero doses which are below 10% and 30% of the appropriate fraction of the dose limit. The effects on dose histories of recording levels are smaller than those of notional doses or threshold doses.

It is worth noting that threshold doses or recording levels must be used in all personal monitoring services since there will always be doses which are below the threshold of detection, but are still non-zero. These must be set to zero or to the threshold dose. The evidence presented here suggests that the former will give much more accurate dose histories.

Discussion

While it is possible that notional doses may occasionally underestimate the dose incurred by the worker it is probable that their inclusion generally increases the annual recorded dose significantly. Moreover, the effect on individual dose histories is not systematic, being determined by the number of dosemeters which have not been assessed. This is in contrast to threshold doses and recording levels which lead to a systematic distortion of the dose scale. Fortunately separate records of notional dose are generally kept. Estimates of dose will almost certainly be improved by setting notional doses to zero, or to the appropriate fraction of the measured dose.

If the dose threshold is low, the presence of threshold doses in dose histories may not be serious for epidemiological studies. For example, if the essence of the method is to compare age specific death rates in low dose and high dose groups then the qualitative conclusions may be unaffected by an increase in the mean dose to the low dose group. However, large inaccuracies in doses are undesirable and it is easy to imagine that this kind of error might cause serious problems in trying to fit specific dose-response models. Unlike notional doses, separate records of the contribution of threshold doses to the recorded dose are not generally kept. Three methods for improving estimates of dose have been suggested (Darby et al 1982). The simplest of these was to subtract the minimum annual dose appropriate to the issue period from all recorded annual doses. This led to significant improvements in the estimation of doses and has the useful property of ensuring that no dose is overestimated. Moreover it requires a knowledge of only the dose threshold and the number of dosemeters worn in a year. The other two methods for improving estimates of dose lead to more accurate answers, but require considerably more data.

We now investigate threshold doses and recording levels by considering the distribution of dosemeter assessments to each individual. The distribution of all dosemeter assessments for the group of 513 workers was found to be very skew, with most of the results close to zero but with a long tail (Darby et al 1982). The Weibull distribution was found to model the data significantly better than the log-normal distribution. It was possible to apply rigorous statistical tests to the distribution of dosemeter assessments for all workers. It is much less easy to investigate our present interest, the distribution of dosemeter assessments for an individual, since there are only twenty-six doses and most of these were generally recorded as zero. However, a number of simple tests suggest that this distribution is also very skew. Thus for 90% of the workers the median dose was zero, almost as frequently the standard deviation exceeded the mean and the mean exceeded the median.

The effect of threshold doses and recording levels on the doses attributed to workers was modelled assuming that the distribution of doses to an individual was Weibull. Expected values of annual doses were calculated by summing the contribution from all parts of the distribution above the threshold. To simulate threshold doses, doses below 0.2 mSv were set to this value. Recording levels were simulated by setting to zero doses below 0.2 mSv or 0.6 mSv. Table 2 shows the consequences of the model for the expected annual doses of workers on two-weekly monitoring. These calculations are illustrative since we do not know the precise dose-distribution curve. However, they are broadly consistent with the observations on real dose histories described above. They demonstrate that threshold doses lead to very much larger errors than do recording levels but that the simple correction described above gives greatly improved estimates of dose. These corrected estimates are always lower than the true dose. The model suggests that the deviation is relatively constant. Recording levels lead to relatively small underestimates of annual doses. Again, doses are underestimated by a relatively constant amount. It is probable that epidemiological studies would not be seriously jeoparised if annual doses were all underestimated by a small quantity.

These features arise from the skewness of the distribution of dose assessments. The mean dose is largely determined by the tail of the distribution; the main bulk of the density is too close to zero to contribute greatly. If the contribution from the bulk of the distribution is set to zero, the mean is little affected (as in recording levels). On the other hand if the bulk of the distribution is deemed to fall at a non-negligible threshold dose, the average dose is significantly affected. The precise figures given in Table 2 depend on the details of the model. However, the main conclusions will be true whenever

True Average Dose mSv	Dose Recorded if Recording Level		Dose Recorded if Threshold Dose 0.2 mSv	
	0.2 mSv	0.6 mSv	uncorrected	corrected
1	0.5	0.1	5.5	0.3
5	4.6	4.1	9.2	4.0
10	9.6	9.1	14.1	8.9
15	14.6	14.1	19.1	13.9
20	19.7	19.1	24.1	18.9
30	29.7	29.1	34.0	28.8
40	39.7	39.1	44.0	38.8
50	49.7	49.1	54.0	48.8

Table 2: Predicted effect of recording levels and threshold doses on annual doses attributed to workers on two-weekly monitoring if the distribution of individual dosemeter assessments is very skew (Weibull).

the distribution of dosemeter assessments to individuals is of the general form described above. Thus for example, a log-normal model gave similar results to the Weibull distribution.

Summary

a) Notional doses can seriously distort dose histories. They should be removed or replaced by the appropriate fraction of the measured dose.

b) Dose histories which are based on the use of recording levels like those discussed in this paper can probably be accepted as they are.

c) If dose histories contain threshold doses then a correction should be considered. Simply subtracting the minimum annual dose may well lead to very significant improvement.

References

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