A MATHEMATICAL DECISION MODEL TO PREDICT THE OPTIMAL NUMBER OF BEDS IN LABOUR ROOM AND MATERNITY WARD OF A LARGE TEACHING HOSPITAL

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ABSTRACT

The pattern of deliveries taking place at a Command Hospital were studied with a view to predict the optimal number of beds required in the labour room. The data was collected on the basis of authentic records maintained in the labour room and a mathematical decision model was built up. The number of deliveries per day and shift-wise were found to be close to corresponding values of variance. Further, the application of chi-square test confirmed that Poisson distribution could be applied for such forecasts. The study revealed that optimal number of beds required in the labour room should be a maximum of 8 in a day. Further analysis on an 8-hourly shift basis revealed that the maximum number of deliveries in any given shift would be 4, the probability of higher number of deliveries being very small ($p < 0.05$). Thus catering to 4 deliveries per shift should be the optimum provision in such a large teaching hospital.

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Introduction

Child-bearing is an essential natural process, because of its requirement to keep the human species going. Further, child-birth should be a peak experience, a happening that unites mother, father and infant psychologically into a caring, living and involved family [1]. However, in the absence of proper obstetric services this pleasant experience can turn into a nightmare not only for the woman undergoing it but for her family as well. Optimal number of beds are required to be catered for in labour rooms as well as in maternity wards for patients reporting for delivery.

One of the methods of predicting the demand for such beds is the Poisson distribution. The Poisson distribution results from a set of assumptions about an underlying process called as Poisson Process, which can be described by the following statements [2]:

(a) The occurrence of an event independent of occurrence of second event.

(b) Theoretically, an infinite number of occurrences of the event must be possible in the interval.

(c) The probability of the single occurrence of the event in a given interval is proportional to the length of the interval.

(d) In any infinitesimally small portion of the interval the probability of more than one occurrence of the event is negligible.

The present study was undertaken to build up a mathematical decision model based on Poisson distribution to predict the requirement of optimal number of beds in the labour room and whether the requirements were being met or not.

Material and Methods

The study was undertaken at Command Hospital Southern Command, Pune which is a 1052 bedded tertiary care referral-cum-teaching hospital

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providing care to its dependent clientele from the armed forces and civilians. One of the services this hospital provides to its clientele is obstetric service. The number of beds available in the labour room and maternity wards were found out by direct observation. The data pertaining to the total discharges and bed days for the patients admitted for delivery in the year 1995 were collected from the hospital records, while the same for deliveries, on daily and shift basis, were obtained from the labour room registers. For distribution on shift basis, each day was divided into 3 shifts of eight hours, i.e., 0001 h-0800 h, 0801 h-1600 h and 1601 h-2400 h. Data analysis was based on Poisson distribution pertaining to deliveries to find out the Poisson probability value (p), and expected value (E), for the corresponding number of deliveries. Chi square test was applied to verify whether Poisson distribution could be applied for this purpose [3].

The Chi-square test confirmed that Poisson distribution could be applied to this study. The data so calculated were compiled to draw an inference about the optimal number of bed requirement in the labour room. First the procedure was applied to deliveries on day basis and then on shift basis.

The bed complement required in the ward to make provisions for the deliveries taking place in the hospital was calculated as under:

Average length of stay (ALS)=Number of total bed days pertaining to these patients in the year 1995/Total number of discharges including deaths of such patients in the same year.

Number of beds required in the maternity ward=Mean number of deliveries per day X ALS of these patients.

Results

Present Bed Complement

The Department of Gynaecology and Obstetrics has a total of 57 beds which have been divided into 6, 27 and 24 beds for Officers', JCOs' and ORs' families respectively. The labour room has 3 labour tables and 8 beds out of which one table has been earmarked for septic labour cases and one bed for patients with eclampsia.

Patient Load

During the year 1995 a total of 1703 deliveries took place in the hospital out of which 478, 677 and 548 deliveries occurred in the first, second and third shifts respectively. The total number of hospital bed days pertaining to the delivery cases were 10447 while total discharges (including deaths) of such cases in the year were 1707. The details about number of deliveries per day or shift, observed number of days or shifts in which particular number of deliveries took place are shown in Tables 1-4. Table 1 shows the deliveries on daily basis while Tables 2,3 and 4 show the same during first, second and third shifts respectively. The maximum number of deliveries in a day were found to be 13 and 9 in a single shift.

Bed requirement in the labour room

The values of mean and variance calculated from data on deliveries on daily, and first, second and third shifts were found to be 4.66 and 4.82, 1.31 and 1.40, 1.86 and 2.06, and 1.50 and 1.69 respectively. As there was not much of difference between the corresponding values of mean and variance, Poisson distribution was applied to find out the values of Poisson probability (p) and Expected value (E) for the occurrence of various number of deliveries on a given day or shift. The same are reflected in the related Tables 1 to 4.

Chi-square values for the data on the deliveries on daily, and first, second and third shifts were found to be 2.54, 3.56, 9.79 and 2.08 which were not significant ($p < 0.05$) at degree of freedom of 12, 5, 7 and 6 respectively. It reveals that Poisson distribution can be applied to this kind of study [4].

Table 1 shows that number of days on which >0, >1, >2, >3, >4, >5, >6, >7, >8, >9, >10, >11, and >12 deliveries could take place were 361, 346, 308, 250, 182, 119, 70, 37, 18, 8, 3, 2 and 0 respectively. It reflected that there were chances of more than 7 deliveries occurring on 37 days ($p=0.1021$) in a year while that for more than 8 deliveries were on 18 days ($p=0.0497$) and for more than 9 deliveries were 8 days ($p=0.026$).

Similarly Table 2 shows that there were chances of occurrence of more than 2 deliveries on

TABLE 1

Observed and expected frequencies of deliveries and expected no of days in a year on which given no of deliveries would take place

No of deliveries per day	Observed no of days on which Xi occurred (O)	Expected probability of Xi	Expected frequency E=P x N (n=365)	Poisson probability of ≤ XI= Σ P for ≤ Xi	Poisson probability of > Xi 1-Poisson of ≤ Xi	Expected no of days in a year when > Xi could occur = Poisson probability of > Xi x 365 i.e. (f) x 365 (nearest integer)
(Xi) (a)	(fi) (b)	(P) (c)	(E) (d)	(e)	(f)	(g)
0	5	0.0094	3.431	0.0094	0.9906	361.569 (36)
1	16	0.0439	16.0235	0.0533	0.9467	345.5455 (346)
2	36	0.1023	37.3395	0.1556	0.8444	308.206 (308)
3	59	0.1591	58.0715	0.3147	0.6853	250.1345 (250)
4	64	0.1856	67.744	0.5003	0.4997	182.3905 (182)
5	66	0.1732	63.218	0.6735	0.3265	119.1725 (119)
6	52	0.1347	49.1655	0.8082	0.1918	70.007 (70)
7	30	0.0897	32.7405	0.8979	0.1021	37.2665 (37)
8	19	0.0524	19.126	0.9503	0.0497	18.1405 (18)
9	9	0.0271	9.8915	0.9774	0.0226	8.249 (8)
10	5	0.0127	4.6355	0.9901	0.0099	3.6135 (3)
11	2	0.0054	1.971	0.9955	0.0045	1.6425 (2)
12	1	0.0021	0.7665	1.022*		
13	1	0.0007	0.2555			
365		$\bar{x} = 4.6657$	$S^2 = 4.8258$			

* As the individual values of E for 12 and 13 deliveries were less than one they had to be combined to make the value of E as > 1

TABLE 2

Observed and expected frequencies of deliveries and expected no of first shifts in a year in which given no of deliveries would take place

No of deliveries per first shift	Observed no of first shift on which Xi occurred (O)	Expected probability of Xi	Expected frequency E=P x N (n=365)	Poisson probability of $\leq X_i = \sum P$ for $\leq X_i$	Poisson probability of $> X_i$ 1-Poisson of $\leq X_i$	Expected no of first shift in a year when $> X_i$ could occur = Poisson probability of $> X_i \times 365$ i.e. (f) x 365 (nearest integer)	
(Xi)	(fi)	(P)	(E)				
(a)	(b)	(c)	(d)	(e)	(f)	(g)	
0	103	0.2698	98.477	0.2698	0.7302	266.523	(267)
1	129	0.3534	128.991	0.6232	0.3768	137.532	(138)
2	75	0.2315	84.4975	0.8547	0.1453	53.0345	(53)
3	38	0.1011	36.9015	0.9558	0.0442	16.133	(16)
4	17	0.0331	12.0815	0.9889	0.0111	4.0515	(4)
5	1	0.0087	3.1755	4.0219*			
6	2	0.0019	0.6935				
7	0	0.00035	0.1277				
8	0	0.00006	0.0219				
9	0	0.000008	0.0029				
10	0	0.000001	0.0004				
11	0	0.0000001	0.00004				
12	0	0.00000001	0.000004				
13	0	0.000000001	0.0000004				
365		$\bar{x} = 1.31$	$S^2 = 1.40$				

* As the individual and combined values of E for 6 to 13 deliveries were less than one they had to be combined with the value of E

TABLE 3

Observed and expected frequencies of deliveries and expected no of second shifts in a year on which given no of deliveries would take place

No of deliveries per 2nd shift	Observed no of 2nd shift on which Xi occurred (O)	Expected probability of Xi	Expected frequency E=P x N (n=365)	Poisson probability of $\leq X_i = \Sigma P$ for $\leq X_i$	Poisson probability of $> X_i$ 1-Poisson of $\leq X_i$	Expected no of 2nd shift in a year when $> X_i$ could occur = Poisson probability of $> X_i \times 365$ i.e. (f) x 365 (nearest integer)
(Xi)	(f)	(P)	(E)			
(a)	(b)	(c)	(d)	(e)	(f)	(g)
0	64	0.1557	58.83	0.1557	0.8443	308.1695 (308)
1	105	0.2896	105.704	0.4453	0.5547	202.4655 (202)
2	83	0.2693	98.2945	0.7146	0.2854	104.171 (104)
3	71	0.167	60.955	0.8816	0.1184	43.216 (43)
4	26	0.0776	28.324	0.9592	0.0408	14.892 (15)
5	12	0.0289	10.5485	0.9881	0.0119	4.3435 (4)
6	1	0.0089	3.358	0.9970	0.003	1.095 (1)
7	2	0.0024	0.876	1.10405*		
8	0	0.0005	0.1825			
9	1	0.0001	0.0365			
10	0	3* 0.00002	0.0073			
11	0	0.000004	0.0015			
12	0	0.0000006	0.00022			
13	0	0.00000008	0.00003			
365		$\bar{x} = 1.86$	$S^2 = 2.04$			

* As the individual values of E for 7 to 13 deliveries were less than one, they had to be combined together to make the value of E as > 1

53 days ($p=0.1453$), more than 3 deliveries on 16 days ($p=0.0442$) and more than 4 deliveries on 4 days ($p=0.0111$). While as the Tables 3 and 4 reveal the same for more than 3 deliveries on 43 days ($p=0.1184$) and 24 days ($p=0.0658$), for more than 4 deliveries on 15 days ($p=0.0048$) and 7 days ($p=0.0187$), and for more than 5 deliveries on 4 days ($p=0.0119$) and two days ($p=0.0046$) respectively.

Bed Requirement in the Maternity Ward

ALS for the patients admitted for confinement was found to be 6.12 days. With the mean number of deliveries per day of 4.66 a bed complement 28.55 (say 29 or 30, one extra bed) would be required in the maternity ward for making provision for the patients admitted for delivery.

Discussion

The study reveals that number of deliveries per day varied from 0 to 13 with a mean of 4.6657 deliveries per day whereas deliveries in shifts varied from 0 to 9 with a mean of 1.31, 1.86 and 1.50

deliveries per first, second and third shifts respectively, i.e., only a little variation between the mean deliveries in various shifts. Further the difference between the values of means and variances were found to be negligible, a feature of Poisson distribution.

The results of application of chi-square show that Poisson distribution can be applied to predict the number of beds required in the labour room as the pattern of deliveries follows Poisson distribution [4].

Table 1 shows that chances of occurrence of more than 8 deliveries in any given day in a year were only 4.97 per cent ($p=0.0497$) i.e., 18 days in a year which comes to about once in 20 days. Thus provision should be made in the labour room to cater for 8 deliveries in a single day.

Further, Table 2 shows that chances of more than 3 deliveries occurring in the first shift are 4.42 per cent ($p=0.0442$) i.e., once in about 21 days. Similarly Tables 3 and 4 show that chances of more than 4 deliveries taking place in the

TABLE 4

Observed and expected frequencies of deliveries and expected no of third shifts in year on which given no of deliveries would take place

No of deliveries per 3rd shift (Xi) (a)	Observed no of 3rd shift on which Xi occurred (O) (b)	Expected probability of Xi (P) (c)	Expected frequency $E=P \times N$ (n=365) (E) (d)	Poisson probability of $\leq Xi = \sum P$ for $\leq Xi$ (e)	Poisson probability of $> Xi$ 1-Poisson of $\leq Xi$ (f)	Expected no of 3rd shift in a year when $> Xi$ could occur = Poisson probability of $> Xi \times 365$ i.e. (f) $\times 365$ (nearest integer) (g)
0	90	0.2231	81.4315	0.2231	0.7769	283.5685 (284)
1	113	0.3346	122.129	0.5577	0.4423	161.4395 (161)
2	91	0.2510	91.615	0.8087	0.1913	69.8245 (70)
3	44	0.1255	45.8075	0.9343	0.0658	24.017 (24)
4	19	0.0471	17.1915	0.9813	0.0187	6.8255 (7)
5	6	0.0141	5.1465	0.9954	0.0046	1.679 (2)
6	0	0.0035	1.2775	1.615002*		
7	1	0.0008	0.292			
8	1	0.0001	0.0365			
9	0	2* 0.00002	0.0073			
10	0	0.000004	0.0015			
11	0	0.0000005	0.00018			
12	0	0.00000006	0.00002			
13	0	0.000000006	0.000002			
365		$\bar{x} = 1.50$	$S^2 = 1.6952$			

* As the individual and combined values of E for 7 to 13 deliveries were less than one, they had to be combined with the value of E for 6 deliveries to make the value of E as > 1

second and third shifts are 4.08 per cent ($p=0.0408$) and 1.87 per cent ($p=0.0187$) i.e. once in 24 and 52 days respectively.

Thus, it would be a waste of resources if beds for more than 4 deliveries in any given shift are provisioned. The labour room has 8 beds, including 1 for patients with eclampsia, hence the requirement is met at all times. The 3 beds in spare are required for post-partum cases.

The hospital has presently 57 combined beds for Gynaecology and Obstetrics while the requirement for delivery cases is for 30 beds. Though the total bed complement should be kept together to provide flexibility of use [5], 30 beds can be earmarked for the patients being admitted for delivery.

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