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Analysis of Y-90 Dose Delivery Uncertainties

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ABSTRACT

The Y-90 delivery dose calculation uncertainty has two independent sources: one from the dose calibrator accuracy, the other from the exposure rate measurement. In this project, we studied the exposure rate measurement uncertainties of our institute's recent 100 cases. The initial assayed dose activity and the dose exposure rate was linearly correlated. The measurement uncertainty was inversely correlated to the initial activity.

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INTRODUCTION

In the process to calculate the delivered Y-90 (Yttrium-90) dosage, there is measurement uncertainty associated with each step which can be calculated with the knowledge of the dose calibrator and survey meter accuracy and the estimated operator's reading uncertainties. The purpose of this project is to analyze the contribution from all the uncertainty sources.

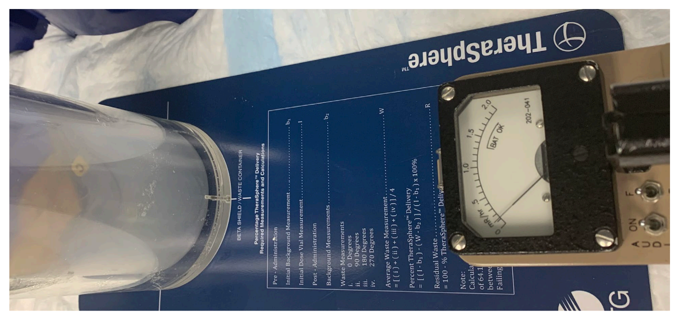
METHODS AND MATERIALS

The first step of Y-90 delivery is to assay the prescribed unit dose, P, using a dose calibrator, whose accuracy contributes to an uncertainty of ΔP. Operator reading uncertainty and the background are not considered in this step, because they are insignificant compared to the dose calibrator accuracy uncertainty.

The second step is to measure the exposure rate, E, of the assayed unit dose using a survey meter with accuracy S. The operator's reading uncertainty is assumed to be ΔE. The uncertainty at this step is ΔE+S×E. The background, B, also has a reading uncertainty ΔB and a meter uncertainty S×B. The net exposure rate is then E-B with an uncertainty ΔE+ΔB+S×(E+B). Usually, E and ΔE are significantly larger than B and ΔB. So, the uncertainty of the initial exposure rate can be simplified as ΔE+S×E and the net initial exposure rate be simplified as E.

Initial exposure rate reading with uncertainty: E ± (ΔE+S×E)

After dose delivery, the waste exposure rate, W, is measured, with operator's reading uncertainty ΔW. It was reasonable to assume the same background exposure rate and uncertainty as those in the second step. The net waste exposure rate is W-B. The uncertainty at this step is ΔW+ΔB+S×(W+B). The waste and the background exposure rates are usually in the same order.



Waste exposure rate reading with uncertainty: W ± (ΔW+ ΔB+ S×(W+B))

The exposure rate ratio of the waste to the initial dose is R = (W-B)/E. The delivery dose is calculated as D=P(1-R). The percentage uncertainty of the delivered dose is

$$\frac{\Delta D}{D} = \frac{\Delta P}{P} + \frac{\Delta R}{1-R}.$$

The exposure rate ratio percentage uncertainty is

$$\frac{\Delta R}{R} = \frac{\Delta E + S \times E}{E} + \frac{\Delta W + \Delta B + S \times (W + B)}{W - B}.$$

RESULTS

The uncertainty from the dose calibrator is independent on that of the exposure rate. We studied the exposure rate uncertainty of our hospital's recent 100 cases. The lowest reading for E was 0.4 mR/h; the highest was 13.4 mR/h. It was reasonable to assume the operator's reading uncertainty to be 0.1 mR/h, which was in the range of the last digit of the reading. The survey meter accuracy was assumed to be 10%. All the waste exposures and the background readings were in the order of 0.01 mR/h, the lowest reading of the survey meter. It was reasonable to assume ΔW, ΔB, S×W and S×B all to be 0.01 mR/h, the minimum reading unit of the survey meter in our practice.

The 17 cases with initial exposure rate below 1mR/h all had exposure rate ratio uncertainties ($\frac{\Delta R}{1-R}$) above 5% (the highest one is 14%). All other cases with initial exposure rate readings above 1mR/h had uncertainties below 5%. Figure 1 shows the exposure rate uncertainty dependence on initial activity and exposure rate and the correlation between initial activity and the exposure rate.

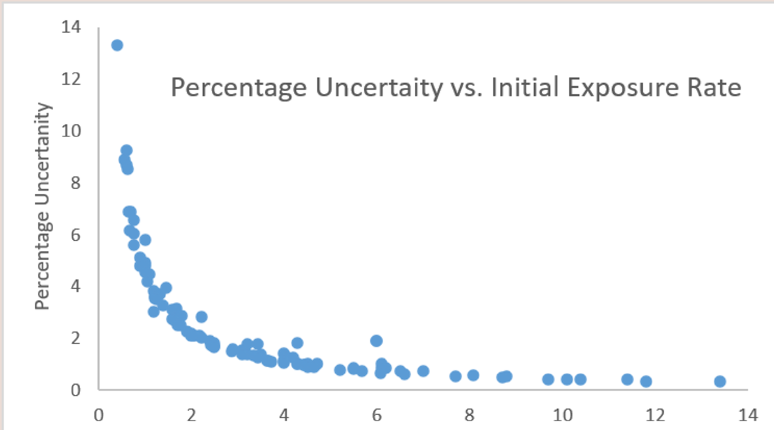


Fig 1. a

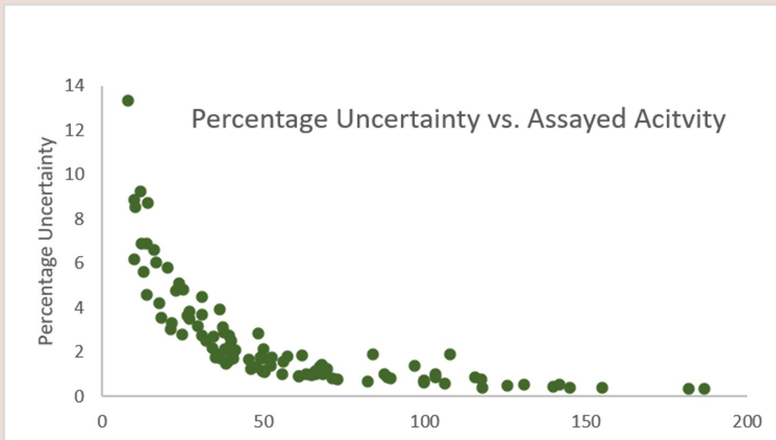


Fig 1. b

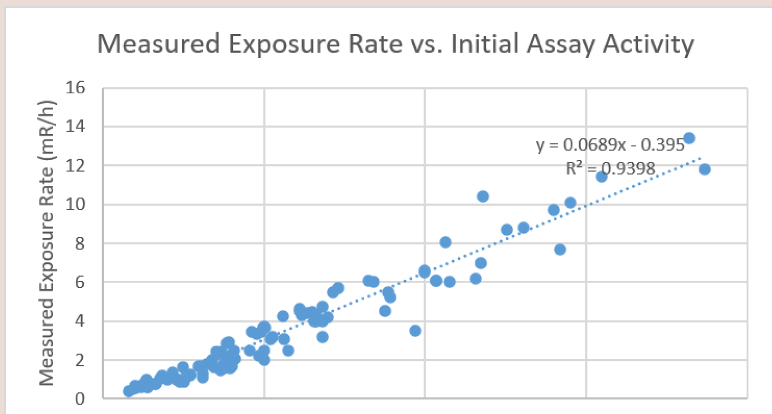


Fig 1. c

Figure 1.a shows the dependence of the exposure rate percentage uncertainty ($\frac{\Delta R}{1-R}$) on the measured initial exposure rate. Figure 1.b shows the exposure rate percentage uncertainty dependence on the assayed Y-90 activity. Figure 1.c shows the correlation between the initial exposure rate and the assayed Y-90 activity.

DISCUSSION

This study shows an example on how to calculate the measurement uncertainties in Y-90 delivery. The total uncertainty is the sum of dose calibrator accuracy and the exposure rate uncertainty. The initial dose activity and measured exposure rate is linearly correlated as shown in Figure 1.c. The percentage uncertainty of the exposure rate is inversely correlated to the initial activity and the initial exposure rate. With large data size, the fitting would be more accurate.

CONCLUSION

The exposure rate ratio is high for low dose cases whose initial exposure rate is low. This is the major reason for high delivery uncertainties for low dose cases.