Marascuilo Method of Multiple Comparisons (An Analytical Study of Caesarean Section Delivery)

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ABSTRACT

Introduction: From last three decades it was observed that the trend of caesarean section delivery is increasing in Indian community. Further this trend is not uniform for its States. This rate differ from place to place with respect to urban, rural, tribal community and also with respect to type of institution either government or private. Techniques in inferential statistics are applied to assess these differences. In order to analyse the proportions of CS, statistical inference i.e. Z-test, Chi-square test and Marascuilo's methods are applied.
Material and methods: While sampling, **i**n order to ensure the inclusion of villages, urban areas and tribal (Adivasi) regions two stage sampling is adopted. Observations and records from hospitals were used for collecting data. The data collection from these health care institutions was undertaken from 1 Jan 2009 to 31 December 2009. Data was analyzed on SPSS 22.
Results: Rejecting the null hypothesis of equality of proportions by chi square test concluded that not all population proportions are equal. Because the result of the chi square test for equality of proportions does not specifically focus the significantly different pairs, there is need to use a multiple comparisons procedure that is the Marascuilo procedure which enables us to make comparisons between all pairs of groups.
Conclusion: The rate of caesarean section is high in urban private sector and very low in tribal areas. A difference is statistically significant in all fifteen comparisons involving 6 population proportions.

Keywords: Caesarean section, Proportion, Marascuilo procedure.

INTRODUCTION

A Caesarean section is the technical name for delivering a baby by operating the mother under anesthesia rather than allowing normal labor and delivery. It is recommended in cases where there is distress due to wrong positioning of the baby in the womb, obstruction or due to many more reasons. In few years we observed that there is remarkable increase in the rate of caesarean section (CS) in both developed and developing countries. India is also showing the same increasing trend. The study is carried out to investigate the real reasons for this increasing trend. The reasons for the said phenomenon are either medical or nonmedical. Several studies have shown that the rate of CS differ from place to place and from region to region. Therefore, we carried out a multicentre, large sample, cross sectional study to analyse the CS rate in Nasik division in Maharashtra state during the year 2009. WHO recommended that no region should have a CS rate over 10–15%.[1,2] Based on a survey by the World Health Organization (WHO) on methods of delivery during the period 2007–08, the rates of CS in Asian countries was 27%.[3] The aim of our study was to estimate the overall CS rate in Maharashtra, and to describe the factors associated with the increased CS rate in Region.

MATERIAL AND METHODS

The study population comprised women who gave birth during the period 1st January 2009 to 31st December 2009. Total 61 hospitals from 5 districts of Nasik region namely Nasik, Ahmadnagar, Dhule, and Jalgaon and Nandurbar comprise the sample. The data include hospitals from rural areas (26), urban areas (35), Private Hospitals (31) and Government Hospitals (30) which includes municipalities, autonomous hospitals and Medical colleges. We selected 61 Maternity hospitals and number of deliveries in the hospitals from the registers that occurred during 2009, excluding miscarriages or termination of pregnancy before 28 gestational weeks.The sampling method for each population is simple random sampling. The samples are independent.The overall rate of CS in the Nasik division was estimated as 20.74 %.

STATISTICAL ANALYSIS

Statistical hypothesis testing is an essential component of biological and medical studies for making inferences and estimations from the collected data in the study; however, there are several methods to study the phenomenon under consideration. In order to compare CS rates in different regions we can have different test procedures such as Chi-square test for testing independence of attribute, Z test for testing equality of two proportions and Marascuilo's test for testing equality of several proportions.We compare these methods for inference and Marascuilo method is better as it provides the magnitude of variation in the pairs of proportions.

The method applied for testing the homogeneity of proportions is based on the chi-square distribution via contingency tables.[4] To test the null hypothesis of no difference in the proportions among the 6 populations, when we have samples from 6 populations, we can test whether there are significant differences in the proportion of CS for these populations using a contingency table approach. We construct the contingency table has two rows and 6 columns.

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H_0:p_1=p_2= ... =p_6 against the alternative that not all 6 population proportions are equal

H_a: Not all p_i are equal (i=1,2,…,6), we use the following test statistic:

$$\chi 2=\sum (fo-fc)2/fc$$

Where *fo* is the observed frequency in a given cell of a *2×6* contingency table, and *fc* is the theoretical count or expected frequency under the assumption that region, instution and mode of delivery are independent. The critical value is obtained from the χ2 distribution table with degrees of freedom (2−1)(6−1)=5, at a given level of significance. We estimate the single overall proportion of CS under H_0 by pooling the results of all the samples *as p¯= (11317)/(72995) =0.155*

Estimate of proportion of Normal Deliveries is *1 – p¯= 0.845*. Multiplying these two proportions by the sample sizes used for each lot results in the expected frequencies of CS and Normal deliveries. We use the observed and expected values from the tables to compute the χ2 test statistic. Table for computing the test statistic

If we choose a 0.05 level of significance, the critical value of *χ2*with 5 degrees of freedom is 11.0705.(*P value < 0.001*). Calculated value exceeds this critical value, we reject the null hypothesis. That is proportions of CS are significantly different in rural, urban and in adivasi areas. In order to compare the two population proportions Z test is applied.[5] Here we are testing equality of CS proportions (Categorical data) in different areas. According to area of residence the two groups are rural and urban, and according to place of delivery we can categorize the institution as government or private hospital. A random sample is drawn from each of thecategory as mentioned above. Here the Null hypothesis is the proportions do not differsignificantly.Differences in thebaseline characteristics between two groups were tested using Z test for proportions. Categorical data were expressed in proportions and the differences in proportions between the two groups were examined using the Z test. H_0: P_1-P_2= 0, where P_1 is the proportion from the first population and P_2 the proportion from the second. The null hypothesis tends to be that there is no difference between the two population proportions; or, more formally, that the difference is zero

Since the null hypothesis states that P_1=P_2, we use a pooled sample proportion (*p*) to compute the standard error of the sampling distribution.

$P= (p_1 * n_1 + p_2 * n_2) / (n_1 + n_2)$

Wherep_1 is the sample proportion from population 1, p_2 is the sample proportion from population 2, n_1 is the size of sample 1, and n_2 is the size of sample 2.

Standard error (SE) of the sampling distribution difference between two proportions is SE.

SE = SQRT { P * *Q* * [$(1/n_1)$ + $(1/n_2)$] }

The test statistic is a Z-score defined by the following equation.

$$Z = \frac{p1 - p\,2}{\sqrt{P * Q \quad [\left(\frac{1}{n1}\right) + \left(\frac{1}{n2}\right)]}}$$

The *p-value* is the probability of observing a sample statistic as extreme as the test statistic. We use normal probability table to assess the probability associated with the Z-score. Since we have a two-tailed test, the p-value is the probability that the Z -score is less than or greater than calculated test statistics calculated Statistic. We use the Normal probability tables to find P-value. Since the P-value is less than the significance level (0.001), we cannot accept the null hypothesis. The results for different proportions are compared in the following table

The third method for comparing multiple proportions is the Marascuillo procedure for testing equality of proportions.[6] The Marascuilo procedure enables us to simultaneously test the differences of all pairs of proportions when there are several populations under investigation.[7] In the Marascuillo Procedure the step one is to compute differences pi−pj for all possible pairs such that i ≠ j. We have six samples of size n_i (i=1, 2,…,6) from 6 populations. We compute the differences p_i−p_j, (where i is not equal to j) among all 6(6−1)/2 = 15 pairs of proportions. The absolute values of these differences are the test-statistics. The second step is to compute test statistics thatis to pick a significance level and compute the corresponding critical values for the Marascuilo procedure from

$$r_{ij} = \sqrt{}\,(\chi^2_{1-\alpha,k-1}) * \sqrt{\frac{pi(1-pi)}{ni} + \frac{pj(1-pj)}{nj}}$$

The third step is to compare each of the 15 test statistics against its corresponding critical r_{ij} value. Those pairs that have a test statistic that exceeds the critical value are significant at α level of significance.

For an overall level of significance of 0.05, the critical value of the chi-square distribution having five degrees of freedom is $\chi^2_{(0.05,5)}$= Chi (0.05,5)= 11.0705 . Calculating the 15 absolute differences and the 15 critical values leads to the following summary table 4.

RESULTS

For comparison of equality of population proportions three methods are applied. The results of the three tests are summarized as follows. Chi-square test for independence of two attributes namely locality and mode of delivery is carried out, the critical value of χ^2 with 5 degrees of freedom is 11.0705. (*P value < 0.001*). Calculated value exceeds this critical value, we reject the null hypothesis. That is proportions of CS are significantly different in rural, urban and in adivasi areas. Secondly Z test is applied to check pair wise differences in population proportions. This yields that area wise and institution wise proportions of CS are significantly different. Earlier we carried out a test for six population proportions for equality of six proportions of CS deliveries in rural, urban, backward areas and in private and government hospitals. The results led to rejection of the null hypothesis of equality. By rejecting the null hypothesis we concluded that not all regions are equal with respect to the proportion of CS deliveries. However, it does not tell us which sectors caused the rejection. Marascuillo procedure allows comparison of all possible pairs of proportions. By applying this test a difference is statistically significant as its value exceeds the critical range value. Except p_1 (rural government) and p_6 (tribal government), all the comparisons involving 6 populations significantly different from each other as far as proportions of CS is concern.The proportions differ significantly

Areas	Urban Gov	Rural Gov	Urban Private	Rural Private	Tribal Gov Urban	Tribal Gov Rural	Total
fo(CS)	6240	1948	1614	412	940	163	11317
Normal	22561	21428	3440	1016	10541	2692	61678
Total	28801	23376	5054	1428	11481	2855	72995
fe (CS)	4465.249	3624.168	783.5621	221.3943	1779.991	442.6335	11317
fo-fe	1774.751	-1676.17	830.4379	190.6057	-839.991	-279.633	
(fo-fe)^2/ fe	705.3894	775.2234	880.1182	164.0989	396.3982	176.6583	3097.886**

Table-1: Calculation of Chi- Square Statistic

	Rural		Urban		Pooled Estimate P	Q = 1 - P	I Z I	P Value
	p_1	**n_1**	**p_2**	**n_2**				
Government	0.083	23376	0.217	28801	0.157	0.843	41.6373[a1]	< 0.001
Private	0.289	1428	0.319	5054	0.313	0.687	2.21974[a2]	0.02643*
	Government		Private					
	p_1	n_1	p_2	n_2				
Rural	0.083	23376	0.289	1428	0.095	0.905	25.653[b1]	<.001
Urban	0.217	28801	0.319	5054	0.232	0.768	15.9525[b2]	<0.001
	Rural		Urban					
Adivasi Government	p_1	n_1	p_2	n_2				
	0.057093	2855	0.081874	11481	0.077	0.923061	4.44641[a3]	<0.001

a1 : Proportion of cesarean section in Government Hospitals in rural and urban do differ significantly, a2 : Proportion of cesarean section in Government Hospitals in rural and urban do differ significantly, b1: Proportion of cesarean section in Private And Government Hospitals in rural differ significantly, b2 : Proportion of cesarean section in Private And Government Hospitals in urban differ significantly, a3 : Proportion of cesarean section in Government Hospitals in rural and urban area of Nandurbar do differ significantly.

Table-2: Proportions of cesarean section deliveries by regional and institution characteristics.

Type of Region	Proportion p_i	Observed Proportion	$1-p_i$	Sample size ni
Rural Govt	p_1	0.08333	0.9167	23376
Rural Private	p_2	0.288515	0.7115	1428
Urban Govt	p_3	0.216659	0.7833	28801
Urban Private	p_4	0.319351	0.6806	5054
TribalGovt Rural	p_5	0.057093	0.9429	2855
TribalGovt Urban	p_6	0.081874	0.9181	11481

Table-3: Region wise Caesarean Section proportions.

	Difference	Value	Critical range	Significant
1	p1 -p2	0.205185	0.00602	Yes
2	p1 -p3	0.133329	0.03989	Yes
3	p1- p4	0.236021	0.00605	Yes
4	p1-p5	0.026237	0.02183	Yes
5	p1-p6	0.001456	0.01119	No
6	p2-p3	0.288515	0.00058	Yes
7	p2-p4	0.030836	0.02183	Yes
8	p2-p5	0.231422	0.03458	Yes
9	p2-p6	0.206641	0.03989	Yes
10	p3-p4	0.102692	0.00811	Yes
11	p3-p5	0.159566	0.00809	Yes
12	p3-p6	0.134785	0.00808	Yes
13	p4-p5	0.262258	0.02183	Yes
14	p4-p6	0.237477	0.02182	Yes
15	p5-p6	0.024781	0.00853	Yes

Table-4: Calculations by Marascuilo's procedure.

in rural and urban areas. This difference is still persistent in private and government hospitals. The proportions of CS in rural government hospitals and that in urban adivasi areas are almost same and equal to 8 percent.

DISCUSSIONS

According to area of residence there has been substantial upward trend in the rate of caesarean section delivery in Nasik division of Maharashtra compare to Normal delivery. Results from the table-3 shows that increased CS rates in urban areas as compare to rural areas. Further in private hospitals this rate is still increasing when compared with the Government hospitals. Previous studies have shown that at the national level, C-section make up about 9 percent of all deliveries but with huge regional variations, and also, a large rural-urban differential. Clearly, as private facilities have expanded, so has the rate of operated deliveries. There have been similar findings in studies conducted in other states of India like West Bengal and Kerala.[8,9]

The study results point that the proportion of CS in four clusters is significantly different. This is tested using Chi – Square test in Table -1. A difference is statistically significant if its value exceeds the critical range value. That all the comparisons involving 6 populations significantly different from each other as far as proportions of CS is concern. Results indicate that private hospitals are largely responsible for this increased CS. According to the above data deliveries by cae-

sarean sections (CS) are 3 to 10 times more prevalent in private institutions compared to government institutions.
There exists a wide gap in the accessibility of health facilities between the rural and urban areas. According to Leonard K L et al (2007) the high incidence of Caesarean Section in the private facilities points towards failing public health facilities.[9] Despite the heightened attention towards reducing Maternal Mortality and Morbidity through various programs and schemes the public health services fail to address the important aspect of reducing out of pocket expenditure for accessing healthcare services as private sectors has more number of deliveries. The indications for carrying out caesarean section also seem to follow a demand driven trend, where pregnant mothers tend to opt for the seemingly painless method of caesarean section. Ready availability and advanced operative and anesthetic techniques further strengthen the supply side of Caesarean sections and hence lead to irrational overutilization of this crucial emergency procedure.[10]

CONCLUSION

For comparing the equality of various population proportions Z-test, Chi-square test and Marascuilo's test are applied. The Marascuilo procedure as described above is a test that addresses the issue of multiple comparisons for proportions when we want to test which specific proportions are different from each other after rejecting the null in an overall chi-square test. The Marascuilo procedure compares all pairs of proportions, which enables the proportions possibly responsible for rejecting H_0 to be identified.

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