A METHOD OF TABULATING DATA FOR EASY REFERENCE AND APPRECIATION OF SIGNIFICANT RELATIONSHIPS

AN OBSTETRIC EXAMPLE

BY

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It is common practice to-day for information collected from patient's notes to be indexed or collated on punched-card systems with the object of ascertaining the aetiology of disease and the efficacy of treatments. The usefulness of this procedure depends primarily upon the collection of all possible relevant information and on the choice, wherever possible, of facts which can be measured accurately. Thus, at the very outset the most careful thought must be given to systematic note-making; otherwise conclusions drawn after years of patient record-keeping may be criticized on the grounds of unreliability of data, or made useless by an absence of information caused entirely by lack of forethought. For this reason it is desirable to inspect the collected information frequently and critically to ensure its accuracy and completeness, quite apart from any wish to draw conclusions from the work.

However, the effort involved in studying say 40 factors and their interrelationship is very considerable and few people would be able to hold the various findings sufficiently in mind to be sure of making the best use of the information collected. We therefore present a chart (Fig. 1),* which we believe to be new, for the purpose of reducing the amount of mental effort required to a very reasonable level. It not only provides a simple method of listing the incidence of factors singly or in pairs but is a diagram from which the answers to relevant questions can be found by instant reference, and their reliability is expressed in statistical terms.

Basically the chart is an arrangement of totals and percentages; each line of percentages should consist of a series of similar numbers if the numbers are due to chance; if they are not, positive or negative correlations are to be suspected.

The chart resembles the mileage chart in the *A.A. Handbook*, and the ease with which that is understood encouraged us to develop and apply the method to obstetrics.

**Explanation.*—The principal cells on the *main diagonal* show the numerical incidence (upper figure) and percentage (lower figure) of 36 factors. The cells in the *bottom left-hand* half show the numerical incidence of patients having the two factors named in the intersecting row and column. The cells in the *top right-hand* half contain two percentages—that is, the number of patients having both of the appropriate row and column factors expressed as a percentage of the total incidence of (1) the *column* factor (upper figure) and (2) the *row* factor (lower figure).

To See If These Percentages Differ Significantly From the Mean.—Taking the lower percentage only, subtract it from the percentage in the principal cell on the same *row* (or vice versa); compare the answer with the figures in columns B to E on the same *row*; observe how many patients are needed for this difference to be significant; lastly, examine the principal cell in the same *column* to see if that number of patients occurs.

Column A shows the minimum number of patients required in the *column* principal cell for the test to be applicable to that row.

Explanation of Chart.—Suppose K factors (36 on this chart) are selected for recording—for example, foetal distress, relative disproportion, breech deliveries, etc. The factors are noted down on the left of the chart, one horizontal row to each. They are also written, in the same order, along the top of the chart with one vertical column to each, giving K² squares or “cells” formed by the intersection of row and column. It will be noticed that some of the factors are mutually exclusive. For example, a patient cannot have more than one length of labour, she cannot have both breech and occipito-posterior vertex presentation. The cells for combinations of such factors are left unfilled.

Incidence of Factors

Consider first that part of the chart below the diagonal cells—that is, the *bottom left-hand* half of the chart. In each of these cells is a single figure which records the incidence, out of 2,324 deliveries, of the combination of two factors—row and column. Thus in the “stillbirths” row and “forceps” column the figure 2 shows an incidence of two cases of forceps delivery in which the baby was still-born.

The *diagonal* cells, having the same factor for both row and column, show the total incidence of this factor. This is the upper of the two figures in the cell, the lower figure expressing the incidence as a percentage of the total deliveries. These diagonal cells are referred to as *principal* cells. Thus the principal cell for forceps shows there were 213 cases out of 2,324 deliveries, a percentage of 9.16.

Percentages

The actual incidence of every pair of factors is therefore tabulated, but it is probably more informative if they are expressed as percentages. As percentages of what? The two cases of forceps delivery with stillbirths may be expressed as a percentage of (1) all forceps deliveries—that is, the percentage of forceps deliveries resulting in stillbirths; (2) all stillbirths—that is, the percentage of stillbirths which were delivered by forceps; (3) all births. In fact the first two of these percentages are recorded on the chart. In the top right-hand half of the chart (above the main diagonal) each cell contains an upper and a lower figure.

The *upper figure* is the incidence of the combination of row and column factors as a percentage of the incidence of the *column* factor. The *lower figure* is the incidence of the combination as a percentage of the incidence of the *row* factor.

Thus the forceps row, stillbirths column, has an upper figure of 0.9 showing that 0.9% of forceps deliveries were stillbirths. The lower figure is 6 showing that 6% of stillbirths were delivered by forceps ($2/213 = 0.9\%$, and $2/33 = 6\%$).

To demonstrate one way in which the chart may be used we take a particular example. If we wish to see what factors are related to stillbirth we examine the *lower figure* in the stillbirth row. We see that 0.2% of post-mature babies were stillbirths, 0.64% of term babies were stillbirths, 23% of premature babies were stillbirths, and so on. However, after “age of mother” we come to the edge of the chart and must now examine the *upper figure* in the stillbirths *column*.

Thus 4.2% of babies born after a first labour stage of 40–60 hours were stillborn, 3.1% of babies born after a first labour stage of 30–40 hours were stillborn, 1.3% of babies born after a first labour stage of 20–30 hours were stillborn, and so on. If we compare these figures with the incidence of stillbirths, 1.42% of all births (lower figure of stillbirth principal cell), we see that post-mature and term deliveries had a smaller proportion of stillbirths than average, while premature deliveries had a much higher

FIG. 1.—University College Hospital, London, 1952-6. *Primiparae* :

	COLUMN FACTORS																	
	1st Stage: Over 80 Hrs.	60 to 80 Hrs.	40 " 60 "	30 " 40 "	20 " 30 "	10 " 20 "	5 " 10 "	5 Hours and Under	2nd Stage: Over 2 Hrs.	46 Mins.-2 Hrs.	16-45 Mins.	15 Mins. and Under	Forceps	Manual Removal	"Toxaemia"	Relative Disproportion	Breech	Occipito-posterior
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1st stage: Over 80 hrs. 1	6 0.26								17 0.6	33 0.2	33 0.19	17 0.7	83 2.4	0	0	17 2	17 2	17 2
.. 60 to 80 hrs. 2		31 1.33							19 3.5	39 1.3	32 0.95	10 1.9	32 4.7	13 5	3 0.4	10 5	0	6 3
.. 40 " 60 " 3			119 5.12						20.2 14.2	45.4 5.7	31.1 3.52	3.4 2.6	21.8 12.2	6.7 11	6.7 3.4	10.1 19	1.7 4	4.2 8
.. 30 " 40 " 4				129 5.55					8.6 6.5	52.3 7.1	35.1 4.28	4.7 3.9	16.4 9.9	1.6 3	7.0 3.8	3.1 6	1.6 4	4.7 10
.. 20 " 30 " 5					316 13.59				8.2 15.3	41.4 13.9	44.9 13.49	5.4 11.1	9.8 14.5	4.7 20	8.2 11.1	1.9 9	1.9 13	3.5 18
.. 10 " 20 " 6						806 34.66			7.2 34.2	44.8 38.3	43.5 33.35	4.5 23.5	8.1 30.5	2.9 32	7.9 27.3	2.6 33	1.1 20	2.5 33
.. 5 " 10 " 7							619 26.62		5.8 21.2	34.8 22.8	51.7 30.31	7.9 31.9	5.9 17.4	2.11 17	11.66 30.7	1.9 19	1.8 24	1.9 20
5 hours and under 8								298 12.81	2.7 4.7	34.9 11.0	50.1 14.16	12.4 24.2	6.1 8.4	3.0 12	18.1 23.1	1.7 8	5.0 33	1 5
2nd stage: Over 2 hrs. 9	1	6	24	11	26	58	36	8	170 7.31				51.9 41.3	7.1 16	8.9 6.4	11.2 30	2.4 9	9.4 27
46 mins.-2 hrs. 10	2	12	54	67	131	361	215	104		946 40.68			9.0 39.9	2.8 35	10.4 41.8	2.4 36	1.7 35	2.5 40
16-45 mins. 11	2	10	37	45	142	351	319	149			1,055 45.37		2.85 14.1	3.23 45	10.07 45.3	1.9 31	1.9 43	1.43 25
15 mins. and under 12	1	3	4	6	17	36	49	37				153 6.58	6.5 4.7	1.9 4	9.8 6.4	1.3 3	3.9 13	3.3 8
Forceps 13	5	10	26	21	31	65	37	18	88	85	30	10	213 9.16	6.6 19	7.5 6.8	15.9 53	13.6 63	11.7 42
Manual removal 14	0	4	8	2	15	24	13	9	12	26	34	3	14	75 3.23	12 3.8	1	8 13	3 3
"Toxaemia" 15	0	1	8	9	26	64	72	54	15	98	106	15	16	9	234 10.06	4.3 16	1.3 6.5	2.6 10
Relative disproportion 16	1	3	12	4	6	21	12	5	19	23	20	2	34	1	10	64 2.75	5 7	17 18
Breech 17	1	0	2	2	6	9	11	15	4	16	20	6	29	6	3	3	46 1.98	
Occipito-posterior 18	1	2	5	6	11	20	12	3	16	24	15	5	25	2	6	11		60 2.58
P.P.H.: 20 oz. and over 19	0	4	4	6	7	14	15	4	10	20	15	9	20	9	4	4	3	2
10 to 19 oz. 20	3	6	20	16	51	100	71	39	36	131	124	15	52	24	24	16	8	14
Under 10 oz. 21	3	21	95	107	258	692	533	255	124	795	916	129	141	42	206	44	35	44
Foetal distress 22	2	3	15	14	27	74	44	15	19	80	88	7	37	10	23	15	6	12
Stillbirths 23	0	0	5	4	4	4	11	5	1	11	10	11	2	1	8	2	3	1
Weight: 9½ lb. and over 24	0	2	2	1	3	13	10	3	8	17	7	2	14	0	3	5	0	2
8 to under 9½ lb. 25	1	10	32	31	64	174	133	46	61	233	180	17	60	16	36	18	5	19
6 " " 8 " 26	4	19	75	86	221	568	402	211	95	638	755	98	126	52	162	35	28	36
Under 6 lb. 27	1	0	10	11	28	51	74	38	6	58	113	36	13	7	33	6	13	3
Post-mature 28	3	11	43	30	78	162	118	54	51	215	210	23	59	17	33	21	8	13
Term 29	2	20	71	93	231	622	470	225	116	719	795	104	145	53	184	42	27	45
Premature 30	1	0	5	6	7	22	31	19	3	12	50	26	9	5	17	1	11	2
Age: Over 40 31	0	0	0	0	2	4	2	0	0	5	3	0	2	0	2	0	0	0
36-40 32	1	5	3	4	12	25	15	8	8	35	22	8	11	2	10	2	1	0
31-35 33	3	4	15	16	33	98	74	32	31	113	111	19	45	14	33	9	4	9
26-30 34	1	14	44	54	99	258	194	102	67	331	329	40	89	18	79	27	15	28
21-25 35	1	6	54	48	144	332	276	125	55	385	480	66	57	36	88	21	19	19
20 and under 36	0	2	3	7	26	89	58	31	9	77	110	20	9	5	22	5	7	4
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18

2,324 Vaginal Deliveries (Multiple Pregnancies Excluded).

[illegible]

proportion than average. Thus by a comparison with the total incidence of the factor being considered we may determine which factors are related to it.

Comparisons

It is apparent therefore that if two factors are unrelated the *lower* percentage figure in their intersecting cell should be about the same as the percentage figure in the principal cell of *that row* (total percentage incidence of *one* factor). The *upper* percentage figure in the intersecting cell should be similar to the figure in the principal cell of the *column* (total percentage incidence of the other factor).

The percentages will not, of course, be exactly the same, and if we wish to decide whether two factors are related we must apply some test of statistical significance.

Statistical Test

As the chart is really a multiple form of 2×2 table, the statistical methods which have been evolved for this type of comparison may therefore be applied to it.

Consider the symbols portrayed in the miniature diagram of the chart (Fig. 2). The symbol N denotes the numerical incidence, the symbol P the percentage incidence, and the suffixes denote the factors considered. Na is the incidence of factor a, Pbd/d is the incidence of the combination bd as a percentage of the incidence of d.

	a	b	c	d	e
a	Na Pa				
b		Nb Pb		Pbd b Pbd d	
c			Nc Pc		
d		Nbd		Nd Pd	
e					Ne Pe

FIG. 2

Data for factors b and d could be extracted and put into the familiar 2×2 table thus :

	d	Not d	Total
b	Nbd		Nb
Not b			
Total	Nd		N

The usual 2×2 table tests are now applicable.

For our purposes, however, we can apply such tests directly to the chart by writing the test criterion in the following form :

$$U = \sqrt{\frac{\frac{N_{ad}}{N_a} - \frac{N_a}{N}}{\frac{N_d}{N} \left(1 - \frac{N_d}{N}\right) \left(\frac{1}{N_a} - \frac{1}{N}\right)}}$$

In this expression, the denominator is the standard deviation of the difference in proportions. If U is greater than 2 or less than -2 the difference is significant at the 5% level.

To apply this to an actual example from the chart consider stillbirths and forceps delivery in a 2×2 table :

	Forceps	Not Forceps	Total
Stillbirths	2	31	33
Not stillbirths	211	2,080	2,291
Total	213	2,111	2,324

The bold figures are obtained by subtraction.

Then, to test whether the percentage of forceps resulting in stillbirth ($2/213 = 0.9\%$) is significantly different from the total percentage of deliveries resulting in stillbirths ($33/2,324 = 1.42\%$), we calculate :

$$U = \sqrt{\frac{\frac{2}{213} - \frac{33}{2324}}{\frac{33}{2324} \left(1 - \frac{33}{2324}\right) \left(\frac{1}{213} - \frac{1}{2324}\right)}}$$

As the chart already shows many of these fractions as percentages we can simplify the arithmetic by writing

$$U = \sqrt{\frac{0.9 - 1.42}{1.42 (100 - 1.42) \left(\frac{1}{213} - \frac{1}{2324}\right)}}$$

Now the factor $\sqrt{1.42 (100 - 1.42)}$ is the same for all cells in the stillbirth row of the chart (and similarly $\sqrt{Pd (1 - Pd)}$ for other rows) and the factor $\sqrt{\frac{1}{213} - \frac{1}{2324}}$ is the same for all cells in the forceps column (and similarly $\sqrt{\frac{1}{Na} - \frac{1}{N}}$ for all other columns). There is therefore

no need to enter each comparison it is desired to study into a 2×2 table, since representative values for different numbers of patients in the column can be calculated for each row—for example, for 10, 100, 500, 1,000 patients. This in fact has been done in the chart columns labelled B, C, D, and E, where, by a further simplification of arithmetic, the minimum difference between Pb and Pbd for significance at the 5% level has been expressed directly. The actual number given is $2\sqrt{Pd (1 - Pd)} \times \sqrt{\frac{1}{Nb} - \frac{1}{N}}$.

For more exact interpolations the value of U should be calculated for the particular cell under consideration.

The number given in the columns B, C, D, and E—that is, the significant difference—is therefore twice the standard deviation. If these differences are exceeded the probability of a significant relationship rises steeply, thus :

1.0 × significant difference (5%) =	2 × Std. Dev.	Probability	5% =	20 : 1
1.3 ×	2.6 × Std. Dev.	Probability	1% =	100 : 1
1.5 ×	3.0 × Std. Dev.	Probability	0.2% =	500 : 1
2.0 ×	4.0 × Std. Dev.	Probability	0.01% =	10,000 : 1

This test criterion is applicable if $\frac{Nb.Nd}{N}$ is equal to or

greater than 5. If this is not so, the exact test for a 2×2 table (see, for instance, *Statistical Tables* by Fisher and Yates) could be applied. The number of patients required in each column to make a row satisfy this criterion

$\frac{Nb.Nd}{N} \geq 5$ is written in column A. If the test is not significant it does not mean that the two factors are necessarily unrelated. It means that there is no *evidence* that they are related. Also, 5% of comparisons where no real difference exists will appear significant, purely by chance.

Examples from the Chart

The first example taken is "first stage of 40-60 hours," which occurs in row 3; the second, foetal distress, in row and column 22.

In rows 1, 2, 3, and 22, and in column 22, all the percentages where $\frac{Na.Nb}{N}$ is less than 5 are in italics; these figures can be indicative only because the samples are too small. All the other percentages in these rows and columns have been compared with the principal cell percentages respectively, and where the difference is significant the figures are in bold type.

Figures which are neither in italics nor in bold type need further consideration; they may be so near the mean as to rule out the possibility of any correlation at all; or they

may differ noticeably from the mean but at a level of significance lower than the 5% which is considered necessary for medical purposes; or, despite a large number of patients, they may remain persistently near to, but not equalling, the significant difference, in which case the possibility must be borne in mind that the condition tabulated may represent a combination of two factors. For example, foetal distress is not significantly related to post-maturity, but the figures may approach a significant difference, and on further study it is discovered that when toxæmia supervenes in post-maturity there is a correlation.

Where the number of patients is too small but the percentage difference is otherwise highly suggestive there is a real case for collecting information from a further group of patients.

It can be seen that in rows 1 and 2 there are insufficient patients to allow us to reach any definite conclusions. In row 3, two factors (columns 9 and 36) are highly significant with more than twice the significant difference—namely, the occurrence of a long second stage and the absence of any mother under 20 years of age. For several other factors the difference exceeds significance—namely, presence of second stage over 2 hours (column 9), absence of short second stage ($\frac{1}{4}$ to $\frac{3}{4}$ hour) (column 11), high incidence of forceps delivery (column 13), occurrence of post-maturity (column 28), rarity of patients at full term (column 29), rarity of very young patients (column 36).

The study of the foetal distress column and row shows a positive correlation with long labour and a negative correlation with short labour, a positive correlation with forceps delivery, relative disproportion, and prematurity, and no significant correlation with post-maturity.

It will be noticed, in following these examples, that if the top percentage in a cell fails because there are too few patients, the lower one fails for the same reason. Similarly, if one percentage in a cell is significant, the other is significant also and to the same degree. The double percentages can thus form a check on the arithmetic, besides being useful when referring simply to the incidence of various paired factors.

The possibilities of the chart have been demonstrated. To discuss every relationship could be the subject of many separate publications, but enough has been said to enable readers to extend and adapt the chart to their own needs.

Summary

A chart is presented upon which the substance of some hundreds of studies can be tabulated; the interrelations of factors can be discovered rapidly and the statistical reliability of the data verified at a glance. It will be useful particularly to those who have access to numerical data from punched-card filing systems.

An obstetric example is given.

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The Department of Scientific and Industrial Research has issued a report on the Fire Research Station's work entitled *Fire Research 1956*. The report discusses fire detection, injuries from burning clothing, fires in industry, the fighting of aircraft fires, chimney fires, and fires caused by children and smokers. The results of investigations carried out at the Station were used by the British Standards Institution in devising a test for the grading of flammable fabrics. *Fire Research 1956* is obtainable from Her Majesty's Stationery Office, price 4s. net.

CHRONIC EAR INFECTIONS

LOCAL TREATMENT WITH HYDROCORTISONE, NEOMYCIN, AND POLYMYXIN COMBINED

BY

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The purpose of this paper is to report the results of a therapeutic trial with a new compound preparation, containing hydrocortisone, neomycin, and polymyxin, used locally in a series of recalcitrant cases of otitis externa, chronic otitis media, and infected mastoid cavities.

The use of local antibiotic preparations in the treatment of chronic ear infections has become popular in recent years. Although initial results were encouraging, follow-up studies have shown that many of these have not been of lasting value. There are probably several reasons for their long-term failure.

1. A mixed flora is commonly responsible for chronic infections of the external and middle ear. The use of a single antibiotic agent even with a "broad-spectrum" action would control only such organisms as are highly sensitive. Other organisms less sensitive or resistant, of which *Pseudomonas pyocyanea*, fungi, and yeasts are the most notorious in ear infections, will soon predominate and maintain the infection.

2. The local application of the antibiotic agent may fail to reach the whole infected area. Where there is evidence of bony involvement or inadequate drainage of the middle ear, local medication must give place to surgical measures. However, in non-surgical ear infections the presence of oedematous inflamed tissues with granulations and adhesions encourages small smouldering pockets of infection, and makes it difficult for topical antibiotic substances to get into intimate contact with the infective organisms.

3. Failure to treat underlying causative factors inevitably leads to relapses. Surgical drainage or ablation must be employed wherever there is mastoid or attic disease in chronic middle-ear infections. In otitis externa the main aetiological factor and most distressing symptom is irritation of the external auditory canal. Unless this is adequately controlled the persistent scratching leads to repeated secondary infection, often from the ano-genital region (Keogh and Russell, 1956).

4. Certain substances, when applied locally, may induce sensitization of the skin and possibly systemic manifestations. Also there is grave danger of increasing the number of resistant organisms by the initial failure of complete bacteriological control of the infection. This applies particularly to local preparations of penicillin and chloramphenicol.

The Combination

With these potential faults of local antibiotic therapy in mind, it was decided to try a combination of neomycin ($\frac{1}{4}\%$), polymyxin B (10,000 units per ml.), and hydrocortisone ($\frac{1}{4}\%$) in an aqueous solution.

Neomycin is a broad-spectrum antibacterial substance produced by the naturally occurring soil organism *Streptococcus fradiae*. It has a marked bacteriostatic and bactericidal action on Gram-positive and Gram-negative organisms, being particularly effective against *Escherichia coli* and *Proteus vulgaris*. It is inactive against fungi and viruses.