ABO Mistyping of *cis*-AB Blood Group by the Automated Microplate Technique

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Keywords

ABO · Mistyping · *cis*-AB · Automation · Microplate technique

Summary

Background: The *cis*-AB phenotype, although rare, is the relatively most frequent of ABO subgroups in Koreans. To prevent ABO mistyping of *cis*-AB samples, our hospital has applied a combination of the manual tile method with automated devices. Herein, we report cases of ABO mistyping detected by the combination testing system. **Methods:** Cases that showed discrepant results by automated devices and the manual tile method were evaluated. These samples were also tested by the standard tube method. The automated devices used in this study were a QWALYS-3 and Galileo NEO. Exons 6 and 7 of the *ABO* gene were sequenced. **Results:** 13 cases that had the *cis*-AB allele showed results suggestive of the *cis*-AB subgroup by manual methods, but were interpreted as AB by either automated device. This happened in 87.5% of these cases by QWALYS-3 and 70.0% by Galileo NEO. Genotyping results showed that 12 cases were *ABO***cis*-*AB01*/*ABO***O01* or *ABO***cis*-*AB01*/*ABO***O02*, and one case was *ABO***cis*-*AB01*/*ABO***A102*. **Conclusion:** *Cis*-AB samples were mistyped as AB by the automated microplate technique in some cases. We suggest that the manual tile method can be a simple supplemental test for the detection of the *cis*-AB phenotype, especially in countries with relatively high *cis*-AB prevalence.

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Introduction

ABO blood group is known to be most important in blood transfusions; correct ABO grouping is the most important step of pre-transfusion testing to ensure safe transfusion to the patient. Considering its importance, manual tests can be of concern as they are prone to human errors. In addition, the labor-intensive nature of manual serologic tests is often considered a burden for efficient laboratory administration. Thus, clinical laboratories have been using automated systems to manage blood banks. Automated laboratory testing has several advantages, including increased quality of pre-analytical steps and reduced error rates [1]. Despite slow progress compared to that of the Western Hemisphere, automated systems for blood banks are beginning to be introduced in Korea.

It is expected that automation can be safe because of the use of bar-coded samples, lack of performance error during the analytical phase, and absence of errors in interpreting or reporting results during post-analytical phase [2]. However, we have observed some mistyping in *cis*-AB phenotype samples. *Cis*-AB is the most frequent among ABO subgroups in Korea, and, depending on the co-inherited ABO allele, phenotypes of *cis*-AB varies from typical *A₂B₃* (when paired with an O allele), *A₂B* (when paired with a B allele), and *A₁B₃* (when paired with an A allele) to atypical *A_{int}B₃*, *A₁B_m*, *A₁B_x* [3]. Nine *cis*-AB alleles (*cis*-*AB01*, *cis*-*AB01*var, *cis*-*AB02* to *cis*-*AB08*) have been reported so far [4], and correct ABO typing in individuals is of importance, as transfusion of AB type blood to these patients can cause hemolytic adverse transfusion reactions [5–7]. To prevent ABO mistyping in *cis*-AB patients, our hospital has applied a combination of a manual tile method with automated devices. Herein, we share our experience with *cis*-AB phenotype cases that automated devices failed to identify properly.

Material and Methods

Data Collection

The cases of this study were seen at our hospital between April 2015 and May 2016. A total of 51,495 were tested for ABO typing. After introduction of the automated devices Galileo NEO (Immucor Gamma, Norcross, GA, USA) and QWALYS-3 (Diagast, Loos, France) at our institute, they were initially evaluated and then used routinely. The sera used for cell typing in QWALYS-3 were anti-A (9113D10 clone) and anti-B (9621A8 clone), and the Galileo NEO used anti-A (F98 7C6 clone) and anti-B (F84 3D6; F97 2D6 clone).

Fig. 1. Example of manual tile testing results of cell typing of (1) *cis*-AB, (2) typical AB and (3) O type blood. All samples were RhD-positive. Results for anti-B sera of *cis*-AB represents weakly reactive, AB represents strongly reactive and O represents negative results.

Currently, all tests done by automated devices are duplicated by the manual tile method in our hospital. This involves mixing undiluted EDTA blood with anti-A (MH04 and A303 clone), anti-B (NB1.19, NB10.5A5 and NB10.3B4 clone), and anti-D (MAD2 clone) BioClone reagent (Ortho Clinical Diagnostics, Raritan, NJ, USA) on an acrylic tile plate. We have followed the manufacturer's instructions regarding the manual slide method with some modification. We omit the initial washing procedure and apply the test on an acrylic tile plate instead of slides. Reaction is interpreted with the naked eye. Examples of visual results of this method are presented in figure 1. The manual tile method is done only on cell typing with anti-A and anti-B. Weak reaction to anti-A or anti-B was defined as weaker agglutination than normal RhD-positive-to-anti-D agglutination. Cases suggestive of a *cis*-AB phenotype by the manual tile method were selected.

We selected cases that were flagged by the automated device, or cases that showed discrepancy between manual and automated methods. Typical cases of discrepancy of automated and manual methods are observations suggestive of decreased reactivity to anti-B in the manual tile method compared to the automated device results or weak agglutination with B-cell RBCs in manual tube method. The outline of the work process during this period is presented in figure 2.

Evaluation of Suspected *cis*-AB Cases

In cases that showed discrepant results by an automated device and the manual tile method, the manual tube method was applied to confirm ABO typing. Cases of interest were tested by both automated devices. In cases of the AB blood type, forward typing with anti-A1 (anti-A1 lectin, Ortho Clinical Diagnostics) was additionally performed to confirm A_2B or A_2B_3 phenotypes, which are typical *cis*-AB blood phenotypes in Korea [8–10]. Reagents used in serologic tests were as follows: forward typing was performed using Anti-A, Anti-B, and Anti-D BioClone reagent (Ortho Clinical Diagnostics) by both tile and tube method. Reverse typing was performed using Affirmagen A1 and B cells (Ortho Clinical Diagnostics) by the tube method.

ABO Genotyping

DNA was extracted from each sample with the Qiagen DNeasy Kit (Qiagen, Hilden, Germany), and ABO exons 6 and 7, along with their flanking intron sequences, were amplified and sequenced in selected samples to confirm the *cis*-AB blood grouping by previously described methods [10]. Sequences were ana-

Fig. 2. The outline of the work process to identify *cis*-AB samples with discrepancies between the automated and manual serological methods. *Only cell typing was done with tile methods. **Anti-A1 was applied to the manual tube method.

Table 1. Cases typed as typical AB by automated methods and that were confirmed to be *cis*-AB types

Case	Automated test (QWALYS-3)				Automated test (Galileo NEO)				Manual tests (tube and tile methods) [§]				ABO genotype		
	anti-A	anti-B	A1 RBC	B RBC	phenotype	anti-A	anti-B	A1 RBC	B RBC	anti-A1	A1 RBC	B RBC		phenotype	
1	4+	4+	-	?	flag ^b	N/T ^a	N/T ^a	N/T ^a	N/T ^a	4+	2+	-	2+	A2B3	<i>cis</i> -AB*01/O*02
2	4+	4+	-	-	AB	N/T ^a	N/T ^a	N/T ^a	N/T ^a	4+	2+	-	1+	A2B3	<i>cis</i> -AB*01/O*02
3	4+	4+	-	-	AB	N/T ^a	N/T ^a	N/T ^a	N/T ^a	4+	3+	-	-	A2B3	<i>cis</i> -AB*01/O*02
4	N/T ^a	N/T ^a	N/T ^a	N/T ^a	AB	4+	4+	-	-	4+	2+	-	W+	A2B3	<i>cis</i> -AB*01/O*01
5	N/T ^a	N/T ^a	N/T ^a	N/T ^a	AB	4+	4+	-	-	4+	3+	-	1+	A2B3	<i>cis</i> -AB*01/O*01
6	N/T ^a	N/T ^a	N/T ^a	N/T ^a	AB	4+	4+	-	-	4+	3+	-	W+	A2B3	<i>cis</i> -AB*01/O*01
7	N/T ^a	N/T ^a	N/T ^a	N/T ^a	AB	4+	4+	-	-	4+	3+	-	W+	A2B3	<i>cis</i> -AB*01/O*01
8	N/T ^a	N/T ^a	N/T ^a	N/T ^a	AB	4+	4+	-	-	4+	2+	-	W+	A2B3	<i>cis</i> -AB*01/O*01
9	4+	4+	-	-	AB	4+	?	-	-	4+	4+	-	-	A2B	<i>cis</i> -AB*01/O*02
10	4+	4+	-	-	AB	4+	?	-	-	4+	1+	-	-	A2Bw	<i>cis</i> -AB*01/O*02
11	4+	4+	-	-	AB	4+	4+	-	-	4+	3+	-	1+	A2B3	<i>cis</i> -AB*01/O*02
12	4+	4+	-	-	AB	4+	4+	-	-	4+	2+	-	W+	A2B3	<i>cis</i> -AB*01/O*01
13	4+	4+	-	-	AB	4+	-	-	2+	4+	-	4+	1+	A1	<i>cis</i> -AB*01/A*102

Results displayed in reaction intensity was results from manual tube methods. Cell typing with anti-A and anti-B was also done with the manual tile method.

Asterisk indicate weak reaction shown in manual tile method.

Not tested.

Indicates results that were inconclusive by the automated device alone.

[§]Results displayed in reaction intensity was results from manual tube methods. Cell typing with anti-A and anti-B was also done with the manual tile method.

* Asterisk indicate weak reaction shown in manual tile method.

^aNot tested.

^bIndicates results that were inconclusive by the automated device alone.

lyzed using Sequencher 5.0 (Gene Codes Corp, Ann Arbor, MI, USA) software. We referred to The Blood Group Antigen Gene Mutation Database (www.ncbi.nlm.nih.gov/gv/mhc/xslcgi.cgi?cmd=bgmute/home) for nomenclature of the detected *cis*-AB alleles [4].

Results

Discrepancies between the Automated and Manual Methods

We identified 13 cases of discrepancies between the automated and manual methods, as presented in table 1. 87.5% (7/8) of *cis*-AB samples tested by QWALYS-3 were interpreted as AB type without any flag as an inconclusive ABO type, and 70.0% (7/10) of *cis*-AB samples were typed as AB by Galileo NEO. Overall, the manual methods showed decreased reactivity to anti-B sera in forward typing compared to that of the automated devices. QWALYS-3 and Galileo NEO flagged one case and two cases, respectively, as inconclusive ABO types, and each automated device interpreted 7 *cis*-AB cases as type AB. These cases were revealed to be *ABO***cis*-*AB01* haplotype with *ABO***O01* or *ABO***O02*. The overall frequency of *cis*-AB during this period was 0.025%.

A *cis*-AB Sample with Remarkable Discrepancy between QWALYS-3 and Others (Galileo NEO, Manual)

We have observed 1 case of *cis*-AB with a pairing haplotype other than O allele. This was case 13 in table 1, with genotype of *ABO***cis*-*AB01*/*ABO***A102*. The QWALYS-3 device showed 4+ reactivity to anti-A sera and anti-B sera in cell typing, with no anti-A or anti-B in her serum, and the case was interpreted as an AB phenotype, while forward typing by Galileo NEO indicated 4+ reactivity to anti-A sera, but did not show reactivity to anti-B sera. Concurrent evaluation by the manual tile method showed similar results when compared with the Galileo NEO; the sample was further evaluated with manual tube testing which also showed a similar phenotype as the Galileo NEO. After transfusion with two packs of A+ leukocyte-reduced RBCs, QWALYS-3 testing showed an indeterminate result against anti-B sera, whereas results of other methods showed no change in anti-B reaction. Although the exact cause of the extra-reactivity to anti-B sera in cell typing remains unsolved, ABO mistyping as typical AB with QWALYS-3 was obvious, based on results prior to transfusion (table 2).

Discussion

This study illustrates the problems when automated devices are applied in a *cis*-AB phenotype-prevalent area. Although a rare subtype, *cis*-AB is encountered more frequently in Korea [10, 11] and Japan [8] than in other populations [12]. A Korean study reported a case of atypical delayed hemolytic transfusion reaction in a patient with *cis*-AB blood type following transfusion of Rh A-positive packed red blood cells and fresh frozen plasma [7]. Since the recommended blood for transfusion to *cis*-AB patients is type O red cells with type AB platelets and AB plasma, it is important to discriminate *cis*-AB from typical AB blood [5-7]. In addition to trans-

Table 2. A *cis*-AB sample with remarkable discrepancy between QWALYS-3 and others (Galileo NEO, manual)

Automated test (QWALYS-3)						Automated test (Galileo NEO)				Manual tests (tube and tile methods) [§]						
anti-A	anti-B	A1 RBC	B RBC	phenotype		anti-A	anti-B	A1 RBC	B RBC	ABO phenotype	anti-A	anti-B	anti-A1	A1 RBC	B RBC	ABO phenotype
Day 0	4+	4+	-	AB		4+	-	-	2+	A, low anti-B	4+	-	4+	-	1+	A, low anti-B
Day 2	4+	3+	-	AB		N/T ^a	N/T ^a	N/T ^a	N/T ^a		4+	-	4+	-	1+	A, low anti-B
Day 3	RBC transfusion (type A, 2 units)															
Day 11 ^c	4+	?	-	flag ^b		N/T ^a	N/T ^a	N/T ^a	N/T ^a		N/T ^a	N/T ^a	4+	N/T ^a	N/T ^a	
Day 18	4+	?	?	flag ^b		4+	-	-	3+	A	4+	-	4+	-	1+	A, low anti-B

[§]Results displayed in reaction intensity was results from manual tube methods. Cell typing with anti-A and anti-B was also done with the manual tile method.

^aNot tested.

^bIndicates results that were inconclusive by testing with the automated device alone.

^cResults from day 11 was replicated by an outside institution.

fusion concerns, there have been several paternity disputes in Korea and Japan because of an apparent contradiction to the general Mendelian inheritance of ABO blood groups [9, 10]. Correct ABO typing to the subgroup level is important in that matter, and, although sometimes challenging to novice personnel, serological testing can discriminate *cis*-AB [13–19], and other ABO subgroups [20, 21] using manual methods (table 3).

Our hospital encountered problems with QWALYS-3 in detecting *cis*-AB subtypes when initially evaluating the performance of this device [22]. QWALYS-3 interpreted multiple cases of *cis*-AB as typical AB; this was the initiation of this study. During our evaluation, we found that the Galileo NEO is subject to similar errors. We attempted to solve this problem by applying anti-A1 sera in cases of AB phenotype while forward typing with the tube method, and in cases with a negative reaction to anti-A1, we also performed ABO serum typing by the standard tube method, with a prolonged incubation time of 15 min at room temperature. We sought to ensure the detection of weak B-cell reaction in reverse typing.

Galileo NEO detects hemagglutination in microplates to determine the ABO blood type. This device has shown good results in ABO typing [23, 24], yet the cited studies found some discrepancies between results from this device and manual methods. Discrepancies were usually a result of weak reactions in manual testing; both studies indicated that this device is more sensitive in detecting agglutination reactions. The QWALYS system utilizes erythrocyte-magnetized technology [25], and its performance in ABO blood typing has been reviewed by many researchers. The QWALYS-2 device was examined by Schoenfeld et al. [26], who concluded that it was suitable for ABO grouping. Multiple Korean domestic studies reported that a later version of this device, QWALYS-3, showed good concordance with manual methods and determined that it could be used in routine pre-transfusion testing in the blood bank [22, 27, 28]. However, our institution previously reported that a *cis*-AB sample was ABO mistyped by QWALYS-3 [22]. Thereafter, to prevent ABO mistyping, our hospital has applied a combination of testing by the manual tile method and examination with automated devices (fig. 2).

The *cis*-AB cases identified in this study show that both automated devices are more sensitive in forward typing than the manual methods but regarding reverse typing, QWALYS-3 and Galileo NEO showed inconsistent results. All of our cases were suspected to be AB subgroups with a *cis*-AB haplotype. We observed that Galileo NEO failed sporadically to detect reactions with B cells in reverse typing. Using a simple manual method, such as the tile method that was applied in this study, these shortcomings of the automated devices can be overcome. Whether or not there are inconsistencies regarding other ABO subgroups is unclear thus far; however, with the exception of *cis*-AB we did not detect any other systematically problematic phenotypes.

Case 13 in our study raised another interesting point. Although Galileo NEO and manual testing showed an A1 phenotype with low anti-B titer, this patient's red cells were typed as typical AB type by QWALYS-3. The phenotype of this *cis*-AB sample might be A type with low titer of anti-B in her serum. The missing or very

Table 3. Various reaction intensity of A/B subgroups and *cis*-AB subgroups

Phenotypes	Cell type			Serum type		Genotypes	Transfusion strategy based on phenotypes	
	anti-A	anti-B	anti-A1	A1	B		RBC	plasma/platelet
A ₁	4+	–	4+	–	4+		A	A
A ₂	4+	–	–	–/2+*	4+		A or O	A
A ₃	2+ mf	–	–	–/2+*	4+		A or O	A
B	–	4+	–	4+	–		B	B
B ₃	–	1+mf	–	4+	–		B	B
A ₂ B ₃	4+	1+ ~3+	–	–	1+ ~2+		A or O	AB
	4+	1+ ~3+	–	1+	1+	<i>cis</i> -AB01/O	O	AB
	4+	1+ ~3+	–	–	–		AB or O	AB
A ₁ B ₃	4+	1+ ~2+	3+ ~4+	–	1+ ~2+		A or O	AB
	4+	1+ ~2+	3+ ~4+	–	–	<i>cis</i> -AB01/A	AB or O	AB
A ₂ B	4+	4+	–	–	–		AB or O	AB
	4+	4+	–	1+ ~2+	–	<i>cis</i> -AB01/B	B or O	AB
A ₁ Bw**	4+	–/W+	4+	–	1+ ~2+		A or O	AB
	4+	–/W+	4+	–	–	<i>cis</i> -AB01/A	AB or O	AB

*The occurrence of anti-A1 is variable in these phenotypes.
 **A₁B_{cl}, A₁B_x, A₁B_m.
 1+ to 4+ = Agglutination reactivity; ± = weak agglutination; mf = mixed-field agglutination; – = no agglutination.

low expression of the B antigen is in contrast with other typical *cis*-AB subjects, and this can be due to allele competition in cases of *cis*-AB/O genotypes. As the phenotype of a *ABO***cis*-AB01/*ABO**A102 subject was previously observed as A1 phenotype multiple times, this lack of B antigen expression (phenotypically A1) is to be considered a not rare phenomenon in *ABO***cis*-AB01/*ABO**A102 subjects [29–31]. This observation can be explained by the fact that the A1 glycosyltransferase is in competition with that from *cis*-AB01 and does not leave enough H substrate to produce detectable B antigen.

The present study summarizes our experience with ABO mistyping by automated microplate devices. All cases with ABO

mistyping in our study had *cis*-AB haplotypes; thus, we suggest that automated microplate-based devices should be used with caution in *cis*-AB-prevalent areas. Retesting automated device results of phenotypically AB subjects that show no reactivity to anti-A1 using the tile method is a suitable approach identify *cis*-AB cases and to avoid mismatched transfusions in these cases.

Disclosure Statement

The authors declare no conflicts of interest relevant to the publication of this article.

References

- Shin KH, Kim HH, Chang CL, Lee EY: Economic and workflow analysis of a blood bank automated system. *Ann Lab Med* 2013;33:268–273.
- Rathod K, Rathod J, Shah M, Gupta M, Soni SA, Shah SD, Shah MC, Bhatnagar NM, Gajjar MD: Switching over to fully automated for blood grouping – experience from a tertiary care teaching hospital blood bank. *Pathol Lab Med* 2013;5:37–39.
- Cho D, Lee SY, Ryang DW: ABO subgroup studies in Korea. *ISBT Sci Se* 2015;10:332–335.
- Patnaik SK, Helmsberg W, Blumenfeld OO: BGMUT database of allelic variants of genes encoding human blood group antigens. *Transfus Med Hemother* 2014; 41:346–351.
- Kang BJ: An anesthetic experience of a patient with *cis* A2B3 blood type. *Korean J Anesthesiol* 2001;40:95–99.
- Kim DW: The problems in transfusion with *cis* AB type blood. *Korean J Anesthesiol* 1993;26:833–838.
- Woo CM, Lee HJ, Kwak H, Shin SW, Kwon JY, Kim HK: Mismatched transfusion reaction in *cis*-AB: a case report. *Korean J Anesthesiol* 2006;51:632–637.
- Yamaguchi H: A review of *cis* AB blood. *Jinrui Iden-gaku Zasshi* 1973;18:1–9.
- Yoshida A: Genetic mechanism of blood group (ABO)-expression. *Acta Biol Med Ger* 1981;40:927–941.
- Cho D, Kim SH, Jeon MJ, Choi KL, Kee SJ, Shin MG, Shin JH, Suh SP, Yazer MH, Ryang DW: The serological and genetic basis of the *cis*-AB blood group in Korea. *Vox Sang* 2004;87:41–43.
- Cho D, Shin MG, Yazer MH, Kee SJ, Shin JH, Suh SP, Jeon MJ, Song JW, Ki CS, Ryang DW: The genetic and phenotypic basis of blood group A subtypes in Koreans. *Transfus Med* 2005;15:329–334.
- Yazer MH, Olsson ML, Palcic MM: The *cis*-AB blood group phenotype: fundamental lessons in glyco-biology. *Transfus Med Rev* 2006;20:207–217.
- Lee SY, Phan MT, Shin DJ, Shin MG, Park JT, Shin JW, Yazer MH, Shin HB, Cho D: A novel *cis*-AB variant allele arising from a de novo nucleotide substitution c.796A>G (p.M266V) in the B glycosyltransferase gene. *Transfus Med* 2015;25:333–336.
- Cai X, Jin S, Liu X, Fan L, Lu Q, Wang J, Shen W, Gong S, Qiu L, Xiang D: Molecular genetic analysis of ABO blood group variations reveals 29 novel ABO subgroup alleles. *Transfusion* 2013;53:2910–2916.
- Mifsud NA, Watt JM, Condon JA, Haddad AP, Sparrow RL: A novel *cis*-AB variant allele arising from a nucleotide substitution A796C in the B transferase gene. *Transfusion* 2000;40:1276–1277.
- Roubinet F, Janvier D, Blancher A: A novel *cis* AB allele derived from a B allele through a single point mutation. *Transfusion* 2002;42:239–246.
- Tzeng CH, Chen YJ, Lyou JY, Chen PS, Liu HM, Hu HY, Lin JS, Yu LC: A novel *cis*-AB allele derived from a unique 796C>A mutation in exon 7 of *ABO* gene. *Transfusion* 2005;45:50–55.

- 18 Liu YC, Ma L, Zhang DM, Zheng L, Liu Y, Wu MH, Xue M, Liang WB: The serological and genetic identification of a *Cis*AB blood sample (in Chinese). *Zhonghua Yi Xue Yi Chuan Xue Za Zhi* 2011;28:552–554.
- 19 Yoon J, Youk HJ, Chang JH, Jang MA, Choi JH, Nam MH, Choi JS, Lim CS: Identification of the ABO**cis*-AB04 allele with a unique substitution C796A: the first case in Korea. *Ann Lab Med* 2016;36:620–622.
- 20 Fung M, Grossman BJ, Hillyer C, Westhoff CM: Technical Manual, 18th ed. Bethesda, American Association of Blood Banks, 2014.
- 21 Han KS, Park KU, Song EY: Transfusion Medicine, 4th ed. Seoul, Korea Medical Book Publisher, 2014.
- 22 Jang MA, Oh JW, Lee ST, Seo JY, Kim DW: Evaluation of the automated blood bank systems Galileo NEO and QWALYS-3 for ABO-RhD typing and antibody screening. *Korean J Blood Transfus* 2014;25:235–242.
- 23 Joo SY, Han KS, Kwak YK, Park KU: Evaluation of an Automated solid-phase cell adherence assay in the Galileo System (Immucor) for routine pretransfusion tests. *Korean J Blood Transfus* 2011;22:134–143.
- 24 Xu W, Wan F, Lou Y, Jin J, Mao W: Evaluation of an automated microplate technique in the Galileo system for ABO and Rh(D) blood grouping. *Clin Lab* 2014;60:241–244.
- 25 Bouix O, Ferrera V, Delamaire M, Redersdorff JC, Roubinet F: Erythrocyte-magnetized technology: an original and innovative method for blood group serology. *Transfusion* 2008;48:1878–1885.
- 26 Schoenfeld H, Bulling K, von Heymann C, Neuner B, Kalus U, Kiesewetter H, Pruss A: Evaluation of immunohematologic routine methods using the new erythrocyte-magnetized technology on the QWALYS 2 system. *Transfusion* 2009;49:1347–1352.
- 27 An TK, Song YK, Seo HS, Kim KL, Kim JA, Ko CH, Lee DH, Kong SY: Evaluation of automated blood bank systems AutoVue Innova and QWALYS-3 for ABO-RhD grouping and antibody screening. *Korean J Blood Transfus* 2012;23:204–209.
- 28 Koh YE, Yoon J, Kwon Sh, Kim YH, Choi JY, Kim JY, Cho CH, Lim CS, Yoon SY: Evaluation of the automated blood bank instrument QWALYS-3 for cross-matching tests. *Korean J Blood Transfus* 2014;25:218–225.
- 29 Cho D, Kee SJ, Shin JH, Suh SP, Ryang DW: Unusual phenotype of *cis*-AB. *Vox Sang* 2003;84:336–337.
- 30 Whang DH, Shin BM, Lee HS, Hur M, Han BY, Han KS: Unusual phenotype expression in a *cis*-AB trait: *cis*-AB child from a group A father and a group O mother. *Korean J Blood Transfus* 2000;11:169–175.
- 31 Kang SH, Lee YK, Park MJ, Shin DH, Cho HC, Lee KM, Han KS: A Case of *cis*-AB without B antigen expression. *Korean J Blood Transfus* 2001;12:245–251.