Optimizing Radiopharmaceutical Utilization: The Shortage-Outdating Operating Curve

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An inventory model—optimizing radiopharmaceutical utilization and providing the user with a family of curves with which to estimate both waste and service levels—is proposed. Percent of wasted supply compared with percent of unsupplied demand was calculated for I-131 and for I-123 as a function of the number of capsules placed on standing order. These operating curves represent analysis of actual patterns of use in our central radiopharmacy. Individual patient's radiopharmaceutical dose cost obviously includes the cost of unused standing order supplies. The actual dollar cost of operating differing levels of unmet demand can be easily determined.

The central radiopharmacy (CRP) is a well-recognized entity within the nuclear medicine community. One function of the CRP is to effect significant economies of operation through ordering policy and inventory control procedures (*1-5*). Clearly this centralized ordering function can be effective when it is recognized that the sum of the standard deviation of demands for a particular radiopharmaceutical at individual institutions will generally exceed the standard deviation of the total system demand.

In practice, there is a great deal of statistical fluctuation around the average number of doses required at each individual institution. When doses are ordered centrally, the number of doses required to meet demand tends to average out, resulting in less waste compared with the waste that would arise by independent institutional ordering. In this way centralization tends to reduce the overall variation observed (*6,7*), decreasing decay loss and waste at an individual facility.

Suppose, for example, that each of two hospitals has an average demand of three doses of a particular drug per day with a standard deviation of two doses per day. Assuming their demands are independent, the s.d. of their pooled demand would then be the square root of 8, or 2.83. This is less than the sum of the individual s.d.'s of 4.

A second function of the CRP is to encourage the use of as well as provide superior alternative radiopharmaceuticals when they are available (*7-10*).

This study presents some preliminary investigations into the problems of developing suitable inventory levels and a standing order policy for our central radiopharmacy, which is located at the Presbyterian-University Hospital of the University Health Center of Pittsburgh and serves the Pittsburgh area. The illustrative example cited deals with service levels and wastage that were projected to occur because of ordering policy, during a conversion from I-131 to I-123 for thyroid studies in cases in which sodium pertechnetate did not provide the required diagnostic information.

We developed and examined a methodology for comparing various standing order policies for the designated radiopharmaceutical. We aimed to establish a balance between risk of shortage (inability to supply the drug) and the proportions of stock which perish within a central system by decay or expiration.

Materials and Methods

Demand and dosage requirements for each of the hospitals involved in this study were estimated by direct interview with individual nuclear medicine technologists in respective nuclear medicine departments and corroborated by examination of patient records. Discrete probability distributions associated with the number of doses administered of every one of the radiopharmaceuticals were generated at each of the designated hospitals for every day of the week. The probability distribution of total system demand for every drug on every day of the week was then developed by simulating convolution of individual hospital demands.

Iodine capsules purchased on standing order enter inventory, decay, then are ultimately used to satisfy demand; or they are discarded because of decay or expiration, or both. The process by which capsules enter and leave the system was simulated using GASP, a Fortran-based computer simulation language (University of Pittsburgh Computer Center) (*11*). Daily demands for every drug in the system were generated as sample realizations of input data. Five hundred replications of weekly demand were used to obtain the shortage-outdating characteristic curve for various standing orders for each of the drugs we considered, e.g., Ga-67 citrate, Yb-169 DTPA, etc. The shortage-outdating operating curve represents the end product of analysis. Use of this curve allows one to estimate the percentage of drug loss caused by waste depending upon the service level chosen. Likewise, one can estimate percent of waste or service level from the number of capsules that are chosen for purchase.

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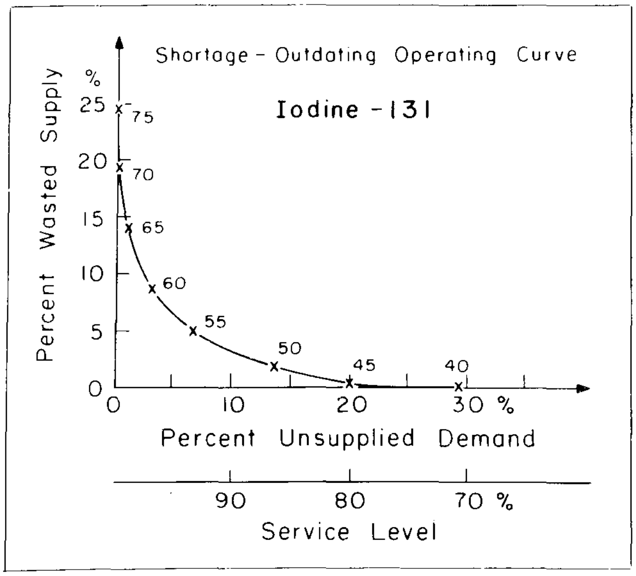

FIG. 1. Shortage-outdating operating curve for I-131 Na capsules: wasted supply compared with unsupplied demand (service level). Numbers on the curve represent numbers of capsules to be purchased on standing order to meet predetermined service level criteria.

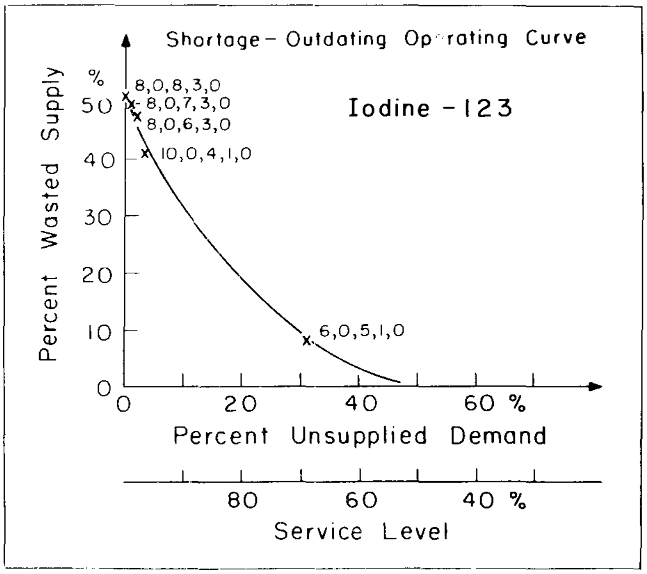

FIG. 2. Shortage-outdating operating curve for I-123 Na capsules: wasted supply compared with unsupplied demand (service level). Numbers on the curve represent number of capsules to be purchased on a given day of the week on standing order to meet predetermined service level for that week.

Results

The shortage-outdating operating curve for I-131 Na can be seen in Fig. 1. The ordinate value gives the mean percentage of the total supply that will be discarded because of outdating (either by decay or expiration). The abscissa gives the mean percentage of demands (requests) arising in the system that cannot be satisfied (unsupplied demand) by the available stock (generally called the service level). Hence, on the average, to satisfy 90% of the demands (10% unsupplied demand) for I-131 requires a standing order of 53 capsules per week and results in an average of 3% of the capsules being wasted. If, on the other hand, one chose a 98% service level this would require a standing order of 65 capsules per week and would result in about 14% outdating. Likewise, a standing order purchase of 70 capsules per week would result in a 99% service level, but would also result in 18% wastage.

For I-123 Na (Fig. 2) various daily, rather than weekly, standing orders were considered. Thus, for the curve cited herein, the numbers along the curve represent capsules ordered for a particular day during a week. One might choose to supply 98% of all demands for a given week (and not supply 2%) and would place a standing order for the sequence (8,0,7,3,0). For the 18 capsules of I-123 Na, eight would be dispensed on Monday, none on Tuesday, seven on Wednesday, three on Thursday, and none on Friday. However, the cost would be higher than a comparable number of I-131 Na capsules and about 50% would be wasted because of outdating (24-hr useful life). The Monday-Wednesday-Thursday schedule at our hospital was a deliberate scheduling decision chosen by the physician, technologist, and nuclear pharmacist and based on patient load, equipment availability, convenience, cost, and demand of participating hospitals. The radiopharmaceutical ordering schedule chosen represents conditions at the time of the study; it varies as schedule or demand changes. A new schedule would be reflected in a new curve.

TABLE 1. Thyroid Dosage as a Function of Age (rads/μCi)

Radioiodine	Newborn	Ten years	Standard Man
I-123	0.16	0.03	0.015
I-131	16.0	3.0	1.5

(From Ref. *10*.)

Keeping cost in mind, one might choose to waste 8% of his supply and place the standing order sequence (6,0,5,1,0). However, 12 capsules per week would on the average result in 30% unsupplied demand. This may or may not be critical since the half-life of I-131 Na (8.04 days) is much longer than I-123 Na (13.2 hr) and I-131 Na is routinely kept on hand in most nuclear medicine facilities.

Discussion and Conclusions

We propose an inventory model to optimize radiopharmaceutical utilization, which provides the user with a family of curves with which to estimate percentage of inventory waste depending upon the service level chosen.

The shortage-outdating characteristic curves we developed are intended as guidelines for estimating inventory levels in a multihospital central radiopharmacy. The model developed is a considerable simplification of the actual operation. However, the results are useful in providing an estimate of the shortage-outdating characteristics of the centralized system and will provide a method of evaluating economies of scale (relative cost savings), which can be achieved by centralization.

Service levels and outdating which are currently being experienced at member hospitals can be compared to the anticipated characteristics for the central system. With respect to the individual patient's radiopharmaceutical dose, a more accurate cost determination can be estimated based on the service level chosen.

Additionally, note that the total cost of any radionuclide diagnostic procedure must be measured in rads (*10*) (Table 1) as well as in dollars. The dollar cost of a radiopharmaceutical consists of the manufacturer's charge, shipping charge, and waste. The availability of I-123 allows the physician the opportunity to choose up to a 100-fold reduction in rads when substituting for I-131, depending upon level of radionuclide contamination in I-123.

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