SETTING INVENTORY LEVELS FOR A CENTRALLY LOCATED BLOOD BANK OF A METROPOLIS - A SIMULATION APPROACH

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Abstract

Blood is a scarce and non-synthesisable resource which would perish eventually when kept under artificial storage. The major problem encountered in blood bank administration is that of making decisions on policies for setting up inventory levels to meet the needs as soon as they arise and simultaneously keep the expiry of blood on the shelf within reasonable limits. The selection of such policies is greatly influenced by demand, daily transfusion, shortages, outdating and shortage-outdate rates.

A true mathematical inventory modelling is nearer to impossibility due to the complexity of interaction between these variables and the stochastic nature of the processes involved.

Early works have shown that there exists a universal relationship between these variables that holds for all blood types. Statistical methods will yield the inventory levels to be set up on the basis of these variables. But this warrants cumbersome analysis of extensive data collected over a minimum period of 12 months. The volume of work involved makes this method unwieldy. Simulation tending towards a systems approach appears to be more effective and efficient in the analysis of such inventory situations. The objective of this study is to investigate and analyse with the use of computer simulation, the relationship between inventory levels, mean demand and shortage-outdate rates for all Rh system blood types in a centrally located blood bank of a metropolis like Bombay. Environmental study of present day management of independant blood banks has also been performed.

Introduction

The practice of blood transfusion and storage methods have undergone tremendous transformations during the last few years. The bulk of the literature produced so far discussing and suggesting management policies for blood banks has nearly become of no practical use, thanks to the sophistication and consequent complexity added to the whole system. Despite continued research on cryogenic preservation of whole blood and blood components no practical solutions have come out of the cryocooled vaults of the laboratories. A remarkable achievement in this side is the enhancement of the life of whole blood from the earlier 21 days to 35 days using Citrate-Phosphate-Dextrose-Adenine(CPDA) instead of Acid-Citrate-Dextrose(ACD) solutions. The statistical effects of varying life span of whole blood over a wide range have been studied by Pegels (1978) using simulation approach.

In Operations Research the very idea of perishability of inventory items was sparked off by blood bank management problems. Researchers like Millard (1960), Elston and Pickrell (1963), Jennings (1973), Brodheim et.al. (1975), Cohen and Pierskella (1975) and Costas Sapountzis (1984,1989) have presented extensive mathematical analyses. Nonetheless the actual problem seems to be too complex to be discussed by single mathematical models.

One of the major drawbacks of the mathematical models is lack of emphasis on the information needs for the blood bank inventory control. Consequently the policies evolved treat blood as a mere commercial perishable product.

During the data collection phase of the present study, this inadequacy was observed by the authors. The finest example is that of the concept of ordering of inventory items. No medical professional could conceive of the idea of 'ordering' for blood as and when needed except for the requests for emergency shipments from other hospitals. Even in such cases lack of a coordinated information system quite often marr the efficient operation of the bank. Outdating which is a key parameter considered in most models seems to be of no importance in a metropolis like Bombay where shortage is the one and only problem. It was also noticed that a majority of the hospital blood banks failed in maintaining records of occurences of shortage. This naturally leads to wrong predictions of future demand.

Jennings (1969) has neatly pointed out the information needs and the Technical Manual of American Association of Blood Banks (1977) has presented an elaborate treatise on the standards to be maintained by the blood banks, in respect of records, tests, procedures etc.

Catassi and Peterson (1966) were the first to bring out a proposal for an information based management system for blood banks. Later Jennings (1968), Stewart and Stewart (1968), Hirsch et.al.(1970) and Brodhein (1978) proposed various computer based systems for the surveillance of inventory control.

Computer simulation study of the management policies for determining optimum inventory levels was done by Elston and Pickrel (1963) using UNIVAC 1105. They considered a class of ordering policies assuming an arbitrary 25:4 ratio of the costs of shortage to outdating. The study revealed that following a FIFO(First-In-First-Out) policy, the average age of blood in store could be enhanced when the random input is doubled. Another major work using simulation methods was that of Cohen and Pierskella (1975) on management strategies for administration of a regional blood bank. Based on the assumption of a relatively fixed supply of donors, the effect of controlling the ordering, issuing and cross matching policies on the systems are studied. They showed that FIFO dominates LIFO(Last-In-First-Out) over a reasonable range of crossmatch release period, D. Optimal policies with a view to minimize percentage shortages and percentage outdating of all blood groups are suggested by Prem Vrat and Khan (1976) on the basis of a simulation model similar to the inventory bank model proposed by Elizer Naddor.

Systems Approach to Blood Bank Management

Jennings' whole blood inventory model (Fig. 1) encouraged researchers to consider blood banking as a dynamic system. Flow of material (blood) in the system is analogous to that of a dynamic system. Studying issues of such a system from a system-perspective results in a better understanding of the poor system performance. This approach emphasises the connections among the various parts that constitute a whole. The system thinking is concerned with connectedness and wholeness (Nancy Roberts et.al. 1983). The problem is looked upon from an integrated vantage point.

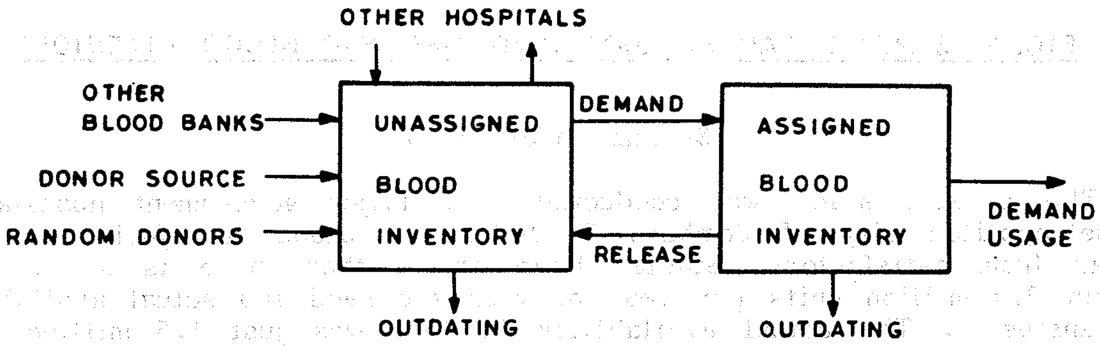
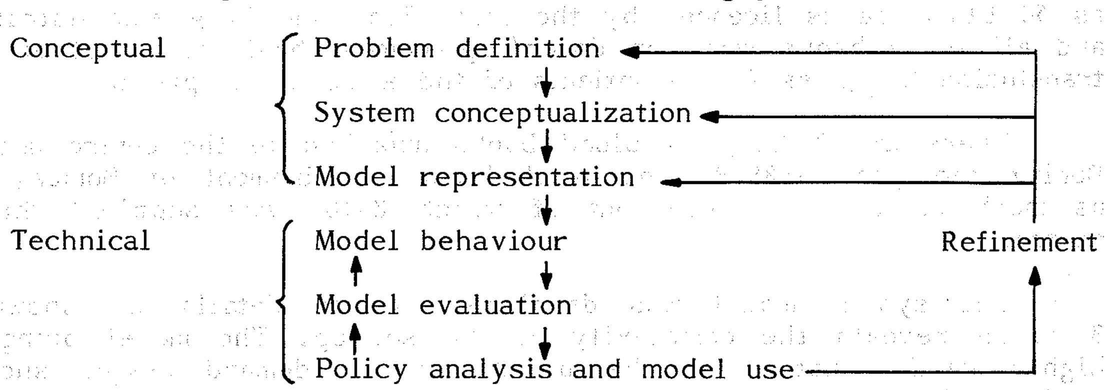


FIG. 1 CLASSICAL BLOOD INVENTORY MODEL

The model building process involves the following phases.



The modelling process uses two important schemes to highlight the dynamics of the system, i.e. thinking about how the quantities vary through time and thinking about whether a substantial feedback relationship exists.

Simple causal-loop diagrams of the blood inventory system are shown in Fig. 2(a) and (b).

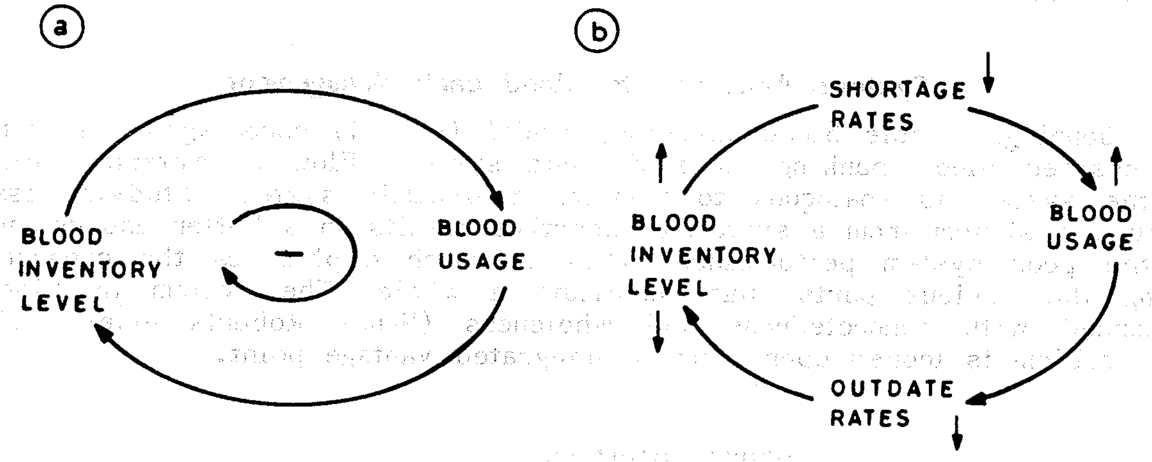


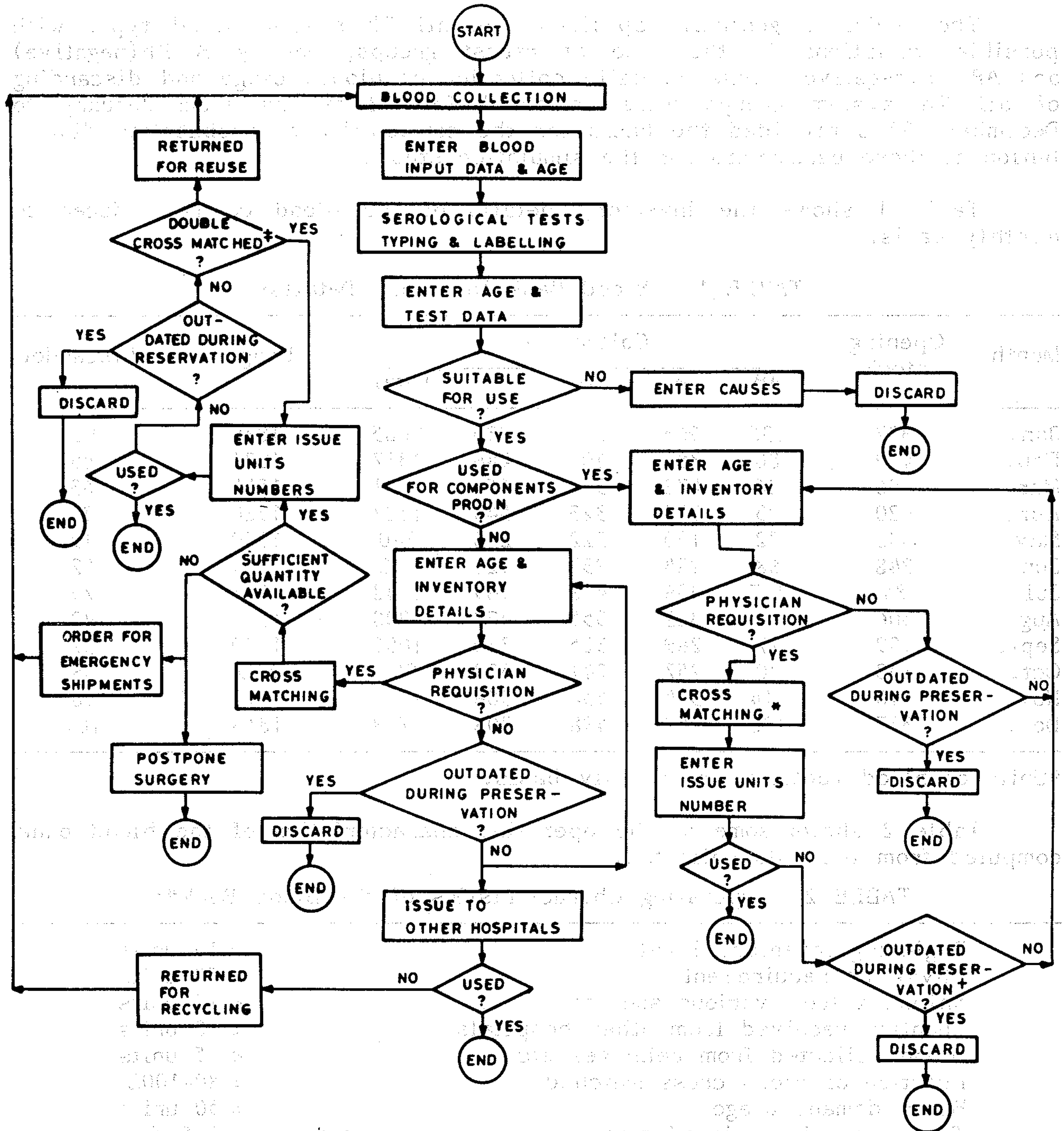
FIG. 2 SIMPLE CAUSAL LOOP DIAGRAMS FOR BLOOD INVENTORY

System Under Study

The present study was conducted in a major government hospital in the metropolitan city of Bombay. In India the blood transfusion services are far from satisfactory. Studies have shown that there is a huge gap of about 3.5 million units per year between the need and actual availability for transfusion. The actual availability in 1990 was just 1.5 million units as against the minimum requirements of about 5 million units. 75% of the blood banks of the country operate in a highly unsatisfactory manner due to a host of reasons - absence of well developed voluntary programmes, lack of a unified approach and the improper rule-of-thumb management policies, in spite of the standards and administrative guidelines set by the Directorate General of Health Services. The blood transfusion services are primarily confined to metropolitan cities. Bombay city has as much as 50 blood banks licenced by the State Food and Drug Administration (FDA) and all these banks work on donor/replacement basis and most of them have transfusion facilities for in-patients of the attached hospitals.

There are 7 hospital blood banks attached to the centre under study. During the year 1989-90 the total blood requirement of Bombay city was as much as 2 lakhs units out of which 8-10% was supplied through this centre.

The system model was developed, whose details are shown in Fig. 3 which reveals the complexity of the set up. The model brings out the highly random nature of the blood supply, demand usage, shortage and outdate characteristics. The model was used for purposes of comparison of alternate inventory policies of a regional blood centre. Evolution of an effective and efficient management policy is absolutely dependant upon the daily monitoring of the inventory level and variation of this level.



* FOR RED BLOOD CELLS ONLY

\+ RESERVED FOR A PARTICULAR PATIENT

‡ CROSS MATCHED FOR TWO OR MORE PATIENTS SIMULTANEOUSLY

FIG. 3 SYSTEM FLOW DIAGRAM

Collection and Analysis of Data

The model is generally applicable to all Rh system blood types with possible variations in the case of rarest groups, namely B Rh(negative) and AB Rh(negative). Data on daily collection of blood, usage and discarding of all Rh system groups were collected for 12 months from January to December. This provided the basis for the computation of probability distribution of these parameters for the simulation study.

Table 1 shows the inventory details of the blood centre reduced to monthly basis.

TABLE 1 Blood Bank Inventory Details*

Month	Opening stock	Collection					Usage	Discarded
		AB	A	B	O	Total		
Jan.	337	136	563	651	735	2085	1839	124
Feb.	459	80	389	402	446	1317	1231	49
Mar.	496	86	472	522	651	1731	1544	63
Apr.	620	93	372	323	540	1327	1320	35
May	592	72	190	222	256	740	1060	19
Jun.	248	68	284	239	321	912	1034	42
Jul.	84	117	336	426	469	1348	1051	75
Aug.	306	103	322	355	528	1308	1383	42
Sept.	189	77	269	325	330	1001	1020	37
Oct.	133	70	257	241	333	901	845	49
Nov.	140	114	344	454	506	1411	1118	56
Dec.	377	126	467	498	708	1799	1816	105

*Units of blood (bottles) on monthly basis.

Table 2 shows some of the operating characteristics of the blood bank computed from the data collected.

TABLE 2 Operating Characteristics of the Blood Bank**

Beginning inventory level	≃ 15 units
Physician requirement	> 50 units
Shipment from various sources	< 15 units
Quantity received from other hospitals	< 10 units
Blood collected from relatives etc	< 15 units
Fraction of blood cross matched	= 80-100%
Blood demand usage	≃ 50 units
Time spent in assigned state	≃ 1.5 days
Fraction of cross matched blood actually used	= 60-70%
Fraction of blood outdated in store	< 5%
Fraction of blood discarded during tests	≃ 5%

**All groups put together on average daily basis.

Quantity and age of blood in store are taken as the level variables characterizing the state of the system at any particular time.

Results and Conclusions

Simulation analysis was done on an IBM 360 using DYNAMO II/F which is a Fortran-based version of DYNAMO.

Fig. 4 and Fig. 5 show the relationship between the inventory levels, mean daily demand and shortage-outdate rates. These provide means for the calculation of desired inventory levels on the basis of shortages and outdates.

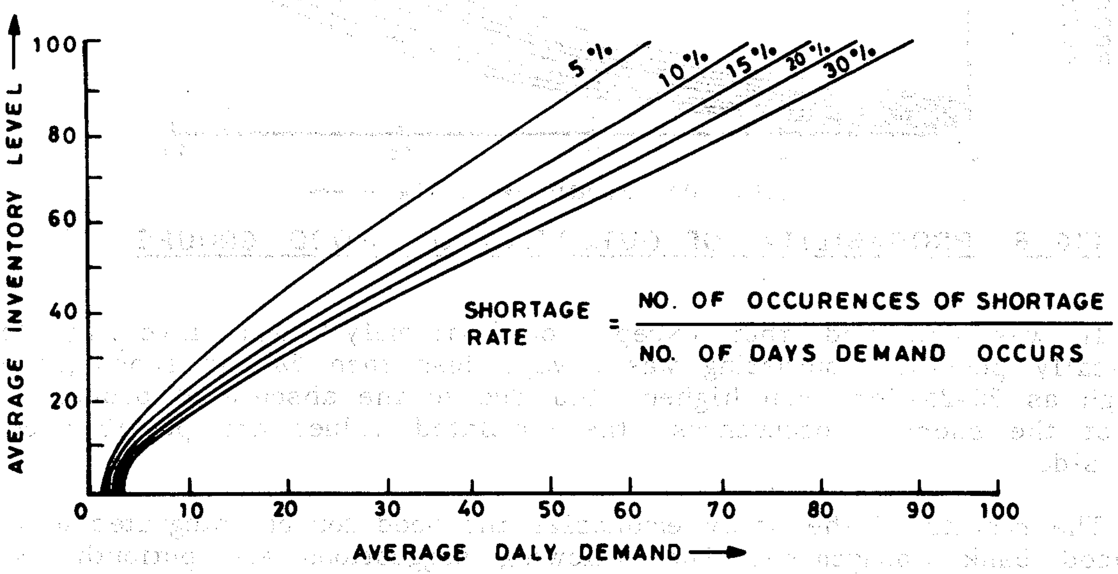


FIG. 4 SHORTAGE RATE CHARACTERISTICS

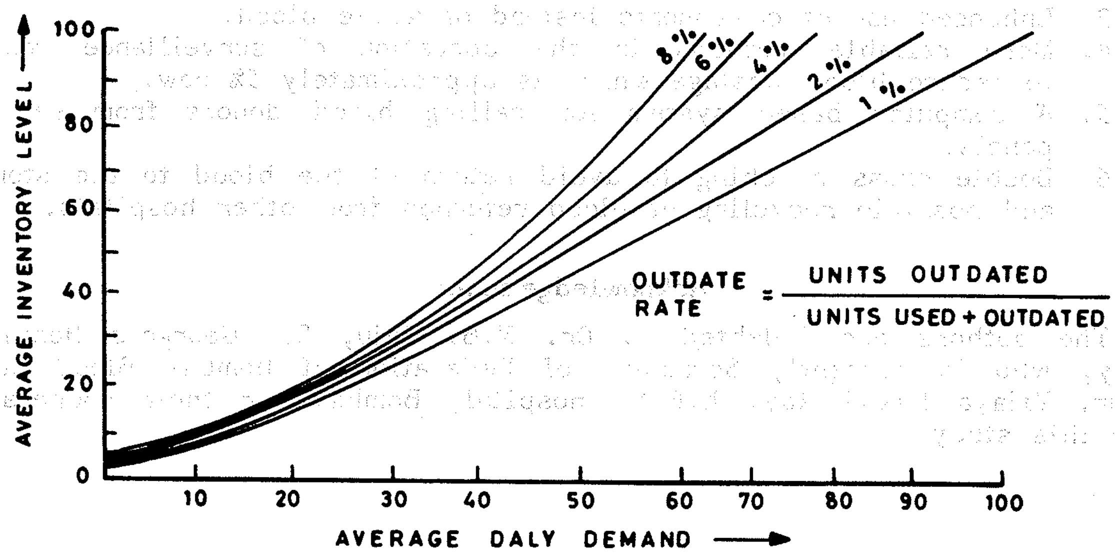


FIG. 5 OUTDATE RATE CHARACTERISTICS

As the life of blood in store increases the probability of outdating increases more rapidly in the case of rare groups compared to the very common(Fig. 6).

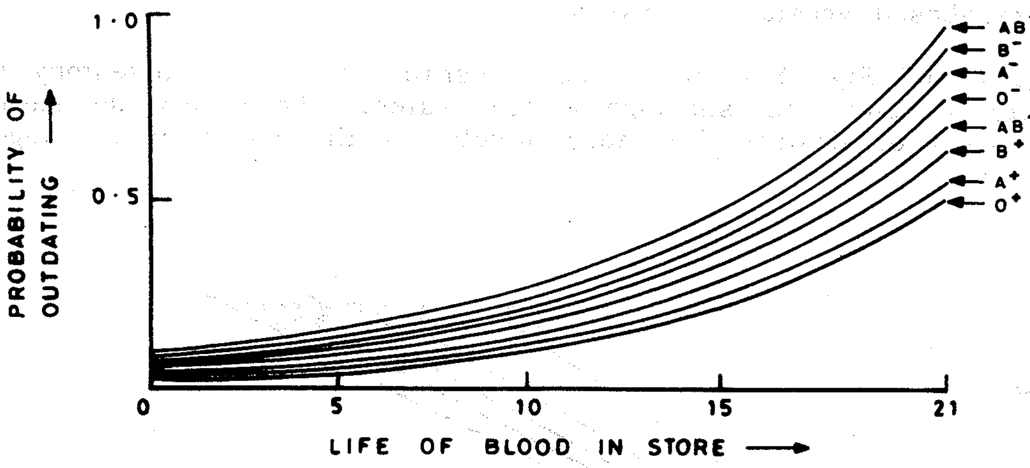


FIG. 6 PROBABILITY OF OUTDATING OF BLOOD GROUPS

It was observed that except for extremely large inventory levels practically possible, outdating was always less then 5% and shortages occur as high as 20-25% or even higher. And due to the absence of proper recording of the shortage occurences, the simulated values are possibly on the lower side.

The results of the study emphasize the need for an integrated approach in blood bank management. The following suggestions are putforth by the authors in this regard for better performance.

1. A coordinated effort with other blood banks.
2. Providing facilities for fractionation and pheresis in all major banks.
3. Enhanced use of components instead of whole blood.
4. More reliable methods in the operation of surveillance centres to reduce blood wastage which is approximately 5% now.
5. A computer based system for calling blood donors from selected panels.
6. Double cross matching to avoid return of the blood to the storage and possible recycling of blood returned from other hospitals.

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