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SHORT COMMUNICATION

Effects of Different Kinds of Hand Sanitizers on Complete Blood Count and Leukocyte Differential Count

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SUMMARY

Background: **To explore the effects of different contents and types of hand sanitizers on the complete blood count and leukocyte differential count.**
Methods: **EDTA anticoagulant whole blood samples of healthy individuals were selected, and were treated with 75% alcohol, liquid hand sanitizer, and gel hand sanitizer. The samples were detected by the Sysmex automatic blood analyzer, and the capillary blood smear was prepared. The appearance of cells was examined under the microscope.**
Results: **The absolute lymphocyte count, MCV, MCHC, and HGB were significantly increased, while PLT and MCH were significantly decreased after adding 1 µL 75% alcohol ($p < 0.05$). By adding 1 µL liquid hand sanitizer, the absolute counts of lymphocyte, neutrophil and basophilic, MCHC, HGB, and PLT were significantly increased ($p < 0.05$). The results of WBC, MCHC and HGB were significantly increased when 1 µL gel hand sanitizer was added. The classification of leukocytes was obviously abnormal and could not be detected by the instrument. The effect of gel hand sanitizer on WBC was time-dependent. Pyknotic, karyorrhexis, and karyolysis of nuclei were observed under microscope.**
Conclusions: **Three kinds of hand sanitizers had effects on complete blood counts and leukocyte differential counts, in particular, gel hand sanitizer has the greatest impact on the results of tests. Therefore, gel hand sanitizer is not suitable for hand disinfection of operators before the collection of capillary blood samples.**
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KEY WORDS

75% alcohol, liquid hand sanitizer, gel hand sanitizer, capillary blood collection, complete blood count, leukocyte differential count

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INTRODUCTION

The complete blood count as well as the leukocyte differential count are central to diagnostic evaluation of blood cell diseases and can give important information in a broad variety of clinical conditions, such as infectious diseases and neoplastic diseases that are reflected in quantitative changes of blood cells [1-4]. There are two types of specimens commonly used in clinic, venous and capillary blood. The results of venous blood have fewer influencing factors than capillary blood, so the venipuncture blood collection is widely used. However, for pediatric patients with small blood vessels and poor compliance, the success rate of intravenous blood collection is low and the probability of complications is high. Capillary blood collection is essential for children [5]. On the other hand, according to World Health Organization (WHO), 12.3% of patients had adverse events of bruises and hematoma at the venipuncture site. For the patients with anemia or leukemia, venous blood collection frequently may increase the degree of anemia due to the need for long-term monitoring of complete blood count parameters. Moreover, the applicability of venous blood collection for severely burned patients and extremely obese patients is lower than that of capillary blood collection, and venous blood collection is not suitable for adult patients who are afraid of venipuncture. Therefore, capillary blood collection is essential and necessary in clinical practice [6]. The quality of capillary blood collection is particularly important and is key to the accuracy of complete blood count results.

According to the requirements of WHO, before capillary blood collection, health workers should use soap and water to perform hand hygiene, and then put on well-fitting and non-sterile gloves, which can be used up to 10 times [7]. Chinese Consensus on Capillary blood Collection requires that glove surfaces should be disinfected with a quick hand sanitizer when capillary sampling. Currently, the pandemic of coronavirus disease 2019, caused by a novel human coronavirus SARS-Cov-2, has become a global health concern. Since there are no specific therapies for SARS-CoV-2, early prevention of further spread will be crucial to control the ongoing infectious thread [8]. Strict hand disinfection before blood collection for health workers can effectively reduce the spread of infectious diseases, which is of great significance in the prevention and control of nosocomial infection. However, improper use of hand sanitizer in clinical practice may contaminate blood samples, affect the accuracy of test results of capillary blood, and may lead to abnormal scatter plot of hematology analyzer or inability to classify leukocytes. In our laboratory, we have experienced capillary blood samples contaminated with hand sanitizers, and we have observed that the results of complete blood count and leukocyte differential count were significantly affected. At present, no relevant research has paid attention to the impact of hand sanitizer on complete blood counts. Our study evaluated the effects of different types and concentrations of hand sanitizers on complete blood count and leukocyte differential count, which plays an important role in guiding the selection and application of hand sanitizer in capillary blood collection.

MATERIALS AND METHODS

Study population and sample collection

Ten healthy volunteers were enrolled. The volunteers were required to be of the same blood type without hemolysis. EDTA anticoagulant blood samples were collected from all the participants in a standard procedure of venous blood collection. All the samples were mixed, and then divided into Eppendorf tubes (100 µL/tube) to simulate the actual clinical capillary blood collection.

The study was approved by the ethics committee of Peking University Third Hospital. Written informed consent was obtained from each individual at the time of enrollment.

Choice of hand sanitizer

We chose a variety of hand sanitizers commonly used for hand hygiene in clinical practice, including 1) alcohol (Beijing Zhenyu Minsheng Pharmaceutical company limited), containing 75% ethanol; 2) liquid hand sanitizer (3M Avagard ™ ,Shanghai Xixi Aier Qidong Daily Chemicals Pharmaceutical company limited), containing 63.1 - 77% ethanol, 0.45 - 0.55% glucose chlorhexidine; 3) Gel hand sanitizer (American Gocho Industries), containing 70% ethanol, and a small amount of water, isopropanol, octyl glycol, glycerol, isopropyl tetradecanoate, vitamin E, acrylate, C10-30 alkyl acrylate cross-linked polymer and aminomethyl propanol.

ABO and Rh grouping

ABO typing was performed by testing red blood cells with anti-A and anti-B antisera. Rh typing was determined with anti-D (Besser Biotechnology). The results of ABO and Rh grouping was determined by whether there was agglutination or not. All the volunteers enrolled were Rh-positive blood type O, and the whole blood samples from all the volunteers were mixed together, there was no hemolysis.

Complete blood counts and leukocyte differential counts

EDTA anticoagulant blood samples were detected with a Sysmex XS 800i automatic blood analyzer (Sysmex Corporation Kobe, Japan) within 2 hours, and the parameters such as red blood cells (RBC), hemoglobin (HGB), mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), mean corpuscular hemoglobin concentration (MCHC), platelets (PLT), white blood cells (WBC), and leukocyte differential counts

Table 1. Effects of different volumes of 75% alcohol on the results of complete blood counts and leukocyte differential counts ($\bar{x}$ ± SD).

Analytes	Control group	75% alcohol			p-value
		1 µL	2 µL	5 µL	
WBC (× 10^9/L)	8.45 ± 0.06	9.43 ± 0.23	9.51 ± 0.15	10.03 ± 0.46	0.680
LYMPH # (× 10^9/L)	2.84 ± 0.15	3.37 ± 0.04 [a]	3.40 ± 0.04 [a]	3.72 ± 0.26[a]	0.000 *
LYMPH (%)	35 ± 0.00	35.8 ± 1.25	35.67 ± 0.40	37.03 ± 1.05	0.209
NEUT # (× 10^9/L)	4.89 ± 0.10	5.34 ± 0.22	5.34 ± 0.10	5.52 ± 0.16	0.430
NEUT (%)	57.7 ± 0.00	56.67 ± 0.99	56.2 ± 0.20 [a]	55.17 ± 0.93 [a, b]	0.002 *
MONO # (× 10^9/L)	0.47 ± 0.01	0.52 ± 0.03	0.58 ± 0.04	0.58 ± 0.05	0.799
MONO (%)	5.5 ± 0.00	5.57 ± 0.15	6.07 ± 0.31	5.80 ± 0.53	0.568
EO # (× 10^9/L)	0.08 ± 0.00	0.10 ± 0.02	0.09 ± 0.01	0.09 ± 0.01	0.395
EO (%)	0.9 ± 0.00	1.03 ± 0.15	0.97 ± 0.06	0.90 ± 0.10	0.535
BASO # (× 10^9/L)	0.03 ± 0.00	0.03 ± 0.00	0.04 ± 0.01	0.04 ± 0.00	1.000
BASO (%)	0.4 ± 0.00	0.30 ± 0.00	0.37 ± 0.12	0.37 ± 0.06	0.978
RBC (× 10^{12}/L)	5.47 ± 0.39	5.28 ± 0.56	5.60 ± 0.01 [a]	5.83 ± 0.10 [a, b]	0.003 *
MCV (fL)	79.17 ± 0.9	80.22 ± 0.22 [a]	82.45 ± 0.38 [a, b]	91.35 ± 0.31 [a, b, c]	0.000 *
MCH (pg)	27 ± 1.00	26.76 ± 0.21 [a]	27.59 ± 0.16 [a, b]	30.18 ± 0.07 [a, b, c]	0.000 *
MCHC (g/L)	329 ± 1.15	345 ± 1.19 [a]	357 ± 0.62 [a, b]	385 ± 0.67 [a, b, c]	0.000 *
HGB (g/L)	131 ± 1.15	137 ± 1.71 [a]	145 ± 0.62 [a]	150 ± 2.43 [a, b, c]	0.000 *
HCT (%)	41.3 ± 1.00	41.0 ± 4.36	43.27 ± 0.16	45.69 ± 0.79 [a, b]	0.005 *
PLT (× 10^9/L)	290 ± 1.15	267 ± 8.83[a]	266 ± 3.08 [a]	309 ± 3.56 [a, b, c]	0.000 *

LYMPH # - absolute lymphocyte count, LYMPH% - the percentage of lymphocytes, NEUT # - absolute neutrophil count, NEUT% - the percentage of neutrophils, MONO # - absolute monocyte count, MONO% - the percentage of monocytes, EO # - absolute eosinophil count, EO% - the percentage of eosinophil, BASO # - absolute basophilic count, BASO% - the percentage of basophilic, a - the difference was statistically significant compared with the control group, b - the difference was statistically significant compared with the 1 µL treatment group, c - the difference was statistically significant compared with the 2 µL treatment group, * - indicated that the difference between different treatment groups was statistically significant.

were recorded. Each packaged sample (100 µL/tube) was treated with 0 µL, 1 µL, 2 µL, and 5 µL of various sanitizers (75% alcohol, liquid hand sanitizer, and gel hand sanitizer) for 10 minutes, respectively. Different types and volumes of hand sanitizers were added after the blood sample, and the tubes were mixed by gently flicking with fingers. The test was carried out at room temperature. For gel sanitizer, 1 µL was added to each packaged sample for 1 minute, 5 minutes, and 10 minutes. Because the addition of hand sanitizer had a certain dilution effect on the test results, WBC, RBC, PLT, and leukocyte differential counts were corrected by the following formula.

Corrected value = detection value × (100 µL + the volume of sanitizer added)/100 µL

Morphologic examination of the blood

Capillary blood smears were prepared manually and were stained (Wright-Giemsa) by a Sysmex SP-10 automatic staining machine (Sysmex Corporation Kobe, Japan). Manual classification of leukocytes was counted by Sysmex DI-60 automatic digital cell morphology recognition and analysis system (Sysmex Corporation Kobe, Japan), and was confirmed by two experienced technicians under microscope. A total of 200 nucleated cells were read on each slide [9].

Statistical analysis

SPSS26.0 software was used for statistical analysis of the data. Continuous variables of non-normal distribution were expressed by median [quartile], and non-parametric Mann-Whitney-U test was used for comparison between groups. The data of normal distribution was expressed as mean ± standard deviation ($\bar{x}$ ± SD). The t test was used for comparison between groups, and $p < 0.05$ was considered statistically significant.

Table 2. Effects of different volumes of liquid sanitizer on the results of complete blood counts and leukocyte differential counts ($\bar{x}$ ± SD).

Analytes	Control group	Liquid Hand Sanitizer			p-value
		1 μL	2 μL	5 μL	
WBC (× 10^9/L)	8.45 ± 0.06	9.36 ± 0.17	9.60 ± 0.20	10.36 ± 0.14	0.544
LYMPH # (× 10^9/L)	2.84 ± 0.15	3.12 ± 0.07 [a]	3.14 ± 0.10 [a]	2.87 ± 0.35 [a]	0.000 *
LYMPH (%)	35 ± 0.00	33.37 ± 0.50	32.7 ± 0.35 [a]	27.7 ± 2.06 [a, b, c]	0.000 *
NEUT # (× 10^9/L)	4.89 ± 0.10	5.45 ± 0.14 [a]	5.58 ± 0.10 [a]	6.19 ± 0.27 [a]	0.025 *
NEUT (%)	57.7 ± 0.00	58.3 ± 0.79	58.1 ± 0.17	59.7 ± 1.82 [a, b, c]	0.011 *
MONO # (× 10^9/L)	0.47 ± 0.01	0.50 ± 0.05	0.54 ± 0.06	0.94 ± 0.17 [a, b, c]	0.002 *
MONO (%)	5.5 ± 0.00	5.27 ± 0.47	5.63 ± 0.46	9.07 ± 1.62 [a, b, c]	0.000 *
EO # (× 10^9/L)	0.08 ± 0.00	0.08 ± 0.02	0.10 ± 0.01 [a, b]	0.11 ± 0.22 [a, b]	0.007 *
EO (%)	0.9 ± 0.00	0.87 ± 0.23	1.27 ± 0.25 [a, b]	1.07 ± 0.21	0.003 *
BASO # (× 10^9/L)	0.03 ± 0.00	0.14 ± 0.07 [a]	0.15 ± 0.05 [a]	0.07 ± 0.04 [b, c]	0.007 *
BASO (%)	0.4 ± 0.00	1.50 ± 0.70 [a]	1.53 ± 0.58 [a]	0.67 ± 0.35 [b, c]	0.000 *
RBC (× 10^{12}/L)	5.47 ± 0.39	5.47 ± 0.03	5.49 ± 0.02	5.85 ± 0.04 [a]	0.005 *
MCV (fL)	79.17 ± 0.9	80.05 ± 0.26	83.77 ± 0.06 [a, b]	93.29 ± 0.13 [a, b, c]	0.000 *
MCH (pg)	27 ± 1.00	26.87 ± 0.10 [a]	27.91 ± 0.06 [a, b]	30.33 ± 0.40 [a, b, c]	0.000 *
MCHC (g/L)	329 ± 1.15	347 ± 1.58 [a]	355 ± 0.00 [a, b]	380 ± 4.72 [a, b, c]	0.000 *
HGB (g/L)	131 ± 1.15	142 ± 1.19 [a]	143 ± 0.53 [a]	152 ± 0.67 [a, b, c]	0.00 *
HCT (%)	41.3 ± 1.00	42.4 ± 0.36	43.13 ± 0.12	46.74 ± 0.38 [a, b, c]	0.002 *
PLT (× 10^9/L)	290 ± 1.15	308 ± 8.13 [a]	313 ± 4.31 [a]	308 ± 6.77 [a]	0.021 *

LYMPH # - absolute lymphocyte count, LYMPH% - the percentage of lymphocytes, NEUT # - absolute neutrophil count, NEUT% - the percentage of neutrophils, MONO # - absolute monocyte count, MONO% - the percentage of monocytes, EO # - absolute eosinophil count, EO% - the percentage of eosinophil, BASO # - absolute basophilic count, BASO% - the percentage of basophilic, a - the difference was statistically significant compared with the control group, b - the difference was statistically significant compared with the 1 μL treatment group, c - the difference was statistically significant compared with the 2 μL treatment group, * - indicated that the difference between different treatment groups was statistically significant.

RESULTS

Effects of different volumes of 75% alcohol on the results of complete blood counts and leukocyte differential counts

Different volumes (0 μL, 1 μL, 2 μL, and 5 μL) of 75% alcohol was added in each package tube. All the tests were carried out and repeated 3 times for each sample. The absolute lymphocyte count, MCV, MCHC, and HGB were significantly increased, while PLT and MCH were significantly decreased after adding 1 μL 75% alcohol, and the differences were statistically significant compared with control group ($p < 0.05$). As the volume of 75% alcohol increases, the absolute lymphocyte count, MCV, MCHC, and HGB showed an increasing trend (Table 1).

Effects of different volumes of liquid hand sanitizer on the results of complete blood counts and leukocyte differential counts

By adding 1 μL liquid hand sanitizer, the absolute counts of lymphocyte, neutrophil and basophilic, MCHC, HGB, and PLT were significantly increased, and the difference was statistically significant compared with the control group ($p < 0.05$). With the increasing volume of liquid sanitizer, absolute neutrophil count, MCV, MCH, MCHC, and HGB also increased, as shown in Table 2.

Effects of different volumes of gel hand sanitizer on the results of complete blood counts and leukocyte differential counts

We found that the results of WBC, MCHC, and HGB were significantly increased when 1 μL gel hand sanitizer was added, and the differences were statistically significant compared with the control group ($p < 0.05$). Moreover, the classification of leukocytes was obviously abnormal and could not be detected by the instrument. WBC, MCV, MCHC, HGB, and PLT showed an obvious upward trend as the added volume of gel sanitizer increased, WBC and PLT showed the most significant changes, as shown in Table 3.

Table 3. Effects of different volumes of gel hand sanitizer on the results of complete blood counts and leukocyte differential counts ($\bar{x}$ ± SD).

Analytes	Control group	Gel Hand Sanitizer			p-value
		1 µL	2 µL	5 µL	
WBC (× 10^9/L)	8.45 ± 0.06	28.54 ± 0.36 [a]	30.44 ± 3.70 [a, b]	40.52 ± 4.05 [a, b, c]	0.000 [*]
LYMPH [#] (× 10^9/L)	2.84 ± 0.15	-	-	-	-
LYMPH (%)	35 ± 0.00	-	-	-	-
NEUT [#] (× 10^9/L)	4.89 ± 0.10	-	-	-	-
NEUT (%)	57.7 ± 0.00	-	-	-	-
MONO [#] (× 10^9/L)	0.47 ± 0.01	-	-	-	-
MONO (%)	5.5 ± 0.00	-	-	-	-
EO [#] (× 10^9/L)	0.08 ± 0.00	-	-	-	-
EO (%)	0.9 ± 0.00	-	-	-	-
BASO [#] (× 10^9/L)	0.03 ± 0.00	-	-	-	-
BASO (%)	0.4 ± 0.00	-	-	-	-
RBC (× 10^{12}/L)	5.47 ± 0.39	5.29 ± 0.55	5.23 ± 0.19 [a]	5.20 ± 0.08 [a, b, c]	0.000 [*]
MCV (fL)	79.17 ± 0.9	82.63 ± 0.22	82.88 ± 0.46 [a, b]	91.04 ± 0.67 [a, b, c]	0.000 [*]
MCH (pg)	27 ± 1.00	26.87 ± 0.21	27.88 ± 0.12 [b]	28.49 ± 0.07 [a, b, c]	0.000 [*]
MCHC (g/L)	329 ± 1.15	308 ± 1.58 [a]	305 ± 2.46 [a, b]	303 ± 2.43 [a, b, c]	0.000 [*]
HGB (g/L)	131 ± 1.15	145 ± 0.60 [a]	147 ± 1.63 [a]	158 ± 1.78 [a, b, c]	0.000 [*]
HCT (%)	41.3 ± 1.00	41.75 ± 4.33	42.92 ± 1.60	43.33 ± 0.27 [a, b, c]	0.000 [*]
PLT (× 10^9/L)	290 ± 1.15	320 ± 12.84 [a]	339 ± 5.04 [ab]	394 ± 15.55 [a, b, c]	0.000 [*]

LYMPH [#] - absolute lymphocyte count, LYMPH% - the percentage of lymphocytes, NEUT [#] - absolute neutrophil count, NEUT% - the percentage of neutrophils, MONO [#] - absolute monocyte count, MONO% - the percentage of monocytes, EO [#] - absolute eosinophil count, EO% - the percentage of eosinophil, BASO [#] - absolute basophilic count, BASO% - the percentage of basophilic, a - the difference was statistically significant compared with the control group, b - the difference was statistically significant compared with the 1 µL treatment group, c - the difference was statistically significant compared with the 2 µL treatment group, * - indicated that the difference between different treatment groups was statistically significant, -: It indicated that XS-800I could not classify and count WBC.

The effect of gel hand sanitizer on the results of complete blood counts was time-dependent

The results showed that WBC were significantly increased after adding 1 µL gel hand sanitizer, and the differences were statistically significant compared with the control group ($p < 0.05$). We found that the effect of gel sanitizer on WBC was time-dependent. The results of WBC increased from (8.45 ± 0.06) x 10^9/L to (17.16 ± 0.54) x 10^9/L after the addition of gel hand sanitizer for 1 minute. When gel hand sanitizer was added for 5 minutes and 10 minutes, WBC was (22.42 ± 1.1) x 10^9/L and (28.54 ± 0.36) x 10^9/L, respectively. Moreover, the classification of leukocytes was obviously abnormal and could not be detected by the instrument as shown in Table 4. When 1 µL gel sanitizer was added for 1 minute, the neutrophil area in the scatter plot of the instrument was gray, indicating that it could not be accurately classified. After the addition of gel sanitizer for 5 and 10 minutes, the gray areas in the scatter plot were enlarged, the neutrophils and lymphocytes could not be identified. The dots in the neutrophil region showed an upward tailing pattern, and the intensity of side fluorescence (SFL) increased (Figure 1).

Effect of gel sanitizer on morphology of blood cells

We observed the cell morphology under a microscope, leukocytes showed varying degrees of destruction after adding 1 µL gel sanitizer. We found that some cells with blurred edges (Figure 2A), and in others the cytoplasm began to disintegrate (Figure 2B), even the nucleus and cytoplasm are completely destroyed and cannot be recognized (Figure 2C). Many nuclei have become pyknotic (shrunken and dark) and have then undergone karyorrhexis (fragmentation) and karyolysis (dissolution). Smudge cells can also be observed. The results of microscopic examination of blood film for manual leukocyte classification indicated that among all well-defined nucleated cells, the percentage of neutrophils decreased to 45%, the percentage of lymphocytes increased to 49%, and the monocytes increased to 4%. It is suggested that neutrophil destruction is the main cause of inaccurate manual classification of white

Table 4. Effects of adding 1 μL gel sanitizer for different duration on blood routine results ($\bar{x}$ ± SD).

Analytes	Control group	Gel Hand Sanitizer			p-value
			1 μL		
		1 minute	5 minutes	10 minutes	
WBC (× 10^9/L)	8.45 ± 0.06	17.16 ± 0.54 [a]	22.42 ± 1.1 [a, b]	28.54 ± 0.36 [a, b, c]	0.000 [*]
LYMPH [#] (× 10^9/L)	2.84 ± 0.15	-	-	-	-
LYMPH (%)	35 ± 0.00	-	-	-	-
NEUT [#] (× 10^9/L)	4.89 ± 0.10	-	-	-	-
NEUT (%)	57.7 ± 0.00	-	-	-	-
MONO [#] (× 10^9/L)	0.47 ± 0.01	-	-	-	-
MONO (%)	5.5 ± 0.00	-	-	-	-
EO [#] (× 10^9/L)	0.08 ± 0.00	-	-	-	-
EO (%)	0.9 ± 0.00	-	-	-	-
BASO [#] (× 10^9/L)	0.03 ± 0.00	-	-	-	-
BASO (%)	0.4 ± 0.00	-	-	-	-
RBC (× 10^{12}/L)	5.47 ± 0.39	5.43 ± 0.12	5.35 ± 0.58	5.29 ± 0.55	0.665
MCV (fL)	79.17 ± 0.9	79.36 ± 0.27	83.22 ± 0.47	82.63 ± 0.22	0.459
MCH (pg)	27 ± 1.00	26.80 ± 0.26	26.76 ± 0.21	26.87 ± 0.21	0.942
MCHC (g/L)	329 ± 1.15	319 ± 3.16 [a]	310 ± 0.60 [a]	308 ± 1.58 [a]	0.000 [*]
HGB (g/L)	131 ± 1.15	145 ± 1.79 [a]	142 ± 2.07 [a]	145 ± 0.60 [a]	0.000 [*]
HCT (%)	41.3 ± 1.00	42.88 ± 0.90	39.71 ± 4.33	41.75 ± 4.33	0.563
PLT (× 10^9/L)	290 ± 1.15	301 ± 7.03	306 ± 14.33	320 ± 12.284	0.055

LYMPH [#] - absolute lymphocyte count, LYMPH% - the percentage of lymphocytes, NEUT [#] - absolute neutrophil count, NEUT% - the percentage of neutrophils, MONO [#] - absolute monocyte count, MONO% - the percentage of monocytes, EO [#] - absolute eosinophil count, EO% - the percentage of eosinophil, BASO [#] - absolute basophilic count, BASO% - the percentage of basophilic, a - the difference was statistically significant compared with the control group, b - the difference was statistically significant compared with the group treated for 1 minute, c - the difference was statistically significant compared with the group treated for 5 minutes, * - It indicated that the difference between different treatment groups was statistically significant.

blood cells. However, the morphology of platelets and red blood cells was less affected than that of leukocytes.

DISCUSSION

Hand hygiene is recognized as one of the most effective means to prevent nosocomial infection, it is also an effective means to help prevent the spread of infectious diseases in a non-hygienic environment [10-13]. At present, we believe that using soap and alcohol can effectively decline virus transmission. In the past two years, due to the outbreak of SARS-Cov-2, the requirements for hand hygiene and sanitizer of medical staff and patients are more stringent in clinical practice [14]. The Centers for Disease Control and Prevention recommends that people wash their hands regularly with soapy water for 20 seconds or use hand sanitizer with an alcohol content of at least 60%, proper hand hygiene can reduce the spread of 24% - 31% infectious diseases, and alcohol containing hand sanitizer has also been shown to be effective in inactivating enveloped viruses, including coronaviruses [15,16]. Some studies also pointed out that the dry coronavirus can stay on the surface of medical latex gloves. Therefore, hand sanitizers are necessary and helpful in the clinical work [17]. Alcohol hand sanitizer, liquid hand sanitizer, and gel hand sanitizer all contain alcohol. Alcohol is the main component of various hand sanitizers which can inactivate the virus. It is mainly through the dissolution of lipid membrane and protein denaturation, resulting in membrane destruction and metabolic inhibition and then inactivation of the virus. Our experimental analysis showed that three kinds of hand sanitizers, including alcohol hand sanitizer, liquid hand sanitizer, and gel hand sanitizer, had different effects on capillary blood. Among them, gel hand sanitizer had the greatest influence on the classification of leukocytes. Adding 1 μL gel hand sanitizer could affect WBC and the classification of leukocytes. When the automatic blood analyzer Sysmex XS 800i irradiated cells with a forward scatter

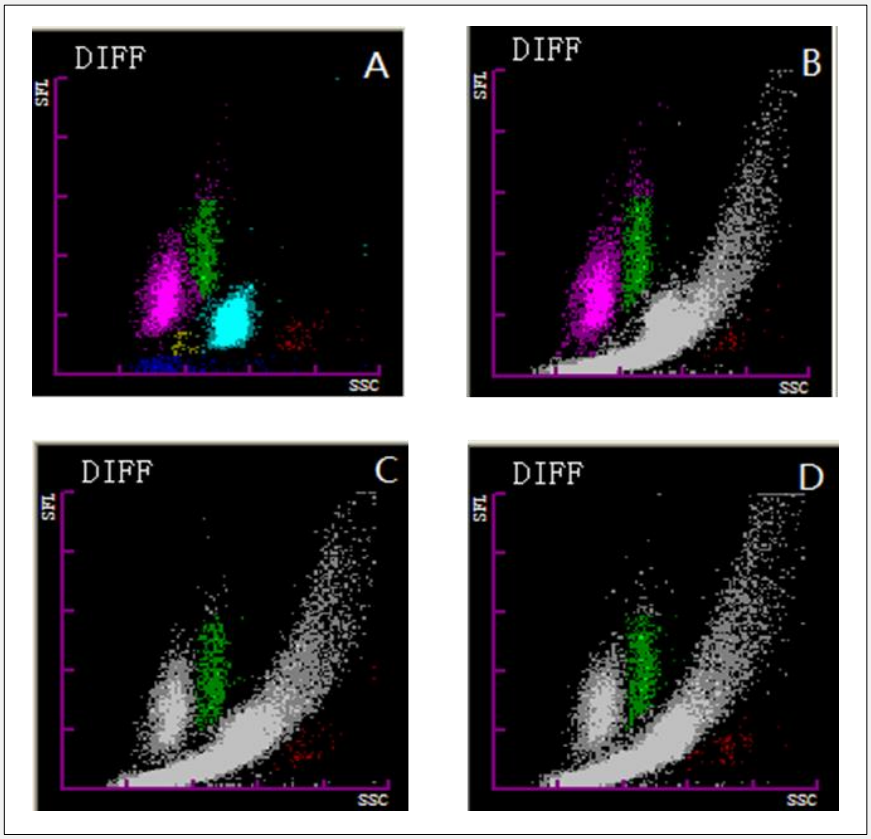

Figure 1. Effect of gel hand sanitizer on leukocytes classification scatter plot of hematology analyzer.

A. Control group, B. 1 μL gel sanitizer was added for 1 minute, C. 1 μL gel sanitizer was added for 5 minutes, D. 1 μL gel sanitizer was added for 10 minutes.
SSC - side scatter, SFL - side fluorescence, DIFF - leukocyte differential channel.

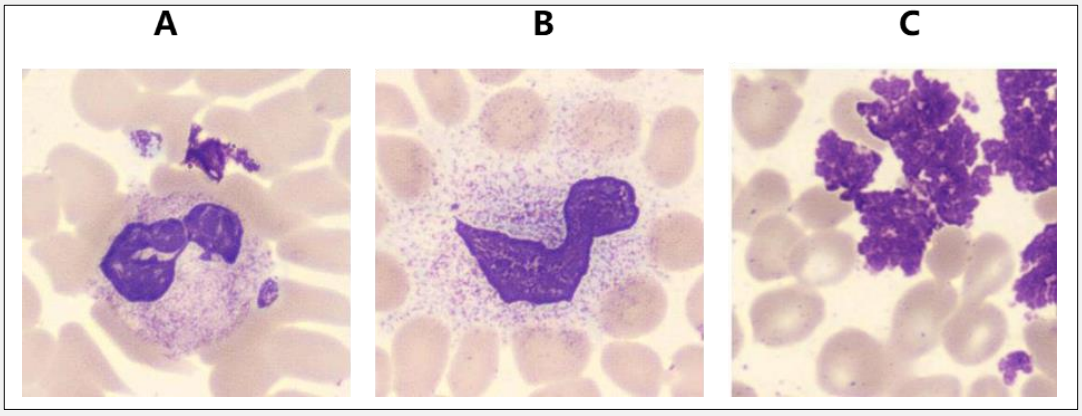

Figure 2. Effect of gel hand sanitizer on the morphology of white blood cells (10 × 100).

(FSC) laser beam, the signal scattered forward at a small angle (0.5 - 10) relative to the axis used to detect the surface properties of particles such as cells, the signal strength was proportional to the cell volume. While the side scatter (SSC) laser beam was used to irradiate the cell, the signal scattered by the light at an angle of 90° was used to detect the internal structural properties of the cells. In addition, fluorescent dyes bound to DNA/RNA nucleic acids in cells, so the side fluorescence (SFL) usually reflects the amount of nucleic acid content and the maturity of cell development. When the cell structure was complete and the morphology was normal, leukocytes could be classified into five categories according to FSC, SSC, and SFL. It was found that the gel hand sanitizer could lead to the deformation and lysis of blood cells. Smudge cells and damaged leukocytes were found under the microscope, leading to the failure of the automatic hematology analyzer to correctly classify leukocytes.

Gel hand sanitizer has the greatest effect on the WBC and leukocyte differential count. In order to understand the reasons for the great impact of gel hand sanitizer on leukocytes, we carried out the same experiments with isopropanol and glycerin, the other ingredients in the gel hand sanitizer. The results showed that both isopropanol and glycerol had less effects on the detection of white blood cells. We considered that the effect of gel hand sanitizer on the classification of leukocytes might be due to the effect of other organic solvents in the gel sanitizer. At the same time, gel hand sanitizer added glycerin and other substances to achieve the purpose of moisturizing. Compared with alcohol hand sanitizer and liquid hand sanitizer, it was more difficult to volatilize and easy to remain on hands, which might be one of the reasons why gel hand sanitizer had a greater effect on capillary blood.

Our experimental results confirmed that the gel hand sanitizer left on hands, even if mixed with 1 μL, in a very short time, had a great effect on the results of complete blood count and leukocyte differential count. In the process of blood collection, there are opportunities to pollute blood samples in the process of opening or closing the blood collection vessel and contacting the skin of patients, which seriously affects the accuracy of blood routine tests and interferes with the clinician's correct interpretation of the results. Previous studies have shown that the ability of the gel hand sanitizer to inactivate the virus was lower than that of the alcohol hand sanitizer, the greater the amount of gel hand sanitizer, the longer of duration on the hands, and the inactivation effect on bacteria and viruses [18]. Therefore, in clinical work, we do not recommend the use of gel hand sanitizer for hand hygiene before capillary blood collection, and we suggest alcohol sanitizer is more useful and had a smaller influence on complete blood counts and leukocyte differential counts.

In order to satisfy the amount of blood needed for this experiment, 10 healthy volunteers were enrolled. The blood groups of healthy volunteers were detected, and the blood of healthy volunteers with the same blood group was mixed to simulate the blood volume of capillary blood collected in clinical practice. Our study has significance in guiding the selection of hand sanitizer before capillary blood collection. However, it is necessary to further increase the sample size and recruit patients with different diseases to explore whether the effects of various hand sanitizers on complete blood counts and leukocyte differential counts are related to patients' disease status. In order to better realize the standardized operation procedures of capillary blood collection in clinical practice, future studies could include more types of hand sanitizers and further study the components and causes of sanitizers affecting the blood routine tests.

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Declaration of Interest:

All the authors declared they had no competing interests.

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