MEDINFO 98
B. Cesnik et al. (Eds)
Amsterdam: IOS Press

The Multi-Item Univariate Delta Check Method: A New Approach

Insoo Rheem[a], Kap No Lee[b]

[a]*Department of Clinical Pathology, College of Medicine, Dankook University, Cheonan, Korea*
[b]*Department of Clinical Pathology, College of Medicine, Korea University, Seoul, Korea*

Abstract

The delta check methods are methods for detection of random errors in clinical laboratory tests including specimen abnormalities, specimen mix-up, problems in analysis processes, and clerical errors. Methodologically, it is known that the multivariate delta check methods are more superior to the univariate delta check methods. However, due to some problems in reality including technical difficulties, it is hard to put the multivariate delta check methods into practice. Since the univariate delta check methods are methods at hand, there has been a need for an efficient and effective univariate delta check method. In order to meet such a need, we propose "the multi-item univariate delta check (MIUDC) method". By the multi-item univariate delta check (MIUDC) method, we mean a method in which univariate delta checks are performed on multiple items and specimens with the positive univariate delta check in at least k items are put under a detailed investigation. Our research objectives are the determination of an appropriate value of such k and identification of test items deserving of more interest. Through real data and simulation studies, we concluded that an appropriate value of k is 4 because, with k=4, we can have light checking-out volumes and high efficiency. Also, we identified total cholesterol, albumin, and total protein as items deserving of more interest because the false positive rate associated with them in the MIUDC was zero in a simulation study. We present the MIUDC method as a quality control method that is easy-to-implement and efficient.

Keywords

Quality Control; Delta Check; Multi-Item Univariate Delta Check (MIUDC); Laboratory Information System

Introduction

Errors in clinical laboratory tests can be classified, according to the type of errors, into systematic errors and random errors and, according to the time and the situation of occurrence, into pre-analytical errors, analytical errors and post-analytical errors.

The advance of internal has remarkably reduced systematic errors in laboratory tests and external quality control methods that utilize control materials and the development of automatic analyzers. However, the above-mentioned quality control methods were not sensitive to random errors before or after analysis. The delta value check method has been recognized to be powerful and efficient in detecting random errors including specimen abnormalities, specimen mix-up, problems in analysis processes, and clerical errors [2-6].

Difficulties in calculation that hindered the practice of the delta check in the past is now no longer a problem thanks to the development of computers. But, high false positive rates, which creates heavy burden of checking-work load, are still a problem in the practice of the delta check [5]. We propose a new approach to the reduction of false positive rates, naming our method 'the multi-item univariate delta check (MIUDC) method'. Using data collected in the Department of Clinical Pathology at Korea University Guro Hospital via the Korea University Laboratory Information System, we illustrate our method.

The delta value check method is a quality control method in which the patient's current test result is compared with previous test result and the difference greater than the delta limit value is evaluated to determine whether it is due to the change of patient conditions or due to the errors related to the test. Since Lindberg (1967) proposed the concept of delta check [1], this method has been under study and put into practice in clinical laboratories. For detection of specimen mix-up, which is the most important purpose of delta check, it will be more efficient to make a detailed investigation into the specimen that showed the beyond-limit values in multiple items. Multivariate delta check methods have been studied by Sheiner et al (1979), Iizuka et al (1982), J. W. Kim et al (1990), and I. Rheem et al (1996) [6-9]. Though the multivariate delta check has been reported to be more efficient than the univariate delta check [7-9], it is not yet in wide use because there are technical difficulties and it is uncertain whether the testing on the selected items is requested.

In this research, in order to assess the efficiency and the false positive rates of the delta check method, we calculated the rates of detecting the specimen mix-up. From these results, we made answers to the following two questions: (1) What is the appropriate minimum number of test items, each of which shows positive univariate delta check, that leads to a detailed investigation on a specimen? (2) Which test items deserve more interest?

Materials and Methods

At Korea University Guro Hospital, the delta check system is supported by the KULAB (Korea University Laboratory) Information System on the hospital computer system (LG DPS98-1, TOTAL & DPS COBOL) and the check of delta and panic values has been put into practice since June 1993. As of October 1993, the test items on delta check were 16 items in clinical chemistry and 4 items in hematology. The absolute delta percent change, which is defined as |(current value - previous value) / previous value x 100%, is used for delta checks and the criteria for test items were determined based on the experiences and the literature review (Table 1).

Table 1 - Criteria for delta checks at Korea University Guro Hospital

Item	Delta limit value*	Reference range	Unit
AST	50	8-30	U/L
ALT	50	8-30	U/L
ALP	50	20-90	U/L
TBil	50	0.2-1.2	mg/dL
DBil	50	0-0.5	mg/dL
TP	20	6-8	g/dL
ALB	20	3.3-5.2	mg/dL
TC	50	130-270	mg/dL
GLU	50	65-110	mg/dL
BUN	50	7-20	mg/dL
CRE	50	0.7-1.4	mg/dL
Na	5	135-145	mEq/L
K	20	3.5-5.5	mEq/L
Cl	10	98-110	mEq/L
Ca	15	9-11	mg/dL
P	20	2.7-4.5	mg/dL
WBC	45	4.0-10.0×10$_3$	/mm$_3$
Hgb	20	12-16	g/dL
Hct	20	38-52	%
PLT	40	150-350×10$_3$	/mm$_3$

* absolute delta percent change = |(current - previous) / previous| x 100%

The duration in which the delta check is possible through our hospital computer was set as three months in consideration of the capacity of the hospital computer system. Results of delta and panic value checks are outputted with the daily test report. Test items are 16 items in clinical chemistry, which are aspartate aminotranferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), total bilirubin (TBil), direct bilirubin (DBil), total protein (TP), albumin (ALB), Total Cholesterol (TC), Glucose (GLU), blood urea nitrogen (BUN), creatinine (CRE), sodium (Na), potassium (K), chloride (Cl), calcium (Ca), phosphorous (P), and 4 items in hematology, which are WBC, hemoglobin (Hgb), hematocrit (Hct), platelet (PLT).

Materials for this study are the delta check values obtained at the Korea University Guro Hospital Clinical Pathology Laboratory in October 1993. Basic statistics were obtained from hematology and clinical chemistry test results and rates of positive delta checks for each of test items and for each of specimens were obtained from clinical chemistry test results.

Raw data in ASCII (American Standard Code for Information Interchange) type were acquired from chemistry auto-analyzers ASTRA-8 (Beckman, USA) and CX-4 (Beckman, USA) and from a hematology auto-analyzer Coulter Model S-Plus (Coulter Electronics, USA) and transformed to the DBF (Data Base Format) type data. Foxpro 2.5 (Microsoft, USA) and SAS 6.04 (SAS Institute Inc., USA) were used for data analysis.

1. Basic Statistics

From the hematology and clinical chemistry test results, rates of positive delta checks per day and per test item were obtained.

2. Rates of Positive Delta Checks from the Multi-Item Univariate Delta Checks: A Real Data Study

By the multi-item univariate delta check method, we mean a method in which univariate delta checks are performed on multiple items and specimens with the positive univariate delta check in at least k items receive a detailed investigation. Our research objectives include the determination of such k. In our research, for each of 480 specimens' current-previous pairs; we performed univariate delta checks on 8 chemistry test items, which are ALP, TBil, TP, ALB, TC, Cl, and Ca. Then, we calculated the proportion of specimens that show the positive univariate delta check in at least j items, for j=1,..., 8.

3. True and False Positive Rates from the Multi-Item Univariate Delta Checks: A Simulation Study

Among the specimen pairs that went through the clinical chemistry tests, we took at random 100 specimen pairs as a random sample. The false positive rate is defined as the proportion of specimens identified as positive among these 100 specimens. Then, in order to generate artificial mix-ups, we replaced the previous value of each patient with that of another patient, thus obtaining 100x99=9,900 artificial mix-ups. The true positive rate is defined as the proportion of specimens identified as positive among these 9,900 mixed-up specimens. From these 10,000 specimen pairs, we calculated true and false positive rates, setting the criterion for the positiveness of the specimen as the positive univariate delta check in at least j *items, for* j*=1, ..., 8.*

Results

1. Basic Statistics

Table 2 contains rates of positive delta checks per day and per test item obtained from the hematology and clinical chemistry test results. Among 85,224 tests during October 1993 on predescribed 20 items, 4,983 tests (item average positive rate:

5.8%=4,983/85,224; daily average: 199 tests=4,983 tests/25) resulted in the positive univariate delta check. Percentage of positive delta checks for each item ranges from 0.9% to 19.7%. Items with such percentage higher than the average percentage 5.8% are AST (9.4%), ALT (10.5%), TBil (6.2%), DBil (10.7%), ALB (6.9%), GLU (8.7%), K (7.0%), P (19.7%), WBC (10.8%), and PLT (9.7%).

Table 2 - Percentage of positive delta checks on each item

Item	Daily total	Daily average*	No. tested, each item	Positive delta check(%)
AST	405	16.2	4321	9.4
ALT	453	18.1	4333	10.5
ALP	110	4.4	4024	2.7
TBil	221	8.8	3563	6.2
DBil	343	13.7	3207	10.7
TP	147	5.9	3863	3.8
ALB	264	10.6	3836	6.9
TC	50	2.0	2817	1.8
GLU	157	6.3	1813	8.7
BUN	205	8.2	3790	5.4
CRE	107	4.3	3790	2.8
Na	146	5.8	3802	3.8
K	275	11.0	3947	7.0
Cl	72	2.9	3804	1.9
Ca	94	3.8	9967	0.9
P	175	7.0	890	19.7
WBC	624	25.0	5774	10.8
Hgb	254	10.2	5870	4.3
Hct	306	12.2	5868	5.2
PLT	575	23.0	5945	9.7
Total	4983	199.3	85224	5.8

* 25 days of October 1993

2. Rates of Positive Delta Checks from the Multi-Item Univariate Delta Checks: A Real Data Study

As we see in Table 3, among eight items, the item with the highest positive rate was Cl (20.2%) and the items with the lowest and the second lowest positive rates were Ca (4.2%) and TC (4.6%). The average positive rate for all eight items were 10.7% and items with positive rates higher than the average were TBil (17.9%), ALB (17.1%), and Cl (20.2%). The proportion of specimens with the positive delta check in at least one item was 49.6% whereas the item average positive rate was 5.8%. The proportion of specimens with the positive delta check in at least four items was 2.7%, below 5%

.Here, notice that the proportion of specimens with the positive delta check only in TC, ALB, and TP, the most important items in the multivariate delta check [7-9], was 0.8%.

Table 3 - Percentages of specimens with positive delta checks (8 items; 480 specimens)

Item or Item sets	Positive Delta Check	
	Frequency	Percent
ALP	41	8.5
TBil	86	17.9
TP	38	7.9
ALB	82	17.1
TC	22	4.6
CRE	24	5.0
Cl	97	20.2
Ca	20	4.2
Average of above 8 items	51	10.7
All of TC, ALB, TP	4	0.8
1 item or more	238	49.6
2 items or more	115	24.0
3 items or more	42	8.8
4 items or more	13	2.7
5 items or more	2	0.4
6 items or more	0	0
7 items or more	0	0
8 items or more	0	0

3. True and False Positive Rates from the Multi-Item Univariate Delta Checks: A Simulation Study

True and false positive rates are presented in Tables 4 and 5. In Table 4, the average positive rates for all eight items were 41.2%. Items with positive rates higher than the average were ALB (55.8%), Cl (53.9%), and TBil (50.9%) and the item with the lowest positive rate was Ca (22.3%). Among 9,900 mixed-up specimens, the proportion of specimens with at least one positive univariate delta check was as high as 96.6%. In Table 5, among 100 unmixed specimens, the proportion of specimens with at least one positive univariate delta check was 51%, too high a false positive rate. In Table 4, among 9,900 mixed-up specimens, only 0.3% showed the positive univariate delta check in all 8 items.

Let us determine the appropriate minimum number, say k, of test items, each of which shows positive univariate delta check, that leads to a detailed investigation on a specimen, taking both true and false positive rates into consideration. $k \geq 6$ is inappropriate because the true positive rate is too low. $k \leq 3$ is also inappropriate because the false positive rate is too high. Now, we narrow comparison down to between $k=4$ and $k=5$. With $k=4$, the false positive rate is 3%, low enough, and the true positive rate is considerably higher (45.3% vs. 22.3%, more than double). Thus, we conclude that k=4 is appropriate. This conclusion is supported by the ROC (Receiver Operating Characteristic) curve in Figure 1.

Notice that, in Table 5, the proportion of specimens showing the

positive univariate delta check only in TC, ALB, and TP was 0%, zero false positive rate. Recall that TC, ALB, and TP are the most important items in the multivariate delta check [7-9].

Table 4 - True positive rates from the multi-item univariate delta check (8 items; 9,900 mixed-up specimens)

Item or Item sets	Positive Delta Check	
	Frequency	Percent
ALP	4098	41.4
TBil	5040	50.9
TP	3214	32.5
ALB	5527	55.8
TC	3183	32.2
CRE	4028	40.7
Cl	5336	53.9
Ca	2207	22.3
Average of above 8 items	4709	41.2
All of TC, ALB, TP	795	8.0
1 item or more	9562	96.6
2 items or more	8559	86.5
3 items or more	6753	68.2
4 items or more	4485	45.3
5 items or more	2205	22.3
6 items or more	818	8.3
7 items or more	221	2.2
8 items or more	30	0.3

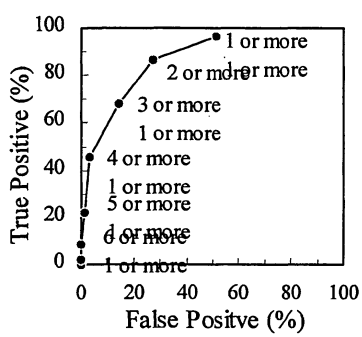

Figure 1 - The ROC Curve for the Multi-Item Univariate Delta Check

Discussion

As the number of test items increases, the chance for at least one item to show the positive delta check will rapidly increase. Thus, if we make a detailed investigation into the specimen showing the positive univariate delta check in at least one item, we will suffer from too heavy check-out volumes and relatively low efficiency; in Table 3, the proportion of specimens with the positive univariate delta check in at least one item was 49.6%, and, in Table 5, the false positive rate in this case was 51%. In selecting specimens to be put under a detailed investigation, we need first to decrease workload and then to *increase efficiency.* For reduction of waste in checking-out work, it is our opinion that the false positive rate should not exceed 5%. Our research found that if we put specimens with positive univariate delta check in at least four test items under a detailed investigation, check- out volumes will be light and efficiency will be high; in Table 3, the positive rate in this case is 2.7% and, in Table 5, the false positive rate in this case is 3%.

Table 5 - False positive rates from the multi-item univariate delta check (8 items; 100 unmixed specimens)

Item or Item sets	Positive Delta Check	
	Frequency	Percent
ALP	10	10
TBil	18	18
TP	10	10
ALB	26	26
TC	4	4
CRE	2	2
Cl	19	19
Ca	7	7
Average of above 8 items	12	12
All of TC, ALB, TP	0	0
1 item or more	51	51
2 items or more	27	27
3 items or more	14	14
4 items or more	3	3
5 items or more	1	1
6 items or more	0	0
7 items or more	0	0
8 items or more	0	0

As for test items deserving of more interest, notice that, in Table 3, the positive rate associated with only TC, ALB, and TP was 0.8% (a considerably low check-out volume), and that, in Table 5, the false positive rate associated with only TC, ALB, and TP was 0% (no waste in checking-out work). Thus, if we are most interested in the lowest possible false positive rate, it will be efficient to investigate specimens with the positive univariate delta check in TC, ALB, and TP.

When we can afford, in personnel and time, a heavier workload, we can get a higher true positive rate if we investigate specimens with the positive univariate delta check in at least three items; in this case, the positive rate in a real data study was 8.8% (Table 3), the true positive rate in a simulation study was 68.2% (Table 4), and the false positive rate in a simulation study was 14% (Table 5).

Though several literatures have reported that the multivariate delta check is more effective [7-9], as of now, it is not easy to put the multivariate delta check into practice because there are technical difficulties and it is uncertain whether the testing on the selected items is requested. In terms of practicality, the univariate delta check methods are methods at hand. Thus, more researches are needed on the effective use of the univariate delta check and our 'multi-item univariate delta check (MIUDC) method' is the product of such a research.

Conclusion

1. The multi-item univariate delta check (MIUDC) method is effective for the selection of the specimens to be put under a detailed investigation.
2. In the MIUDC, let k be the minimum number of test items, each of which shows positive univariate delta check that leads to a detailed investigation on a specimen. Then k=4 is appropriate.
3. In the MIUDC, when we can afford, in personnel and time, a heavier workload and want a higher true positive rate, k=3 will be appropriate.
4. TC, ALB, and TP are items deserving of more interest because the false positive rate associated with them in the MIUDC was zero in a simulation study.

References

[1] Lindberg DA. Collection, evaluation, and transmission of hospital laboratory data. *Methods Inf Med* 1967: 6(3): 97-107.

[2] Ladenson JH. Patients as their own controls: use of the computer to identify "laboratory error". *Clin Chem* 1975: 21: 1648-53.

[3] Wheeler LA, Sheiner LB. Delta check tables for the Technicon SMA 6 continuous-flow analyzer. *Clin Chem* 1977: 23(2 PT. 1): 216-9.

[4] Nosanchuk JS, Gottmann AW. CUMS and delta checks. A systematic approach to quality control. *Am J Clin Pathol* 1974: 62(5): 707-12.

[5] Kim JW, Kim JQ, Kim SI. Differential application of rate and delta check on selected clinical chemistry tests. *J Korean Med Sci* 1990: 5(4): 189-95.

[6] Sheiner LB, Wheeler LA, Moore JK. The performance of delta check methods. *Clin Chem* 1979: 25(12): 2034-7.

[7] Iizuka Y, Kume H, Kitamura M. Multivariate delta check method for detecting specimen mix-up. *Clin Chem* 1982: 28(11): 2244-8.

[8] Kim JW, Kim JQ. Multivariate Delta Check by Mahalanobis' Generalized Distance Method in the Clinical Chemistry Laboratory. *Journal of Clinical Pathology and Quality Control (Korea)* 1990: 12(1): 69-74.

[9] Rheem I, Rheem S, Lee KN. The Study on Detecting Specimen Mix-up by the Multivariate Delta Check. *Korean J Clin Pathol* 1996: 16(4): 483-96.

Address for correspondence

Insoo Rheem
Department of Clinical Pathology
Dankook University Hospital
San 16-5 Anseo-dong
Cheonan
ChungNam
Korea 330-715
Email : insoo@mail.com