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# Questionnaire Survey on Current Red Blood Cell Transport and Storage in Korea for Reducing Wastage

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**Background:** To ensure safe red blood cell (RBC) transfusion practice, it is important to comply with storage and transport requirements of RBC units. We conducted a comprehensive survey on the practice of RBC transport and storage to explore the awareness of and compliance with the 30-minute rule, the current status of RBC unit transport, and possible utility of temperature indicators (TIs) to reduce RBC wastage.

**Methods:** From June to August of 2019, 64 blood bank physicians (14 questions) in 64 secondary- and tertiary-care hospitals and 673 nurses (13 questions) in 42 tertiary-care hospitals replied to a questionnaire survey. The results of the survey were analyzed with descriptive statistics.

**Results:** Among the physicians surveyed, 97.0% (N=62) of hospitals had transfusion guidelines in place. The RBC wastage in 2018 ranged from less than five units to more than 200 units. Among the nurses surveyed, 99.4% (N=669) were aware of and complied with the 30-minute rule; 13.5% (N=91) of the nurses had experience of RBC wastage due to violation of the 30-minute rule. Both physicians (67%, N=43) and nurses (83.1%, N=559) responded that TIs would help reduce RBC wastage.

**Conclusions:** This is the first survey on the practices related to RBC transport and storage in Korea. This study provides fundamental data on current practice for the blood cold chain, insights into RBC wastage, and highlights the utility of TIs.

**Key Words:** Red blood cells, Survey, Transport, Storage, 30-minute rule, Temperature-sensitive indicator, Wastage

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## INTRODUCTION

Red blood cell (RBC) units are the most widely transfused component during patient care, including critically and non-critically ill patients [1, 2]. For safe RBC transfusion practice, it is important to comply with storage and transport requirements of RBC units [3-5]. RBC units should be kept at 1–6°C during storage in a blood bank refrigerator and at 1–10°C during transport, according to the American Association of Blood Banks [3]. The Korean transfusion guidelines state that RBC units exceeding a core temperature (CT) of 10°C should not be retrieved from the blood bank [4].

Based on a study performed in the early 1970s, the 30-minute rule has been used as a customary time limit; to ensure that the CT of RBC units does not exceed 10°C, in clinical practice, RBC transfusion should be initiated within 30 minutes after issue from the blood bank [4, 6-8]. The World Health Organization (WHO) states that RBC units kept out of the blood bank re-

frigerator for over 30 minutes should be discarded; if RBC units are not transfused immediately at wards or operating rooms (ORs) without blood refrigerators, RBC units should be issued from the blood bank just prior to transfusion [7]. To ensure that the temperature of RBC units remains below 10°C during transport, each transport container needs to be in a controlled temperature condition [8].

An international survey showed that the overall wastage rate of issued RBC units ranged from 1.9% to 2.8% in the United States, Africa, Europe, and Australia; up to 1.4% of RBC units were discarded due to an improper transport container or violation of the transport temperature requirement [9]. The 30-minute rule was also suggested to cause increased RBC wastage [10, 11]. RBC wastage due to violation of the 30-minute rule or uncontrolled temperature ranged from 0.4% to 22.3% among all discarded RBC units [12, 13].

Temperature-sensitive indicators (TIs), which are adhesive labels with an irreversible color change at 10°C, were recently introduced to transfusion practice to monitor the surface temperature (ST) of RBC units and are expected to help maintain the blood cold chain and reduce RBC wastage [5, 14-18]. However, some practical issues surrounding the use of current TIs remain with regard to heterogeneity and lack of standardization, questioning whether TIs are indeed useful for reducing RBC wastage in transfusion practice [5, 17].

The blood cold chain is a process to store and transport blood safely from the site of donation to the site of transfusion [8]. Nurses take a frontline role in RBC transfusion practice at bedside [7, 19, 20]. Therefore, both blood bank physicians and nurses must be aware of and comply with storage and transport requirements of RBC units to guarantee adequate transfusion practice and reduce RBC wastage [20-22]. To the best of our knowledge, there has been no published survey on RBC transport and storage practice including blood bank physicians as well as nurses in a real hospital setting. We conducted a comprehensive survey on the RBC cold chain practice to explore the awareness of and compliance with the 30-minute rule, the current status of RBC unit transport, and possible utility of TIs to reduce RBC wastage.

## MATERIALS AND METHODS

### Study population

This study was conducted as part of the 2019 Policy Research Service Project of the Korea Centers for Disease Control and Prevention, titled "The Efficient Management of Blood Resources using Temperature Indicators" (Number 2019E830400). The study protocol was approved by the Institutional Review Board of Konkuk University Medical Center (KUMC 2019-05-028). In June 2019, the survey and questionnaire were designed and critically reviewed by nine experts from three professional academic societies: Korean Society for Laboratory Medicine (KSLM), Korean Society of Blood Transfusion (KSBT), and Korean Nurses Association (KNA). The survey to blood bank physicians comprised a short questionnaire (with 13 questions) to assess the blood cold chain practice of RBC units in the blood bank. The survey was sent by e-mail or post to blood bank physicians who are certified members of KSLM or those of KSBT working at 93 secondary- or tertiary-care hospitals. A total of 64 blood bank physicians working at 64 hospitals (one physician per hospital) replied to the survey completely anonymously. Nurses working at 42 tertiary-care hospitals were sent a short questionnaire (with 15 questions) to assess nursing practice for the blood cold chain of RBC units; a total of 673 nurses replied to the survey completely anonymously. The surveys were conducted from June to August 2019, and the data were compiled in August 2019.

### Questionnaire surveys

The questionnaire surveys consisted of basic demographic questions. For physicians, three questions on basic demographics were included: hospital size, geographic region in Korea, and status of certified members of KSLM. The 13 questions on blood bank practice were related to the existence and content of RBC transfusion guidelines at the hospital, criteria for discarding RBC units after issue or within the blood bank in the RBC transfusion guidelines, transport container to the ward after issue, ST monitoring of RBC units at transport after issue, total number of blood refrigerators at the ward or outpatient clinic, existence of a ward with a blood refrigerator, crossmatching tests in 2018, RBC units issued in 2018, RBC wastage in 2018, crossmatch to transfusion (C:T) ratio in 2018, expected utility of TIs to reduce RBC wastage, and reasons for the expected low utility of TIs to reduce RBC wastage. A blood refrigerator was defined as a refrigerator intended for only blood storage with an automated temperature monitoring system and an alarm when the temperature exceeds unacceptable levels [8]. RBC wastage was defined as discarded amounts of issued RBC units or those stored in the blood bank [9, 12].

For nurses, four questions on basic demographics were included: hospital size, geographic region in Korea, nursing department, and clinical experience as a nurse. The 15 questions on blood bank practice were related to the existence and content of nursing practice guidelines for RBC transfusion, criteria

for discarding RBC units after issue in the nursing practice guidelines for RBC transfusion, use of a transport container to the ward after issue, types of transport containers to the ward after issue, ST monitoring of RBC units during transport after issue, blood refrigerator located at the ward or outpatient clinic, storage time limit of RBC units in the blood refrigerator at the ward, monitoring of temperature of the blood refrigerator at the ward, knowledge of the 30-minute rule, compliance with the 30-minute rule, experience of RBC unit discarding due to violation of the 30-minute rule, reasons for RBC unit discard due to violation of the 30-minute rule, expected utility of TIs to reduce RBC wastage, and reasons for the expected low utility of TIs to reduce RBC wastage.

### Statistical analysis

Data are presented as number (percentage). Descriptive statistics were used to summarize survey data. Statistical analysis was performed using the MedCalc software version 19.7.4 (MedCalc Software Bvba, Ostend, Belgium) and Microsoft Excel 2019 (Microsoft Corporation, Redmond, WA, USA).

## RESULTS

Basic demographics of the total respondents are summarized in Table 1. The majority of respondents were from hospitals with 500–999 beds, accounting for 54.7% (N=35) of blood bank physicians and 67.5% (N=454) of nurses. Most of the respondents' affiliated hospitals were located in a metropolitan area (Seoul, Inchon, and Gyeonggi-do). The majority of physicians were certified blood bank physicians (96.9%, N=62). Most of the nurses' affiliated departments of nursing were the general ward (GW) and intensive care unit (ICU), and 47.5% (N=320) of the nurses had more than 10 years of nursing experience.

The survey results of blood bank physicians are summarized in Table 2. The majority (96.9%) indicated the existence of transfusion guidelines at their hospitals, including the 30-minute rule; 85.9% (N=55) of physicians stated that blood refrigerators are equipped at hospital wards. The number of RBC units issued in 2018 ranged from <500 units to >50,000 units. Regarding the C:T ratio, 44.4% (N=28) and 14.3% (N=9) were below 1.1 and above 1.4, respectively. Regarding the expected utility of TIs to reduce RBC wastage, 67% (N=43) and 33% (N=21) of blood bank physicians stated that TIs would have high and low utility, respectively. Reasons for the expected low utility of TIs were as follows: low RBC wastage due to violation of the 30-minute rule (81.0%, N=17), possibility of increasing RBC wastage due to the fast color change of TIs (52.4%, N=11), intra- or inter-observer variability in reading the color change of TIs (33.3%, N=7).

**Table 1.** Basic demographics of the survey respondents (N=737)

| Variables | N of respondents (%) | |
|---|---|---|
| | Blood bank physicians (N=64) | Nurses (N=673) |
| Hospital size | | |
| <100 beds | 0 (0.0) | 1 (0.1) |
| 100–499 beds | 18 (28.1) | 9 (1.3) |
| 500–999 beds | 35 (54.7) | 454 (67.5) |
| 1,000–1,999 beds | 8 (12.5) | 126 (18.7) |
| 2,000–2,999 beds | 2 (3.1) | 16 (2.4) |
| ≥3,000 beds | 1 (1.6) | 67 (10.0) |
| Geographic region in Korea | | |
| Seoul | 22 (34.4) | 304 (45.2) |
| Incheon, Gyeonggi-do | 14 (21.9) | 183 (27.2) |
| Busan, Daegu, Gryengsang region | 9 (14.1) | 67 (10.0) |
| Sejong, Daejeon, Chungcheong region | 8 (12.5) | 34 (5.1) |
| Gwangju, Jeolla region | 6 (9.4) | 82 (12.2) |
| Gangwon-do, Jeju-do | 5 (7.8) | 3 (0.4) |
| Certified members of KSLM | 62 (96.9) | N/A |
| Nursing department | | |
| GW | N/A | 439 (65.2) |
| ICU | | 114 (16.9) |
| OR | | 37 (5.5) |
| ED | | 28 (4.2) |
| OC | | 26 (3.9) |
| Others | | 29 (4.3) |
| Clinical experience of as a nurse | | |
| <1 yr | N/A | 57 (8.5) |
| 1–2.9 yr | | 92 (13.7) |
| 3–4.9 yr | | 89 (13.2) |
| 5–9.9 yr | | 115 (17.1) |
| ≥10 yr | | 320 (47.5) |

Abbreviations: KSLM, Korean Society of Laboratory Medicine; GW, general ward; ICU, intensive care unit; OR, operating room; ED, emergency department; OC, outpatient clinic; N/A, not available; yr, year.

The survey results of nurses are summarized in Table 3. The majority of nurses indicated that their hospitals had existing nursing practice guidelines for RBC transfusion, which included the 30-minute rule as a standard for RBC unit discard, and they were aware of and complied with the 30-minute rule. Some nurses


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**Table 2.** Summary of the survey to blood bank physicians (N=64)

| Questionnaire | N of respondents (%) |
|---|---|
| Presence of RBC transfusion guidelines | |
| Yes | 63 (98.4) |
| No | 1 (1.6) |
| Contents of RBC transfusion guidelines* | |
| Shipping and receiving RBC units from the blood center | 51 (79.7) |
| Storage temperature of RBC unit in the blood bank | 62 (96.9) |
| Transport of RBC units to the ward after issue | 56 (87.5) |
| RBC transfusion | 51 (81.3) |
| Standards for discard of RBC unit after issue* | 63 (98.4) |
| Criteria for discard of RBC units after issue or within the blood bank in RBC transfusion guidelines* | 63 (98.4) |
| Exposure to RT for over 30 minutes | 62 (96.9) |
| ST of RBC units to reach 10°C | 34 (53.1) |
| Damaged RBC units | 56 (87.5) |
| Contaminated RBC units | 53 (82.8) |
| Withdrawal of RBC transfusion due to the change of patient's condition | 39 (60.9) |
| Transfusion-related adverse reactions | 48 (75.0) |
| Transport container to ward after issue | |
| Cooler only | 22 (34.4) |
| Cooler with refrigerant | 31 (48.4) |
| Cooler with refrigerant and TI | 1 (1.6) |
| Others (e.g., cool bag, plastic box, plastic bag) | 10 (15.6) |
| ST monitoring of RBC units at transport after issue | 1 (1.6) |
| Total numbers of blood refrigerators at ward or outpatient clinic | 55 (85.9) |
| 1 | 26 (47.3) |
| 2 | 12 (21.8) |
| 3 | 3 (5.5) |
| ≥4 | 14 (25.4) |
| Ward with blood refrigerator* | 55 (85.9) |
| GW | 3 (5.5) |
| ICU | 21 (38.2) |
| OR | 52 (94.5) |
| ED | 20 (36.4) |
| OC | 1 (1.8) |
| Crossmatching tests in 2018† | |
| <1,000 | 2 (3.2) |
| 1,000–4,999 | 10 (15.9) |
| 5,000–9,999 | 13 (20.6) |
| 10,000–49,999 | 32 (50.8) |
| 50,000–99,999 | 5 (7.9) |
| ≥100,000 | 1 (1.6) |

(*Continued to the next page*)

**Table 2.** Continued

| Questionnaire | N of respondents (%) |
|---|---|
| RBC units issued in 2018† | |
| <500 | 1 (1.6) |
| 500–999 | 3 (4.8) |
| 1,000–4,999 | 9 (41.3) |
| 5,000–9,999 | 21 (33.3) |
| 10,000–49,999 | 26 (41.3) |
| ≥50,000 | 3 (4.8) |
| RBC wastage in 2018† | |
| <5 | 6 (9.5) |
| 5–9 | 10 (15.9) |
| 10–19 | 11 (17.5) |
| 20–49 | 16 (25.4) |
| 50–99 | 15 (23.8) |
| 100–199 | 4 (6.3) |
| ≥200 | 1 (1.6) |
| C:T ratio in 2018† | |
| 1.0 to <1.1 | 28 (44.4) |
| 1.1 to <1.2 | 16 (25.4) |
| 1.2 to <1.3 | 7 (11.1) |
| 1.3 to <1.4 | 3 (4.8) |
| ≥1.4 | 9 (14.3) |
| Expected utility of TIs to reduce RBC wastage | |
| High utility | 43 (67.2) |
| Low utility | 21 (32.8) |
| Reasons of expected low utility of TIs to reduce RBC wastage* | 21 (32.8) |
| Low RBC wastage due to violation of the 30-minute rule | 17 (81.0) |
| Possibility to increase RBC wastage due to a too-fast color change of TIs | 11 (52.4) |
| Intra- or inter-observer variability in reading a color change of TIs | 7 (33.3) |

*Multiple choice; †The number of respondents was 63, excluding one from a newly opened hospital (<1 year).
Abbreviations: RBC, red blood cell; RT, room temperature; TI, temperature-sensitive indicator; ST, surface temperature; GW, general ward; ICU, intensive care unit; OR, operating room; ED, emergency department; OC, outpatient clinic; C:T ratio, crossmatch to transfusion ratio.

(13.7%, N=92) indicated experience of RBC unit discard due to violation of the 30-minute rule. Regarding the expected utility of TIs to reduce RBC wastage, 83.1% (N=559) and 16.9% (N=114) of nurses answered that TIs would have high and low utility, respectively. Reasons for the expected low utility of TIs were as follows: difficulty of reading a color change of TIs (76.3%, N=87), low RBC wastage due to violation of the 30-minute rule (62.3%, N=71); possibility of delayed transfusion due to reading the color change of TIs (62.3%, N=71), insufficient time to read the color change of TIs due to nursing tasks (46.5%, N=53); and possibility to increase RBC wastage due to the fast color change of TIs (1.8%, N=2).

## DISCUSSION

This questionnaire survey of blood bank physicians and nurses focused on the practice for the blood cold chain of RBC units at a blood bank and bedside, and their awareness and expected utility of TIs. In particular, our survey focused on the awareness and compliance of the 30-minute rule, the practical situation of RBC transport, and possible utility of TIs to reduce RBC wastage. Most of the blood bank physicians answered that their hos-


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**Table 3.** Summary of the survey to nurses (N=673)

| Questionnaire | N of respondents (%) |
|---|---|
| Presence of nursing practice guidelines for RBC transfusion | |
| Yes | 616 (91.5) |
| No | 4 (0.6) |
| Unknown | 53 (7.9) |
| Contents of nursing practice guidelines for RBC transfusion* | |
| Preparation for RBC transfusion | 614 (99.7) |
| Storage of RBC units until transfusion | 571 (92.7) |
| Storage temperature for RBC units | 558 (90.6) |
| Transport temperature for RBC units | 355 (57.6) |
| Nursing practice during intra-transfusion | 600 (97.4) |
| Standard and procedure for return and discard of RBC units | 615 (99.8) |
| Criteria for discard of RBC units after issue in nursing practice guidelines for RBC transfusion* | 615 (99.8) |
| Exposure to RT for over 30 minutes | 570 (92.7) |
| ST of RBC unit to reach 10°C | 251 (40.8) |
| Damaged RBC units | 555 (90.2) |
| Contaminated RBC units | 547 (88.9) |
| Withdrawal of RBC transfusion due to the change of patient's condition | 468 (76.1) |
| Transfusion-related adverse reactions | 528 (85.9) |
| Use of transport container to ward after issue | |
| Yes | 666 (99.0) |
| No | 1 (0.1) |
| Unknown | 6 (0.9) |
| Types of transport container to ward after issue | |
| Cooler only | 278 (41.7) |
| Cooler with refrigerant | 361 (54.2) |
| Cooler with refrigerant and TI | 8 (1.2) |
| Others (e.g., cool bag, plastic box, plastic bag) | 19 (2.8) |
| ST monitoring of RBC units at transport after issue | 8 (1.2) |
| Blood refrigerator equipped in ward or outpatient clinic | 200 (29.7) |
| GW | 83 (41.5) |
| ICU | 51 (25.5) |
| OR | 36 (18.0) |
| ED | 20 (10.0) |
| OC | 10 (5.0) |
| Storage time limit of RBC units in blood refrigerator at ward | |
| ≤30 min | 6 (3.0) |
| ≤12 hr | 9 (4.5) |
| ≤24 hr | 170 (85.0) |
| >24 hr | 5 (2.5) |
| No standard | 2 (1.0) |
| Unknown | 8 (4.0) |

(*Continued to the next page*)

**Table 3.** Continued

| Questionnaire | N of respondents (%) |
|---|---|
| Monitoring of temperature of blood refrigerator at ward | |
| Electronic monitoring only | 40 (20.0) |
| Electronic monitoring with regular check by clinical nurses | 148 (74.0) |
| Unknown | 12 (6.0) |
| Knowledge about the 30-minute rule | 669 (99.4) |
| Compliance of the 30-minute rule | 666 (99.0) |
| Experience of discard of RBC units due to violation of the 30-minute rule | 92 (13.7) |
| Reasons of discard of RBC units due to violation of the 30-minute rule* | |
| Withdrawal of transfusion due to change of patient's condition | 77 (11.4) |
| Delayed transfusion due to other nursing tasks | 12 (1.8) |
| Delayed transport of RBC units | 2 (0.3) |
| Exposure to RT over 30 minutes after issue | 1 (0.2) |
| Failed blood refrigerator in ward | 1 (0.2) |
| Patient's absence | 1 (0.2) |
| Expected utility of TIs to reduce RBC wastage | |
| High utility | 559 (83.1) |
| Low utility | 114 (16.9) |
| Reasons of expected low utility of TIs to reduce RBC wastage* | 114 (16.9) |
| Difficulty of reading a color change of TIs | 87 (76.3) |
| Low RBC wastage due to violation of the 30-minute rule | 71 (62.3) |
| Possibility of delayed transfusion due to reading a color change of TIs | 71 (62.3) |
| Insufficient time to read a color change of TIs due to nursing tasks | 53 (46.5) |
| Possibility to increase RBC wastage due to a too fast color change of TIs | 2 (1.8) |

*Multiple choice.
Abbreviations: RBC, red blood cells; OC, outpatient clinic; RT, room temperature; ST, surface temperature; TI, temperature-sensitive indicator; GW, general ward; ICU, intensive care unit; OR, operating room; ED, emergency department.

pitals have RBC transfusion guidelines that include standards for RBC unit discard after issue. Although most of the guidelines include details about RBC unit transport to the ward after issue, this is generally not accompanied by detailed protocols defining transport conditions, including the transport container and/or temperature monitoring. Most of the nurses also answered that their hospitals have nursing practice guidelines for RBC transfusion that include the standard for RBC unit discard. However, only slightly more than a half (57.6%) answered that the content of transport temperature for RBC unit was included in the guidelines.

The majority of the RBC transfusion guidelines in the blood bank and nursing practice guidelines for RBC transfusion included the 30-minute rule as the standard for discard of RBC units after issue. However, the content of ST monitoring of RBC units during transport was rarely included in either guideline type. Approximately half of the blood bank physicians answered that they do not use a refrigerant during transport of RBC units to maintain transport temperature. Although most nurses were aware of and complied with the 30-minute rule, one veteran nurse with clinical experience of more than 10 years and three nurses with clinical experience <5 years were not aware of the 30-minute rule. Among them, only two nurses answered that they have nursing practice guidelines for RBC transfusion including the 30-minute rule. Taken together, it seems that both blood bank physicians and nurses are aware of the importance of the blood cold chain, are familiar with the 30-minute rule and 10°C rule, and follow the 30-minute rule. In actual practice, little attention has been paid to RBC transport compared with RBC storage, and no detailed protocols and/or guidance have been prepared for the same. National guidelines and/or guidelines from professional societies are needed for the safe transport of


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RBC units.

Regarding the wastage rate of RBC units, in the three of the participating hospitals, the RBC wastage rate ranged from 0.02% to 0.26%. In one of the three hospitals, 2.4% (N=2) of the RBC wastage was due to violation of the 30-minute rule (83 RBC units discarded in 2018). Among nurses with experience of RBC unit discard due to violation of the 30-minute rule, 0.5% (N=3) answered that an RBC unit was discarded due to delayed transport or exposure to room temperature (RT) for over 30 minutes. Kim, *et al.* [23] reported that 0.6% (N=1) of blood units were discarded due violation of the 30-minute rule among 162 discarded blood units. Only 5.5% (N=3) of blood bank physicians answered that the GW was equipped with a blood refrigerator; however, 41.5% (N=83) of nurses answered that their GW was equipped with a blood refrigerator. Since the survey to nurses was conducted anonymously, it is possible that this response referred to the same specific GWs.

In nursing practice, the storage time limit of RBC units in blood refrigerators at the ward varied, with the highest response of 24 hours. One nurse replied that the storage time limit of RBC units was set at 24 hours in the blood refrigerator at ward, but that the majority of RBC transfusions were performed within 30 minutes after issue. The WHO stated that it takes at least 30 minutes for a blood bank refrigerator with a full load of blood units set to 4°C to reach up to 6°C; however, no statement is provided on the time limit for storage in a blood refrigerator at the ward after issue regarding the 30-minute rule [8]. A time limit up to 60 minutes is acceptable for RBC units outside of controlled temperature [8, 11, 24]. RBC units exposed to uncontrolled temperature conditions for 60 minutes should be cooled down below 6°C for over 6 hours prior to reissue [2]. No significant change in RBC quality was found at temperatures higher than 10°C or with storage times longer than 30 minutes [25, 26]. Thus, the 30-minute rule has been amended to the 60-minute rule in the United Kingdom and Canada [24, 27, 28], resulting in significantly reduced RBC wastage [28]. Although we did not survey the actual wastage rate of RBC units and the overall rate of RBC wastage due to violation of the 30-minute rule nationwide, it is expected that the RBC shortage would increase. Blood donations could decrease under certain circumstances, including outbreaks of infectious diseases, such as COVID-19, and a decrease of eligible blood donors due to demographic changes given the declining birth rate and aging society [29, 30]; the increase in elderly people may also be associated with an increased demand of RBC usage [31]. Taken together, the customary 30-minute rule should be reconsidered in the face of contemporary society; extending or changing this time rule should also be considered in other countries.

The majority of blood bank physicians (67.2%) and nurses (83.1%) answered that TIs would have high utility to reduce RBC wastage; however, the distribution of reasons for the expected low utility of TIs to reduce RBC wastage varied between blood bank physicians and nurses. Most blood bank physicians and nurses who indicated that TIs would not be helpful answered like that because of the current low rate of RBC discard due to violation of the 30-minute rule. Moreover, more than a half of the blood bank physicians who selected the expected low utility of TIs answered that TIs could potentially increase RBC wastage due to the too-fast color change. Most of the nurses (76.3%, N=87) who selected the expected low utility of TIs answered that the interpretation of a color change of TIs would be difficult.

The time for a color change indicating 10°C varies across different TIs; in one study, more than 90% of TIs already showed a color change indicating 10°C within 30 minutes under RT [5, 15–17]. Various factors affect the color change of TIs [5]. Reportedly, 87.4% of RBC units were discarded due to violation of the 30-minute rule after issue or color change of TIs among total discarded RBC units [32]. Intra- or inter-observer variability is also a concern in interpretation of the color change [5, 15]; in a recent study, time–temperature indicators (TTIs) showed better performance than TIs [17]. Although TIs could serve as a supplementary tool to reduce RBC wastage, several limitations, including performance, should first be overcome [5, 17, 32]. Although not included in the survey, the cost concerns and cost-effectiveness of TIs might have also resulted in selecting the "low utility" option.

This study has several limitations. First, the survey subjects were limited to blood bank physicians and nurses working at secondary- or tertiary-care hospitals in Korea, which were concentrated in Seoul, Incheon, and Gyeonggi-do. Although transfusion is conducted in approximately 2,500 medical institutions, our survey focused on blood bank physicians and nurses in hospitals where RBC transfusions are expected to be performed frequently [33]. Since the survey to nurses was conducted anonymously, we could not further analyze the results according to hospitals and wards; accordingly, there is a possibility that some survey results may have been derived from a few specific hospitals, leading to bias. Second, this survey did not include questions about the status of RBC transfusion within 30 minutes after issue, the wastage rate of an RBC unit due to delayed transfusion, regular education on RBC transfusion guidelines for nurses, and nursing practice at the ward, including the method of stor-

age and discard of an RBC unit after issue. Further surveys with a larger study population and more detailed questions are needed to more accurately reflect the status of blood cold chain nationwide.

In conclusion, we conducted a survey of both blood bank physicians and nurses on RBC transport and storage in real hospital settings. This study provides fundamental data on the current practice for blood cold chain, and understanding about RBC wastage and the expected utility of TIs. Based on our survey results, to maintain the blood cold chain and guarantee safe transfusion practice, it is necessary to prepare detailed consensus guidelines and/or protocols on RBC transport and storage steps. It should also be mandatory to educate and guide medical personnel in these guidelines adequately.

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## AUTHOR CONTRIBUTIONS

Park M conducted the study, analyzed the data, and wrote the draft; Hur M conceived the study, analyzed the data, and finalized the draft; Kim H, Oh KM, Kim H, and Song YH discussed the data and reviewed the manuscript; Ko DH and Chung YS participated in the data analysis. All authors critically reviewed the manuscript and approved the final version.

## CONFLICTS OF INTEREST

No potential conflicts of interest relevant to this article are reported.

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