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# Applications of Cause-Selecting Control Charts in Hospitals

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## Abstract

In a hospital, there are many clinical departments. In general, the hospital management often uses the index of cure rate (i.e. the rate of patients recovered by the cure of this hospital) to evaluate the medical quality of each clinical department. But, since the cure rate varies significantly with the rate of patient with severe disease, the evaluation by cure rate is unreasonable and incomplete. This paper proposes a new evaluation method called the cause-selecting evaluation method proposed by Prof. Gongxu Zhang(1990). Besides, this method can also be used to diagnose the abnormality of cure rate. The practical case studies check with the theory very well.

## 1. Introduction

In a hospital, the medical quality is the core of the working quality, and the management department always uses the cure rate, one of the important indices, to evaluate the medical quality in China. The cure rate is defined as the percentage of the number of patients recovered by the cure of the hospital. But, in practices, we have many problems when we use this index to evaluate the different clinical departments. For instance, in general, the department of obstetrics has the highest cure rate over 97%, but the department of cancer has the lowest cure rate. If the management department evaluates the working quality of all the clinical departments based on this cure rate, it is unreasonable and incomplete. Here, the problem is that the rate of patients with severe disease varies greatly, for example, the birth is a natural phenomenon, but the

cancer is not yet conquered by the mankind.

As far as the rate of patients with severe disease is concerned, how can the birth be compared with the cancer? A reasonable method is to evaluate them with their generalities about the subjective efforts such as the clinical level of the doctors and nurses and their responsibility etc., but without their particularities about the objective conditions such as the rate of patients with severe disease etc. In other words, the management department of a hospital should evaluate the clinical departments with a "cause-selecting" index of the cure rate, here, the cause-selecting implies that this index is decided only by a part of the assignable causes selected, i.e. the causes about the subjective efforts. Here, the cure rate decided only by the subjective efforts is termed as specific quality, and the cure rate decided by the subjective efforts and the objective conditions together as total quality. Evidently, the specific quality reflects the working quality of the clinical department and the total quality can be felt by the patient directly, the higher the cure rate, the greater the possibility of the patient to be cured.

## 2. A New Diagnosis Theory with Two Kinds of Quality

In any clinical department, there are two kinds of quality: the total medical quality and the specific medical quality. The total medical quality consists of two parts: the specific medical quality and the influence of the objective conditions on it; hence it reflects the practical medical quality of the clinical department. The specific medical quality is decided only by the subjective efforts; hence it reflects the ideal medical quality of the clinical department without the influence of the objective conditions, it is the working quality of the clinical department. Thus, it is reasonable to use the specific medical quality index to evaluate all the clinical departments.

Secondly, we can use the concept of the two kinds of quality to diagnose the abnormality of the medical quality. The fundamental thinking of the new diagnosis theory with two kinds of quality is that the larger the difference between these two kinds of medical quality, the greater the influence of the objective conditions, and vice versa; especially, the two kinds of quality are equal when there is no influence of the objective conditions. Thus, after comparing these two kinds of medical quality, we can diagnose that the abnormality of the medical quality is resulted from whether the subjective efforts or the objective conditions or both of them. In order to compare these two kinds of medical quality, we should measure these two kinds of quality at first. The common

methods used are the control chart, the process capability index, etc. In this paper, we only illustrate the diagnosis with two kinds of control chart proposed by Zhang (1990, 1992), and commented by Wade and Woodall(1993).

## 3. Diagnosis with Two Kinds of Control Chart

The essence of Shewhart control chart is the discrimination between two kinds of quality cause: chance cause and assignable cause: Here, the latter includes all the assignable causes. In other words, Shewhart chart exerts control over all the assignable causes. From this viewpoint we may call it the all-control chart. As mentioned above, the total medical quality reflects all the assignable causes including the causes from generalities about subjective efforts and the causes from particularities about objective conditions. Hence, the Shewhart chart can be used to control the total medical quality. As for the specific medical quality, it reflects only the assignable causes from generalities about subjective efforts, so we need to propose a new type of control chart--the cause-selecting control chart which can automatically select a part of the assignable causes called the controllable assignable causes(for example, the assignable cause about subjective efforts) and exert control on them, and the remaining part of the assignable causes are called the uncontrollable assignable cause(for example, the assignable cause about objective conditions). Hence, the essence of the cause-selecting control chart is the discrimination among three kinds of quality cause: chance cause, controllable assignable cause and uncontrollable assignable cause.

Now, let us illustrate the principle of cause-selecting control chart through the simplest cause-selecting individual $y_i$ chart. The cause-selecting control chart should accomplish the following two tasks:

(1) Select the controllable assignable causes only and exert control on them.
(2) Show an indication of alarm when a controllable assignable cause occurs.

To accomplish the first task, suppose the quality index, i.e. the cure rate of a clinical department of a certain hospital $y$, has the normal distribution $N(\mu, \sigma^2)$; and suppose the rate of patient with severe disease, i.e. the uncontrollable assignable cause, is $x$. Then, under the influence of $x_i$, the parameters: $\mu_i = F(x_i)$, $\sigma_i = G(x_i)$ vary with the suffix $i$. Here, the functions $F(x)$ and $G(x)$ may be found by regression. Thus, the observed value of the quality index has a family of normal distribution. The following transformation

$$y'_{csi} = (y_i - \mu_i)/\sigma_i \tag{1}$$

is proposed to transform $y_i$ into the cause-selecting value $y'_{csi}$ which has the distribution $N(0, 1)$ with its parameters independent of the suffix $i$ under large samples, if the estimated values of $\mu$ and $\sigma$ are used. Now, we can use the $x$ chart(or other charts of normal distribution) to control the $y_{cs}$ values and call it the $y_{cs}$ chart(the cause-selecting chart for individual units). Whenever there is a controllable assignable cause, then the $y_{cs}$ chart will show abnormal. Thus, the cause-selecting chart accomplish the second above-mentioned task.

Here, in many cases, we can suppose $\sigma_i = G(x_i) = \text{constant } \sigma_0$. Thus we can simplify (1) by the following formula:

$$y_{csi} = y_i - \mu_i \approx y_i - \hat{y}_i \tag{2}$$

where $\hat{y}_i$ denotes the regression value. Accordingly, the control limits of the $y_{cs}$ chart are:

$$\begin{aligned} UCL &= \bar{y}_{cs} + 2.66\,\overline{R}_s(y_{cs}) \\ CL &= \bar{y}_{cs} \\ LCL &= \bar{y}_{cs} - 2.66\,\overline{R}_s(y_{cs}) \end{aligned} \tag{3}$$

where $R_s(y_{cs})$ denotes the difference of two adjacent $y_{cs}$ values, and $\overline{R}_s$ is the average of $R_s$ values.

At any clinical department of a certain hospital, there are two kinds of quality: the total medical quality and the specific medical quality, correspondingly, we may establish two kinds of control chart: the Shewhart control chart and the cause-selecting control chart as a diagnosis system. Then, according to the indications of these two kinds of control chart, we have four typical cases as shown in 〈Table 1〉. Here, for the convenience of the statement we supplement the Shewhart chart of the rate of patient with severe disease. The logic of the diagnosis in 〈Table 1〉 is straightforward. In this table 'abnormal' means outlying or out-of-control and 'normal' means the opposite. Some illustrations are given as follows:

〈 Table 1〉 Typical cases of diagnosis with two kinds of control chart

| Case | Rate of patient with severe disease | Cure rate | CS cure rate | Diagnosis |
|---|---|---|---|---|
| | Shewhart chart | Shewhart chart | CS chart | |
| I | Abnormal | Abnormal | Normal | There is a unique uncontrollable assignable cause. |
| II | Abnormal | Normal | Abnormal | There are both a controllable assignable cause and an uncontrollable assignable cause. The latter offsets the former. |
| III | Abnormal | Abnormal | Abnormal | There are both a controllable assignable cause and an uncontrollable assignable cause. |
| III′ | Normal | Abnormal | Abnormal | There is a controllable assignable cause. |
| IV | Normal | Normal | Normal | There is no assignable cause. |

Note: In this table, (1) the CS chart denotes the simple cause-selecting chart, here, 'simple' implies that there is only one uncontrollable assignable cause; (2) the controllable assignable cause implies that the specific medical quality is abnormal and the uncontrollable assignable cause implies that the rate of patient with severe disease has an abnormal influence to the specific medical quality.

(1) Case I : The cause-selecting chart indicates normal, implying that the specific medical quality(the cause-selecting cure rate) is normal. But, the Shewhart chart shows abnormal, implying that the total medical quality(the cure rate) is abnormal. Combining these two statements together, it is very natural to diagnose that the rate of patient with severe disease has an abnormal influence on the cause-selecting cure rate. In case I, if we do not use the cause-selecting chart, then, very possibly, we may diagnose that the cause-selecting cure rate is abnormal according to the indication of its corresponding Shewhart chart. But, this is a false alarm.

(2) Case II : The cause-selecting chart shows abnormal, implying that the specific medical quality(the cause-selecting cure rate) is abnormal. But, the Shewhart chart is normal. The reason for this occurrence is that the abnormal influence of the rate of patient with severe disease just offsets the abnormality

produced by the cause-selecting cure rate. In case II, if we do not use the cause-selecting chart, then, very possibly, we may diagnose that the cause-selecting cure rate is normal. Thus, there is an alarm missing.

(3) Case III and III′ : The cause-selecting chart shows abnormal, impling that the cause-selecting cure rate is abnormal. As for the abnormality of the influence of the rate of patient with severe disease, it can be judged with the aid of the Shewhart chart of the rate of patient with severe disease.

(4) Case IV : Both the specific medical quality and the total medical quality are normal.

## 4. Case Study of the Diagnosis Theory with Two Kinds of Quality

The data of the cure rate and the rate of patient with severe disease of a certain hospital in China are shown in 〈Table 2〉. At first, we need to check whether the

〈 Table 2〉 Data and calculation of $y_{cs}$

| Clinical Dept. (1) | Rate of Patient With Severe Disease(%), $x$ (2) | Cure Rate (%), $y$ (3) | Regression Value, $\hat{y}$ (4) | CS Cure Rate $y_{cs}=y-\hat{y}$ (5) | Moving Range $R_s(y_{cs})$ (6) |
|---|---|---|---|---|---|
| Internal Medicine | 18.19 | 50.45 | 63.92 | −13.47 | − |
| Surgery | 7.61 | 84.71 | 88.71 | − 4.00 | 9.47 |
| Obstetrics | 2.64 | 97.65 | 100.36 | − 2.70 | 1.30 |
| Paediatrics | 3.19 | 98.20 | 99.07 | − 0.87 | 1.83 |
| Five Sense Organs | 9.91 | 90.09 | 83.32 | 6.77 | 7.64 |
| Infectious Disease | 10.96 | 82.96 | 80.86 | 2.10 | 4.67 |
| Nerve | 16.04 | 81.13 | 68.96 | 12.17 | 10.07 |
| Sum | 68.54 | 585.19 | 585.20 | 0 | 34.98 |
| Average | 9.79 | 83.60 | 80.60 | 0 | 5.83 |

influence of patient with severe disease denoted by $x$ is significant or not to the cure rate denoted by $y$. By regression with the data in columns (2) and (3) in 〈Table 2〉, we obtain

$$\hat{y} = b_0 + b_1 x$$

$$b_0 = 106.54$$

$$b_1 = -2.3432$$

$$|r| = 0.861$$

where, $\hat{y}$ is the fitted regression value of cure rate $y$ and $r$ is the correlation coefficient between $x$ and $y$. Because $|r| = 0.861 > 0.754 = r_{0.05}$ (5), the cure rate $y$ is significantly related with the rate of patient with severe disease $x$. Since $b_1$ is negative, the clinical department with high rate of patient with severe disease has a low cure rate. Thus, using the cure rate only to evaluate clinical departments is unreasonable due to lack of comparability.

Secondly, we use the cause-selecting chart to eliminate the influence of the uncontrollable assignable cause, i.e. the rate of patient with severe disease from the total cure rate and thus get the cause-selecting cure rate. Using the data in 〈Table 2〉, we can obtain $\hat{y}$ and $y_{cs} = y - \hat{y}$, which are listed in 〈Table 2〉. The $y_{cs}$ expresses the cause-selecting cure rate. The suffix "cs" expresses the cause-selecting. The control limits of $y_{cs}$ chart are as follows:

$$UCL = \bar{y}_{cs} + 2.66\,\bar{R}_s(y_{cs})$$
$$= 0.00 + 2.66 \times 5.83 = 15.51$$

$$CL = \bar{y}_{cs} = 0.00$$

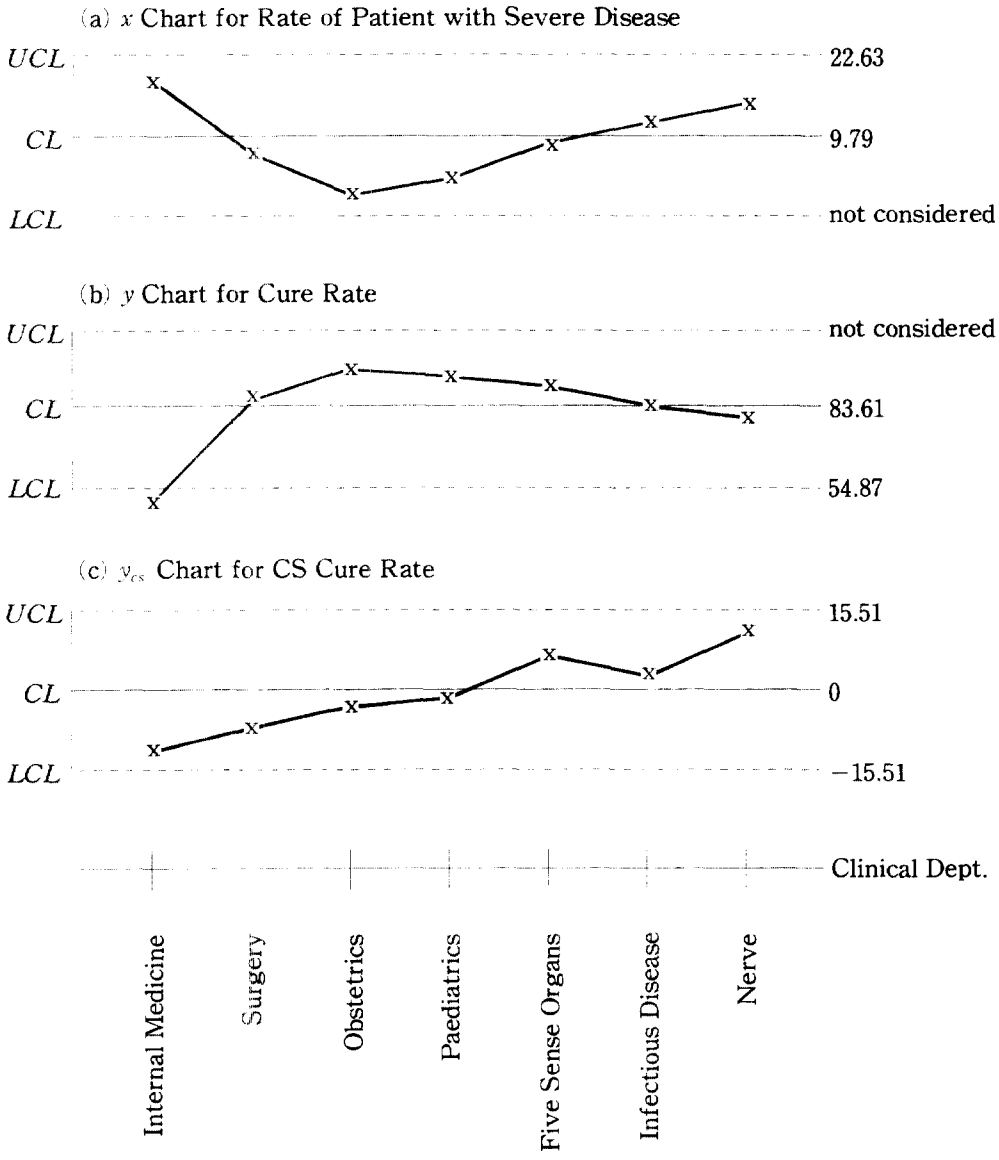
$$LCL = \bar{y}_{cs} - 2.66\,\bar{R}_s(y_{cs})$$
$$= 0.00 - 2.66 \times 5.83 = -15.51$$

〈Figure 1〉 shows the control chart of $y_{cs}$. For the convenience of analysis, we also give the $x$ chart for the rate of patient with severe disease and the $y$ chart for the cure rate.

Based on the data in 〈Table 2〉, we make sequences of the cure rate, rate of patient with severe disease, cause-selecting cure rate as shown in 〈Table 3〉 according to their magnitude from small to large, respectively.

Now, we analyse 〈Figure 1〉 and 〈Table 3〉 as follows.

In 〈Table 3〉, the sequencing is based on the cure rate. Here, the paediatrics and obstetrics are the highest. But, the sequence based on the rate of patient with severe disease is just in the opposite. This illustrates that the rate of patient with severe disease has really a significant influence on the cure rate.




〈 Figure 1〉 Control Chart for Cure Rate

In 〈Figure 1(b)〉, the point plotted for internal medicine is outside the *LCL*, and the corresponding point plotted in 〈Figure 1(c)〉 is inside the control limits. This is just the case I in 〈Table 1〉, so we can diagnose at once that the uncontrollable assignable cause, i.e. the rate of patient with severe disease exists. It means that the rate of patient with severe disease is too high so that the total cure rate is significantly low. This diagnosis checks with the practice very well.

〈 Table 3 〉 Sequences of clinical department

| Number of Sequence | Sequence of Cure Rate | Sequence of Rate of Patient with Severe Disease | Sequence of Cause-selecting Cure Rate |
|---|---|---|---|
| 1 | Paediatrics | Internal Medicine | Nerve |
| 2 | Obstetrics | Nerve | Five Sense Organs |
| 3 | Five Sense Organs | Infectious Disease | Infectious Disease |
| 4 | Surgery | Five Sense Organs | Paediatrics |
| 5 | Infectious Disease | Surgery | Obstetrics |
| 6 | Nerve | Paediatrics | Surgery |
| 7 | Internal Medicine | Obstetrics | Internal Medicine |

# 5. Conclusion

The cure rate is often used in hospital to evaluate the medical quality of each clinical department. But, in fact, it reflects only the total medical quality which has close relation with objective conditions, for example, the rate of patient with severe disease. Hence, the evaluation by cure rate is unreasonable and incomplete.

Using the new diagnosis theory with two kinds of quality, we proposed a new type of index, the cause-selecting cure rate or the specific medical quality index for evaluation. This method can be used not only to find the abnormality of cure rate, but also to diagnose the cause of this abnormality.

We have used the simple regression equation between the rate of patient with severe disease $x$ and the cure rate $y$. However, a better method of analysis is a multiple regression by considering all the important confounding variables including the $x$ and some general demographic characteristics of patients. A further study is desirable for this point of view.

The theory and methods proposed in this paper can be used everywhere including the office work, the factory and even the management of a ministry etc.

# References

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