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Differential Application of Rate and Delta Check on Selected Clinical Chemistry Tests

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Though the present delta value check used in quality control programs is a powerful tool for detecting random errors in clinical chemistry analysis, it has some problems, such as missed true errors and delays in reporting time, because it also has the potential of showing erroneous positive results. Recently, new calculation methods for delta check with delta difference, delta percent change, rate difference, and rate percent change have been suggested by Lacher and Connelly (Clin Chem 34:1966-1970, 1988). Based on this new delta check method, we made the new criteria of which calculation method is applied to the clinical chemistry tests, i.e., the differential application of rate and delta check, and selectively applied the new method to 17 chemistry tests in order to solve the above problems. The applied criteria were the time dependence of the test item and the coefficient of variation of the absolute delta difference. Calcium, inorganic phosphorus, total protein, albumin, sodium, potassium, and chloride were classified as delta difference calculation method group; glucose and cholesterol as delta percent change group; creatinine, total and direct bilirubin as rate difference group; and urea nitrogen, uric acid, ALP, ALT, and AST as rate percent change group. With the previous criteria by Whitehurst et al. (Clin Chem 221:87-92) for 5045 specimens, the check-out rate was 47.8% (2,411 out of 5,045), and the positive predictive value was 0.41% (10 out of 2,411). For the new criteria, the check-out rate was 12.7% (621 out of 5,045), and the positive predictive value was 1.8% (nine out of 621). The workload was decreased by 74.3% (621:2411), and a higher positive predictive value was achieved. We concluded that the new guidelines could resolve some of the workload problems of delta check in clinical chemistry laboratories.

Key Words: *Quality control, Computers, Delta check, Laboratory information system.*

INTRODUCTION

The introduction of the computer into the laboratory has made great contributions to the progress of quality control. Quality control with quality control materials, such as the Westgard multirule chart has been widely accepted. But the computer's limitation in detecting random errors made us to consider a new method of delta check. Delta check is the comparison of the patient's current value with the previous one and the detection of the current values with the different values beyond the delta limit of the test. The delta value is checked by the clinical pathologist, and abnormally-checked results are discussed between the pathologist and the physician. It makes the laboratory more reliable to the physician. It also provides a basis for interpretive reports and helps us to understand the pathophysiologic change of disease.

Since Lindberg (1967) suggested the delta concept, the method and limit of delta check have been studied

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by several workers (Ladenson, 1975; Whitehurst et al., 1975; Wheeler and Sheiner, 1977; Sher, 1979). Their methods have produced heavy check-out volumes and low efficiency. Recently, Lacher and Connelly (1988) introduced the delta interval, the interval between the current and the previous value. They define rate and delta check as follows:

Delta difference=current value-previous value

Delta percent change=delta difference/current value

Rate difference=(delta difference/delta interval)×100%

Rate percent change=delta percent change/delta interval

The heavy check-out volume creates problems, such as the increased probability of missing the true preanalytic or analytic error and the lengthening of the turnaround time. Also, the previously studied delta limits (Ladenson, 1975; Whitehurst et al., 1975; Sher, 1979) are subjectively based on laboratory workload but not on biological variability. If the delta check limit is based on biological variability, too many check-out results will be produced and cannot be handled in the laboratory. Also, the subjects of the previously studied biological variability (Young et al., 1971) are normal healthy persons without any diseases. These problems lower delta check efficiency.

Therefore, an improved method and objective limit are needed. When some laboratory tests are requested, they are used for diagnosis or monitoring of the patients. If they are repeated, they are used for the monitoring the related diseases of the tests. For example, creatinine and urea nitrogen is frequently requested in patients with renal dysfunction or would-be renal dysfunction, and alanine aminotransferase (ALT) and aspartate aminotransferase (AST) in patients with hepatic dysfunction or would-be hepatic dysfunction, and so on. The values of these tests vary as the patient's disease progresses. Therefore, creatinine and urea nitrogen are the time-dependent items. If acute renal failure occurs, creatinine and urea nitrogen change with time. Time-dependent items should be checked by the rate of the delta difference or the rate of the delta percent change. For electrolytes, the host's homeostasis permits the fluctuation of electrolytes within a narrow range, and they do not seem to be changed with time. Electrolytes are the time-independent item. Time-independent items should be checked by the delta difference or delta percent change. The selection of difference or percent change is based on the magnitude of the coefficient of the variation (CV) of the absolute delta difference. The absolute delta difference is defined as follows:

Absolute delta difference=| current value-previsous value |

Difference calculation is applied in the case of the large CV value of the absolute delta difference and the percent change in the case of small CV value.

Table 1. Analytical Brief in Clinical Chemistry Tests

Test Item	Method	Reference Range*	Unit
Calcium	O-cresophthalein complex	88-105	mg/L
Phosphorous	Molybdate	25-45	mg/L
Glucose	Glucose oxidase-peroxidase	700-1100	mg/L
Urea Nitrogen	Urease	100-260	mg/L
Uric acid	Uricase-peroxidase	25-70	mg/L
Cholesterol	Enzyme-quinone chromogen	<2400	mg/L
T.protein	Biuret	600-800	mg/L
Albumin	Bromo cresol green	33-52	mg/L
T.bilirubin	Jendrassik Grof (modified)	2-12	mg/L
D.bilirubin	Jendrassik Grof (modified)	1-5	mg/L
ALP	P-nitrophenyl phosphate 37°C	30-115	U/L
ALT	NADH-UV 37°C	1-40	U/L
AST	NADH-UV 37°C	1-40	U/L
Creatinine	Jaffe picrate	7-14	mg/L
Na	Ion selective electrode	135-145	mmol/L
K	Ion selective electrode	3.5-5.5	mmol/L
C1	Ion selective electrode	98-110	mmol/L

*The reference ranges adopted in Seoul National University Hospital, Korea

Under the above assumptions, we set the new delta check method and limit after the analysis of the laboratory data and evaluated its performance.

MATERIALS AND METHODS

Delta Check Limit Determination

We selected the following 17 routine chemistry items: calcium, phosphorus, glucose, urea nitrogen, uric acid, cholesterol, protein, albumin, total and direct bilirubin, alkaline phosphatase (ALP), alanine aminotransferase (ALT), aspartate aminotransferase (AST), creatinine, sodium, potassium, and chloride. The analytic method and the reference range in our laboratory was presented (Table 1). The test results were obtained from March to April, 1989, at Seoul National University Hospital.

Coefficients of variations of absolute delta difference were obtained to determine which type of calculation mode should be applied between the difference and percent change. The calculation mode of the test items was determined among the delta difference, delta percent change, rate difference, and rate percent change by time-dependence and the CVs of absoulte delta difference. The delta check limits were obtained by 2.5 percentile and 97.5 percentile value from the distribution of the test results.

Evaluation

The new method was compared with the previous method based on Whitehurst et al. (1975). The delta check record from September 4 to 25, 1989, was reviewed. The pairs of test results beyond the limit were counted. Check-out results were classified as nonfurther and further confirmed results. Further confirmed results were subclassified to several kinds of further examined actions, such as the confirmation of clinical information on request sheets, accumulated past results, communication to the ward physician, repeat tests, and result corrections, along with keyboard input errors of manual input results. The frequencies of each type were counted.

RESULTS

The number of test results are presented (Table 2). The number of result pairs are from 500 to 3,800. From the distribution of the absolute delta difference in each test item, the coefficients of variation were obtained (Table 3). As shown in Table 4, the delta difference in-

Table 2. Descriptive Statistics of Clinical Chemistry Tests

Tests (units)	Number of Comparisons[a]	Median Time (day)[b]	Median Current Value	Method Precision 1 SD[c]
Calcium (mg/L)	1113	5	85	0.21
Phosphorus (mg/L)	1101	5	38	0.16
Glucose (mg/L)	649	7	1100	1.5
BUN (mg/L)	2768	6	140	0.7
Uric acid (mg/L)	775	7	50	0.05
Cholesterol (mg/L)	3008	8	1520	1.1
T.protein (g/L)	3185	7	68	0.1
Albumin (g/L)	3485	6	34	0.05
T.bilirubin (mg/L)	3105	7	9	0.03
ALP (U/L)	3095	7	83	2.6
AST (U/L)	3805	7	30	1.2
ALT (U/L)	3796	7	28	1.6
D.bilirubin (mg/L)	536	5	14	0.05
Creatinine (mg/L)	2714	6	10	0.03
Na (mmol/L)	2175	5	135	0.15
K (mmol/L)	2180	5	4.2	0.02
C1 (mmol/L)	2102	5	102	0.17

[a] Number of the comparisons between current and previous specimens

[b] Median interval time between collection of current and previous specimens

[c] Method precision is approximate and was determined from quality control data with averages about equal to median current values.

cluded calcium, phosphorus, total protein, albumin, sodium, potassium and chloride; the delta percent change includes glucose and cholesterol; the rate difference includes total bilirubin, direct bilirubin, and creatinine; the rate percent change includes urea nitrogen, uric acid, ALP, AST, and ALT. The sample number used to evaluate the new method was 5,045 specimens (Fig. 1). The previous method checked out 2,411 specimens (47.8% of 5,045 specimens), and the new method 621 specimens (25.8% of 5,045 specimens). Among the check-out specimens, the previous method and the new method simultaneously checked out 483 specimens; the remaining 138 specimens were checked out by the new method and not by the previous method. Among 2,411 specimens of the previous method, 436 specimens (18.1% of 2,411 specimens) required further confirmation steps. Among 483 specimens of the new method, 123 specimens (19.8% of 483 specimens) required further confirming steps. The proportion of the specimens requiring further confirming steps by the new method was significantly higher than that by the previous method ($p < 0.05$).

The specimens requiring further confirming steps were classified as several kinds of confirming actions each (Table 5). From the disease code confirmation to repeating the tests, more time and resources were needed. In disease code confirmation, the proportion between the above two methods was 2.7%. In repeating the tests, the proportion was 74.5%. Further confirmation action increased from 2.7% to 74.5% as more considerable efforts were needed. Ten specimens were detected as errors by the previous method and nine specimens by the new method. The positive predictive value was 0.41% (10/2,411 specimens) for the previous method and 1.8% (9/483 specimens) for the newmethod.

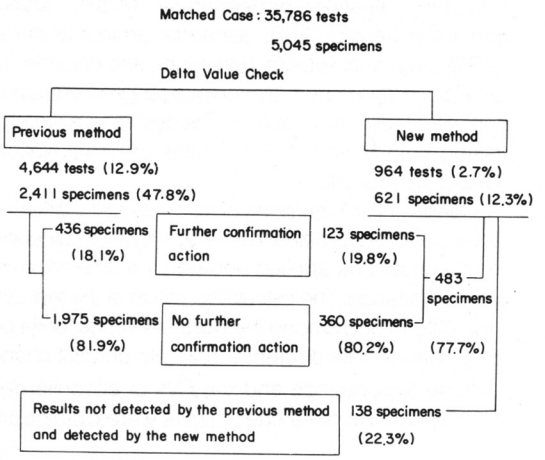

Fig. 1. Result of the Evaluation for the Previous Delta Check and the New Delta Check.

Table 3. Determination of Delta Value Calculation Type

Test	Time-Dependence	Coefficient of Variation	Difference vs Percent Change
Calcium	Independent	0.416	Difference
Phos-phorous	Independent	0.571	Difference
Glucose	Independent	14101	Percent change
BUN	Dependent	77.288	Percent change
Uric acid	Dependent	2.66	Difference
Cholesterol	Independent	715.0	Percent change
T.protein	Independent	0.208	Difference
Albumin	Independent	0.072	Difference
T.bilirubin	Dependent	1.66	Difference
ALP	Dependent	2580	Percent change
AST	Dependent	11991	Percent change
ALT	Dependent	8646	Percent change
D.bilirubin	Dependent	1.64	Difference
Creatinine	Dependent	0.73	Difference
Na	Independent	9.24	Difference
K	Independent	8.46	Difference
C1	Independent	10.83	Difference

Table 4. Proposed Critreria of Delta Value Check in Clinical Chemistry Tests

Test	Delta Value Calculation Mode	Lower Limit	Upper Limit	Unit
Calcium	Delta difference	−18	15	mg/L
Phos-phorous	Delta difference	−23	20	mg/L
Glucose	Delta percent	−52.4	156.8	%
BUN	Rate percent	−21.5	35.3	%/day
Uric acid	Rate percent	−9.7	9.9	%/day
Cholesterol	Delta percent	−39.5	45.5	%
T.protein	Delta difference	−15	13	mg/L
Albumin	Delta difference	−9	8	mg/L
T.bilirubin	Rate difference	−8	9	mg/L/day
ALP	Rate percent	−10.6	21.2	%/day
AST	Rate percent	−22.5	48.9	%/day
ALT	Rate percent	−19.7	56.7	%/day
D.bilirubin	Rate difference	−10	13	mg/L/day
Creatinine	Rate difference	−30	30	mg/L/day
Na	Delta difference	−10	8	mg/L
K	Delta difference	−1.4	1.4	mg/L
C1	Delta difference	−10	9.0	mg/L

Table 5. Comparison of the Previous Method and the New Method for Delta Check in Further Confirmation Action

Action Pattern	Previous Method	New Method
Total number	436 specimens	123 specimens
Disease code confirmation	145	4
Past result search	112	44
Telephone to ward	194	74
Repeat	59	44
Result correction	8	7
Input error confirmation	2	2

DISCUSSION

Since Lindberg (1967) proposed the delta concept, delta check has turned out to be an effective tool for quality control with patient samples (Westgard and Klee, 1986). Quality control with patient samples includes 'the average of the normal methods' or the calculation of several simultaneous requested items, such as a calculation of anion gap (Cembrowski et al., 1983) or bivariate ratio (Kanno et al., 1981), but these methods are not efficient for detecting random errors. Detecting random errors can be achieved by the direct confirmation of the patient data one by one. As a means of direct confirmation, delta check has turned out to be an effective tool of quality control with patient samples (Westgard and Klee, 1986). Several workers (Ladenson, 1975; Whitehurst et al., 1975; Sher, 1979) have suggested the delta limit empirically, and Wheeler and Shiener (1977) proposed it based on laboratory data probability function. Their limit was based on the wookload of laboratory, not on the patient's biological variability. Considerations of pathophysiologic characteristics on the clinical chemistry laboratory test was not considered. Four calculation modes, that is, delta difference, delta percent, rate difference and rate percent change method, have been proposed by Lacher and Connelly (1988), but they did not propose the appropriate use of those four modes. Simultaneous application of the four modes to each test item seems to be a waste of computer power and human effort. To consider simultaneously the results of four modes on each test item is difficult and laborious. In the above

evaluation results, the limit by Whitehurst et al. (1975) produced 47.8% of the specimens with previous results as abnormal. The abnormal results need a clinical chemist's result confirmation step. The larger the volume of the abnormal result, the more time and manpower are consequently needed. There is a delay in reporting the result. But because the past delta check limit is based on laboratory workload, the change of delta limit is associated not only with the reduction of false abnormal results but also with missing true errors. So the simple change of limit value will not produce an efficient delta check, and consideration of a new delta check principle itself is needed.

Consideration of time dependence and the magnitude of the coefficient of variation provides that only one calculation mode should be applied to each test item. The differential application of the delta calculation mode reflects the biological variability. That is, the clinical pathologist considers the delta interval heuristically when checking such things as urea nitrogen, creatinine, and so on. The differential application of rate and delta check is to implement the heuristic rule for the real delta check computation.

Simple confirming of the patient's diagnosis is the most basic confirmation step, and if the test result cannot be explained by the patient's diagnosis, an accumulated result by computer search is needed. The accumulated result searching with the computer is a more time consuming and laborious confirmation step, and if this action is not satisfactory, a discussion with the patient's physician about the test result is needed. But discussing with the patient's physician still laborious, and repeating the test is even more so. Ultimately the purpose of the time spent confirming the patient's diagnosis to discussing with the patient's physician is to detect errors without a repeat test. A test repeat step is conducted when the result cannot be explained by the current clinical state of the patient. So it is desirable to reduce the number of specimens for confirmation steps before repeating the test.

The evaluation results show that, compared to the previous method, the new method detects results with relatively more sensitivity to true errors. From confirming the patient's diagnosis to simply repeating the test result, human delta check activity gradually becomes more laborious and time consuming. In comparing the previous method and our new method in the simple confirmation of the patient's disease, the new method detects markedly fewer specimens than the previous one. Gradually the previous method detects more test and result correction is most important. The previous method detects ten errors and the new method detects nine errors. That is, about 25% of the volume recorded by the previous delta check was detected as abnormal by the new method, while 90% of the error detected by the previous method was detected by the new method. Ten percent of the error (one specimen) was not detected by the new method.

But the result groups detected by the new method and not the previous one have not been examined. That is, the new method detects a group of 138 specimens as error results, but the previous method did not detect them. The previous method did not detect all the true errors. The new method's positive predictive value was 1.8%. On the assumption that there were the same incidences of errors in these groups, the expected true error by the new method was calculated as $138 \times 1.8\% = 2.5$ specimens. So the new method may detect $9 + 2.5 = 11.5$ errors of specimens among 5,045 specimens, and the previous method detects 10 errors. The new method detects 1.5 more specimen errors than the previous method.

Therefore, the new method based on the differential application of the rate and delta check detects a fewer number of results than the previous method based on Whitehurst's criteria (Whitehurst et al., 1975). This leads to a reduction in the result confirmation time by the clinical chemist, a shortening of the turnaround time, and a lessening of the clinical chemist's effort. The new method is higher in positive predictive value than the previous one and may detect more true errors. In conclusion, the new method based on the differential application of rate and delta check improves the delta check performance compared to the previous method based on Whitehurst's criteria.

REFERENCES

Cembrowski Gs, Westgard JO, Kurtycz DFI: *Use of anion gap for the quality control of electrolyte analyzers. Am J Clin Pathol 79:688-696, 1983.*

Kanno T, Takeuchi I, Sudo K: *Bivariate ratio monitoring in clinical laboratories. Am J Clin Pathol 79:782-787, 1981.*

Lacher DA, Connelly DP: *Rate and delta checks compared for selected chemistry tests. Clin Chem 34:1966-1970, 1988.*

Ladenson JH: *Patients as their own controls: Use of the computer to identify "laboratory error". Clin Chem 21:1648-1653, 1975.*

Lindberg DAB: *Collection, evaluation, and transmission of hospital laboratory data. Method Inform Med 6:97, 1967.*

Sher PP: *An evaluation of the detection capacity of a computer-assisted real-time delta check system. Clin Chem 25:870-872, 1979.*

Westgard JO, Klee: *Quality assurance. In Textbook of clinical chemistry, Tietz NW ed. Saunders, Philadelphia, pp. 424-458, 1986.*

Wheeler LA, Sheiner LB: *Delta check tables for the technicon SMA 6 continuous-flow analyzer. Clin Chem 23:2165-2169, 1977.*

Whitehurst P, Di Silvio TV, Boyadjian G: *Evaluation of discrepancies in patients' results—an aspect of computer-assisted quality control. Clin Chem 221:87-92, 1975.*

Young DS, Harris EK, Cotlove E: *Biological and analytic components of variation in long-term studies of serum constituents in normal subjects. Clin Chem 17:405-410, 1971.*