Acta Clin Croat 2023; 62:345-354
doi: 10.20471/acc.2023.62.02.13

Original Scientific Paper

IMPACT OF AIR TRANSPORT ON BLOOD SAMPLE QUALITY

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SUMMARY – The aim of this study was to establish the impact of air transport on blood samples packaged with and without cooling elements and effect of outdoor temperature on sample quality. Venous samples from 38 blood donors in winter and 36 in summer were tested for hemolysis and complete blood count. One tube *per* subject was kept in controlled conditions at +4 ˚C. Two sets of tubes were sent by plane from Zagreb to Brussels, one with and one without cooling elements, and another two sets were sent to London following the same principle. Packages with cooling elements were stored in controlled warehousing conditions at airports (+2 ˚C to +8 ˚C), whereas packages without cooling elements were stored in ambient warehouse conditions. Data loggers were used for temperature monitoring. Our research revealed statistically significant differences in several hematologic parameters when comparing the samples stored in controlled laboratory conditions and those transported by plane. These differences were more pronounced in the samples transported during the summer. Transport conditions without cooling elements had additional negative impact on the sample quality. Transport of samples using cooling elements and controlled warehousing conditions at airports are sometimes not sufficient to maintain laboratory storage conditions.

Key words: *Blood sample quality; Transport conditions; Hematologic parameters*

Introduction

Nowadays, faced with the COVID-19 pandemic and transport of different types of vaccines around the world, we are more than ever aware of the importance of transport and storage conditions of biological materials.

Blood samples are biological materials on which, with good organization and cooperation, it is relatively easy to examine the risks of changes that may be affected by these conditions. It is well known that hematologic parameters of venous blood are sensitive to storage and transport temperatures, as well as to the time interval between blood draw and assay[1]. These parameters are usually measured within several hours after blood draw, but in certain circumstances, blood samples have to be transported to remote destinations, which can sometimes last for more than 24 hours[2]. Prolonged transport time may affect the stability of test parameters, which may compromise the accuracy of the results obtained[3]. The quality control samples used by laboratories on a daily basis to verify the accuracy of test results are mainly produced in one place and then distributed worldwide. Conditions in which they are to be distributed and stored until reaching the end user in testing laboratory are, therefore, of huge importance. Even though an

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Received September 9, 2021, accepted March 2, 2022

adequate amount of time from blood draw to the analysis, as well as the sample storage temperature until analysis have already been described in the literature, there are little data on the impact of storage, distribution and transport on certain test parameters[4-6].

This study was conducted in cooperation with colleagues working in air transport. When designing the study, two basic aims were established, i.e., checking technological monitoring possibilities of special cargo transport (blood samples) in air transport and possible changes during transport and storage, as well the effect of outdoor atmospheric conditions. Results of the first part of the study were published in a paper by Majić *et al.*[7]. The aim of this study was to establish the impact of air transport of blood samples under packing conditions with and without cooling elements that imitate to an extent the prescribed conditions of sample storage, and the possible effect of seasons, i.e., outdoor temperature conditions in which the transport takes place.

Materials and Methods

Subjects and samples

Hematologic parameters were tested in samples obtained from voluntary blood donors (VBDs), with their informed consent and approval from the Ethics Committee of the Croatian Institute of Transfusion Medicine (CITM). Five samples were collected from each donor into 3-mL K2EDTA tubes (BD Vacutainer®, USA).

The first part of the study conducted in winter included 38 VBD blood samples, whereas the second part of the study conducted in summer included 36 VBD blood samples.

Methods

Complete blood count (CBC) was performed using a Cell Dyn 3200 (Abbott Diagnostics, USA), a multi-parameter automated hematology analyzer designed for *in vitro* diagnostic use in clinical laboratories[8]. The following parameters were used for the purpose of this study: white blood cell count (WBC), neutrophil count, red blood cell count (RBC), hemoglobin (HGB) concentration, hematocrit (HCT), mean corpuscular volume (MCV), platelet count (PLT) and mean platelet volume (MPV).

HemoCue Plasma/Low hemoglobin (HemoCue AB, Sweden), which measures low hemoglobin concentrations (from 3 to 30 g/L), was used to determine hemolysis degree[9]. The samples were centrifuged at room temperature for 20 minutes at 2500 xg. The isolated supernatants were recentrifuged under the same conditions in order to remove any residual red blood cells present, which could lead to a falsely elevated result. The hemolysis percentage was calculated using the following formula: (100-HCT)×HGB in supernatant (g/L)/total HGB (g/L).

Study design

Two shipping modules were defined: A – airline transport on the Zagreb-Vienna-Brussels-Vienna-Zagreb regular flight, and B – airline transport on the Zagreb-Vienna-London-Vienna-Zagreb regular flight. Module A has a shorter flight time than Module B. Both modules also include transshipment of packages at the Vienna airport. Transport from CITM to the Zagreb airport was conducted by car.

Two sets of test tubes were sent to Brussels on the same plane (one set was packed with cooling elements during the entire transport time – BRU 1, and one set was packed without cooling elements – BRU 2). The remaining two sets were sent to London by plane, also one with cooling elements (LON 1) and one without them (LON 2).

Packages with cooling elements in both modules (BRU 1 and LON 1) were stored in controlled warehouse conditions at airports (+2 °C to +8 °C), whereas packages without cooling elements were stored in ambient warehouse conditions (BRU 2 and LON 2).

One set of 3-mL test tubes containing blood samples of each subject were stored in prescribed, controlled conditions in a CITM refrigerator at +4 °C (set CITM-C). Upon return of the samples back to Zagreb, the default parameters were measured in all 5 samples.

The same procedure was repeated twice. The first time around, transport and testing were done at the end of winter (March), when outdoor temperature ranged from +8 °C to +10 °C, and the second time around, they were done in summer (June), when outdoor temperature ranged from +26 °C to +28 °C. Moreover, the samples sent to London in June returned with a 1-day delay, which should also be taken into consideration on data analysis. However, we decided to analyze those results as such circumstances may also occur in everyday life.

Data loggers (iMINI, Cryopak Escort, USA), measuring instruments recording temperature, humidity and vibrations, were used to monitor temperature during transport. Two measuring instruments were used for each packed sample. The outer one was placed on top of the box, and it could also be regarded as a reference instrument with regard to outdoor temperature during exposure to outdoor atmospheric conditions. The instrument

placed inside the package was placed on a layer of paper napkins in order to prevent direct contact with the samples. Temperature was checked at 11 predefined points during all phases.

Statistical analysis

Data were grouped according to storage method and shipping module used. ANOVA for repeated measurements with Bonferroni correction was performed in MedCalc software for statistical analysis. The level of statistical significance was set at $p<0.05$.

Results

Two data loggers were placed in each shipment. Temperatures recorded during the flights are shown

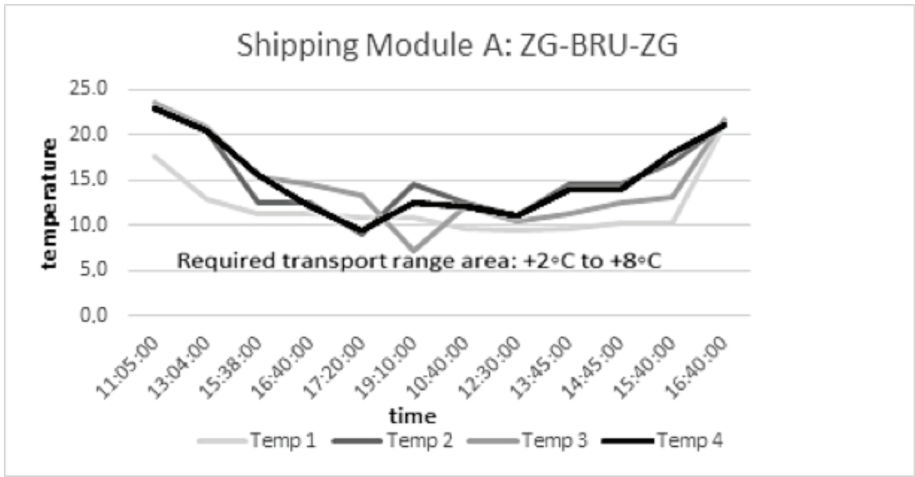

Fig. 1. Temperatures in module A (ZG-BRU-ZG) in case of packages with cooling elements (Temp 1 and Temp 2) and without them (Temp 3 and Temp 4).

Temp 1 = data logger inside the package;
Temp 2 = data logger outside the package;
Temp 3 = data logger inside the package;
Temp 4 = data logger outside the package

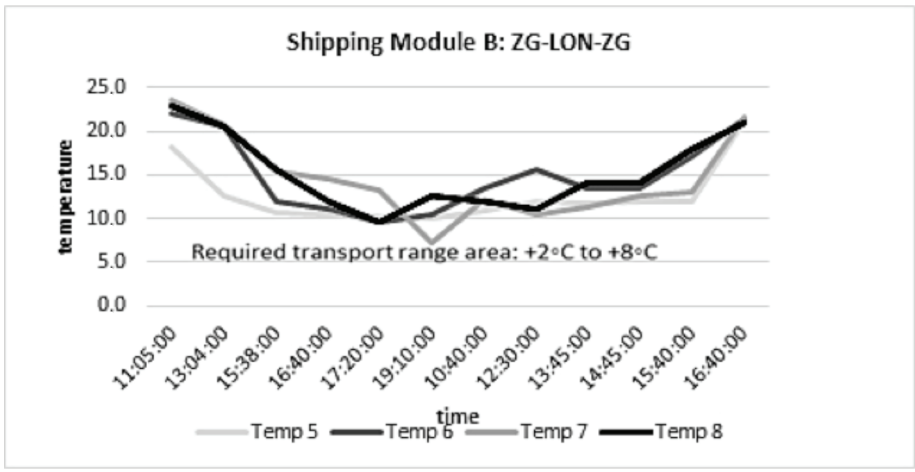

Fig. 2. Temperatures in module B (ZG-LON-ZG) in case of storage with cooling elements (Temp 5 and Temp 6) and without them (Temp 7 and Temp 8). Recommended storage conditions range from +2 ˚C to +8 ˚C.

Temp 5 = data logger inside the package;
Temp 6 = data logger outside the package;
Temp 7 = data logger inside the package;
Temp 8 = data logger outside the package

in Figures 1 and 2. Recommended storage conditions ranged from +2 ˚C to +8 ˚C.

By analyzing Figures 1 and 2, it is evident that the required temperature range was not met fully either with cooling elements or without them in both modules (A and B); however, data loggers inside the packages with cooling elements recorded lower and more stable temperatures, which were closer to the set range.

All transported samples and samples stored in the laboratory refrigerator were tested for hemolysis percentage and the following hematologic parameters: WBC, neutrophil count, RBC, HGB, HCT, MCV, PLT and MPV. The results of the parameters tested are presented in Tables 1 and 2.

One set of blood samples were analyzed immediately after blood draw (CITM day 1) (Tables 1 and 2), whereas all other sets (with the exception of the samples transported in the summer to London) were analyzed after 48 hours. Due to the delayed flight from London to Zagreb in the summer, the samples from this flight

Table 1. Parameters measured in blood samples stored and transported by air in winter period

Parameter measured in winter		CITM day 1	CITM-C	BRU 1	BRU 2	LON 1	LON 2
Hemolysis degree (%)	Mean	-	0.28	0.32	0.37	0.31	0.40
	SD	-	0.13	0.15	0.17	0.14	0.19
	p*	-		0.103	**<0.001**	0.19	**<0.001**
	p**			**<0.001**		**0.01**	
WBC count ($x10^9$/L)	Mean	7.01	6.31	5.93	5.48	6.30	5.93
	SD	1.83	1.65	1.58	1.53	1.65	1.52
	p*			**<0.001**	**<0.001**	1	**<0.001**
	p**			**<0.001**		**<0.001**	
Neutrophil count ($x10^9$/L)	Mean	4.01	3.90	3.33	2.81	3.74	3.31
	SD	1.42	1.42	1.28	1.20	1.31	1.20
	p*			**<0.001**	**<0.001**	**<0.001**	**<0.001**
	p**			**<0.001**		**<0.001**	
MCV (fl)	Mean	84.0	84.5	84.9	85.4	84.9	85.4
	SD	4.7	4.7	4.7	4.8	4.7	4.8
	p*			**<0.001**	**<0.001**	**<0.001**	**<0.001**
	p**			**<0.001**		**<0.001**	
RBC count ($x10^{12}$/L)	Mean	4.94	4.94	4.96	4.97	4.94	4.96
	SD	0.37	0.35	0.35	0.39	0.37	0.37
	p*			1	0.377	1	1
	p**			1		1	
HGB (g/L)	Mean	146	146	147	147	147	147
	SD	9	9	9	9	9	9
	p*			1	**0.029**	**0.02**	0.24
	p**			1		1	
PLT ($x10^9$/L)	Mean	243	245	248	248	246	251
	SD	48	49	46	50	48	47
	p*			1	1	1	0.136
	p**			1		0.066	
MPV (fL)	Mean	8.19	7.50	7.33	7.19	7.34	7.31
	SD	1.17	1.04	0.95	0.98	0.97	0.91
	p*			0.317	**<0.001**	0.06	0.09
	p**			0.61		1	

CITM = Croatian Institute of Transfusion Medicine;
CITM-C = samples stored for 48 hours in a controlled refrigerator in CITM;
BRU 1 = airline transport Zagreb-Vienna-Brussels-Vienna-Zagreb with cooling elements;
BRU 2 = airline transport Zagreb-Vienna-Brussels-Vienna-Zagreb without cooling elements;
LON 1 = airline transport Zagreb-Vienna-London-Vienna-Zagreb with cooling elements;
LON 2 = airline transport Zagreb-Vienna-London-Vienna-Zagreb without cooling elements;
p*statistical significance of differences to non-transported samples stored in CITM;
p**statistical significance of differences between transported samples in controlled and uncontrolled conditions

Table 2. Parameters measured in blood samples stored and transported by air in summer period

Parameter measured in summer		CITM day 1	CITM-C	BRU 1	BRU 2	LON 1	LON 2
Hemolysis degree (%)	Mean SD p*	- - -	0.30 0.19	0.35 0.19 0.107	0.37 0.20 **0.043**	0.37 0.21 **0.016**	0.40 0.23 **0.004**
	p**			1		1	
WBC count (x10^9/L)	Mean SD p*	6.56 1.54	5.85 1.54	5.21 1.49 **<0.001**	5.42 1.30 **<0.001**	3.88 1.26 **<0.001**	4.69 1.17 **<0.001**
	p**			0.438		**0.0012**	
Neutrophil count (x10^9/L)	Mean SD p*	3.51 1.08	3.15 1.07	2.27 1.02 **<0.001**	1.94 0.70 **<0.001**	1.34 0.73 **<0.001**	1.40 0.61 **<0.001**
	p**			0,098		1	
MCV (fl)	Mean SD p*	84.3 3.5	84.8 3.6	84.8 3.5 1	88.5 4.1 **<0.001**	85.3 3.6 **<0.001**	89.8 4.2 **<0.001**
	p**			**<0.001**		**<0.001**	
RBC (x10^{12}/L)	Mean SD p*	4.98 0.28	5.00 0.29	4.97 0.28 **0.014**	4.94 0.29 **0.002**	4.94 0.27 **0.004**	4.93 0.29 **<0.001**
	p**			1		1	
HGB (g/L)	Mean SD p*	148 8	149 8	148 8 **0.04**	148 8 **0.003**	147 7 **0.03**	147 8 **<0.001**
	p**			1		1	
PLT (x10^9/L)	Mean SD p*	236 46	236 47	230 45 0.322	228 40 1	212 52 **<0.001**	233 43 1
	p**			1		**0.003**	
MPV (fL)	Mean SD p*	8.63 1.25	7.76 1.13	7.66 1.13 1	7.13 1.06 **<0.001**	7.18 0.84 **<0.001**	6.80 0.88 **<0.001**
	p**			**<0.001**		**<0.001**	

CITM = Croatian Institute of Transfusion Medicine;
CITM-C = samples stored for 48 hours in a controlled refrigerator in CITM;
BRU 1 = airline transport Zagreb-Vienna-Brussels-Vienna-Zagreb with cooling elements;
BRU 2 = airline transport Zagreb-Vienna-Brussels-Vienna-Zagreb without cooling elements;
LON 1 = airline transport Zagreb-Vienna-London-Vienna-Zagreb with cooling elements;
LON 2 = airline transport Zagreb-Vienna-London-Vienna-Zagreb without cooling elements;
p*statistical significance of differences to non-transported samples stored in CITM;
p**statistical significance of differences between transported samples in controlled and uncontrolled conditions

were analyzed after 72 hours. A significantly higher hemolysis percentage as one of the key indicators of a sample stability was found in the samples transported in the winter without cooling elements (BRU 2 and LON 2) compared to the samples stored in CITM (CITM-C). Moreover, a difference was also recorded in hemolysis measured among the samples transported on the same flights but in different conditions (it was higher in the samples transported without cooling elements).

The samples transported in the summer had significantly higher hemolysis in all samples except for BRU 1, and there were no significant differences between the same-flight samples transported in different conditions.

A statistically significant difference was recorded in the WBC and neutrophil count in the transported samples as compared to the samples stored in CITM, with the exception of WBC count in the samples

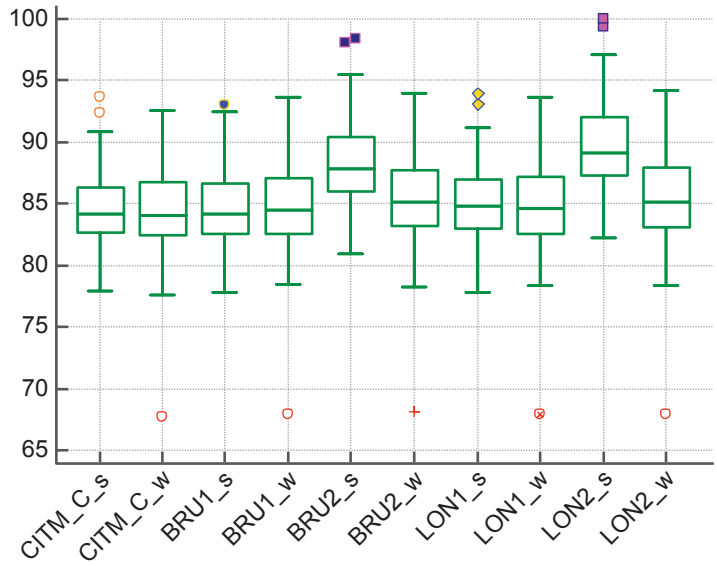

Fig. 3. Comparison of mean corpuscular volume according to transport and storage conditions with regard to testing performed in summer and winter conditions.

CITM-C = samples stored for 48 hours in a controlled refrigerator at the Croatian Institute of Transfusion Medicine;
BRU 1 = airline transport Zagreb-Vienna-Brussels-Vienna-Zagreb with cooling elements;
BRU 2 = airline transport Zagreb-Vienna-Brussels-Vienna-Zagreb without cooling elements;
LON 1 = airline transport Zagreb-Vienna-London-Vienna-Zagreb with cooling elements;
LON 2 = airline transport Zagreb-Vienna-London-Vienna-Zagreb without cooling elements;
W = winter; S = summer

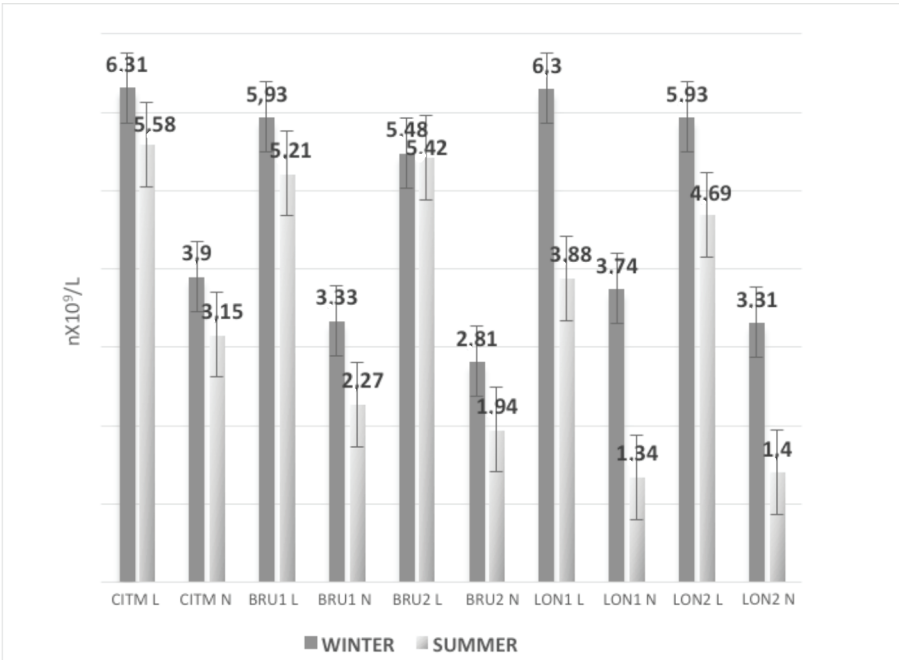

Fig. 4. Comparison of white blood cell count and neutrophil count according to transport and storage conditions with regard to testing performed in summer and winter conditions.

L = white blood cell count (n/L); N = neutrophil count (n/L)

transported in the winter to London with cooling elements (LON 1). A statistically significant difference for WBC and neutrophils was also evident between the same-flight samples transported with and without cooling elements in the winter, while the only significant difference in the summer was observed for WBC on London flights (LON 1 *vs*. LON 2).

A statistically significant difference was also recorded for MCV between the transported samples and the samples in CITM, except for BRU 1 in the summer. A statistically significant difference between the samples transported on the same flight with and without cooling elements was also evident for the same parameter.

The RBC count was stable in all samples transported in the winter without statistically significant difference when compared with CITM-C. The samples transported in the summer had a significantly lower RBC count in comparison with control samples, and there were no significant differences between the same-flight samples transported in different conditions.

There were no statistically significant differences in HGB values between the samples transported in controlled and uncontrolled conditions, but differences were statistically significant when comparing the transported samples with control samples (CITM-C), except for BRU 1 and LON 2 samples in the winter.

The PLT count remained relatively stable in all samples, and a statistically significant difference was only observed between LON 1 and CITM-C samples, and LON 1 and LON 2 samples transported in the summer.

The MPV values remained relatively stable in the samples transported in the winter, and only in BRU 2 samples they were significantly lower when compared to control samples. There were no significant differences in MPV values between the samples transported in different conditions on the same flight. In the summer, however, MPV was statistically significantly lower in all transported samples except for BRU 1. The difference in MPV between the samples stored in different conditions on the same flights was also significant.

Figure 3 shows differences in MCV values according to different atmospheric conditions, and an increase in their values was evident in the samples transported in warmer weather without cooling elements on the flights to Brussels and London.

The comparison of WBC and neutrophil counts obtained in winter and summer transport conditions (Fig. 4) showed an inversion of results. In colder weather, the WBC in the samples transported without cooling elements (BRU 2 and LON 2) was lower on both flights than the values measured in shipments with cooling elements. In warmer weather, the WBC was higher in the samples transported without cooling elements (BRU 2 and LON 2) than in the samples transported with cooling elements (BRU 1 and LON 1).

At the same time, neutrophil count was lower in all types of transport in warmer atmospheric conditions.

Discussion

Transport of people and different types of freight has been continuously growing for decades now, so it is of no surprise that more attention is placed on its impact on the security of both people and freight transported, regardless of the type of transport. Transport conditions for certain types of freight are being more and more formally specified in order to preserve the quality and security of the freight. Blood sample quality and factors influencing their quality have long been in the focus of attention of medical professions concerned with their monitoring and continuous improvement. Transportation, storage, distribution and, of course, medical professionals have been trying for years to detect all important factors which might influence the stability of such sensitive shipments[5,6,10]. Such studies are particularly important considering the fact that blood samples are transported on a daily basis either for calibration, quality control or diagnostic purposes, and that transport conditions as part of the preanalytical phase of testing may greatly affect decisions on the performance of testing systems, and on the laboratory results of patients.

In 1989, a group of experts studied the stability of certain plasma samples in air transport[11], but without accompanying measurements of transport conditions. Another two groups of researchers[1,2] studied changes to samples transported by road, concluding that transport needs to be done with cooling elements. In 1995, Almanza *et al*. compared the quality of samples transported by air and samples stored in simulated conditions, concluding that air transport influenced significantly the sample quality[3]. All those studies have also inspired international organizations to define transport conditions for pharmaceuticals, dangerous goods, etc.[12-14].

Our study was focused on the impact of transport conditions on the stability of samples transported pri-

marily by air, in packages with and without cooling elements, which represents a combination of previous studies[2,11]. We also tried to assess the effect of seasons (outdoor atmospheric conditions) in which samples were transported[3]. We assessed the impact of transport conditions by measuring a series of hematologic parameters in the samples stored in ideal conditions (in laboratory refrigerator at +4 °C), and comparing them with the results of the same parameters measured in the samples after having been transported by air to two different destinations (Zagreb-Vienna-Brussels-Vienna-Zagreb and Zagreb-Vienna-London-Vienna-Zagreb).

The study was so designed that we were able to track the air shipments in real time owing to the Radio Frequency Identification technology and interdisciplinary cooperation with colleagues working in air transport.

According to the results obtained, it is evident that the samples transported with cooling elements and stored in controlled warehousing conditions were generally better preserved, with less deviation from the results obtained in control samples.

When comparing temperature profiles in both modules (A and B), shipments stored and transported in standard conditions showed different deviations from temperature optimum (from +2 °C to +8 °C) as compared with shipments stored and transported with cooling elements. Data loggers placed inside the packages recorded a smaller deviation from the set limits. Scottish researches Elliott and Halbert came to the same conclusion in 2008, when they studied transport by road and packed their samples on dry ice[15].

The degree of hemolysis is considered as one of the key stability indicators of samples. By lowering temperature to +4 °C, the erythrocyte metabolism and the glycolysis process are slowed down to the lowest possible level sufficient for the survival of erythrocytes[16,17]. Our results on hemolysis corresponded to previous studies, in which temperatures were changed using different means, and transport was limited to road transport only. The lowest hemolysis percentage was established in the samples stored in laboratory refrigerator at +4 °C and, statistically, it differed significantly from the samples transported in the summer and winter period without cooling elements.

As expected, the WBC count was statistically significantly different in the transported samples compared to those stored in the laboratory. Moreover, we noted a difference between the samples transported with and without cooling elements on both flights in the winter. During transport in winter conditions, the WBC was lower in shipments without cooling elements, whereas in the summer period it was higher on both flights. It is evident that atmospheric conditions influenced the inversion of results, and it is possible that the longer transport time to London also played a role. The samples from the London flight in the summer were analyzed 72 hours after blood draw, so they were not exactly comparable with control samples; however, they reflected a real-life event which might occur in transport, which is why we decided to analyze these results as well.

Being the most sensitive part of WBC, neutrophil granulocytes change in number due to outdoor temperature factors, especially the cold. Therefore, test results obtained in warmer weather, when there were no significant differences in temperature, are of no surprise, not even in the case of the aforementioned delayed transport from London, which must have influenced the results due to transport duration.

Changes were expected to occur in MCV considering the known mechanisms that take place during storage due to the inflow of extracellular fluid into cells[16–18]. This rise can directly affect the HCT value and the mean corpuscular hemoglobin concentration (MCHC).

The results presented in this study suggest a conclusion that the stability of blood samples is preserved to a greater extent in packages with cooling elements compared to identical packages without cooling elements. A possible limitation of our study might be the fact that, in order to achieve full credibility of results, we should have cooled all packaging elements and packed the samples in a room at +4 °C. By doing so, we would have avoided initial oscillations of the temperature curves. This also indicates the importance of care when arranging certain sensitive packages within the transport area since an inappropriate position of a package might also influence temperature oscillations and, indirectly, changes to sensitive blood parameters.

Blood samples certainly belong to a very sensitive shipment type, and it is crucial to ensure that cooling elements are added to the shipment during transport, as well as to consider a possible location within the transport area, which should comply with all the stipulated requirements.

The influence of sample storage temperature has already been described in the literature[19,20], as well as the impact of the time lapse between taking the sample and testing, but it has not been described yet how and to what extent storage and transport influence certain parameters. According to the paper published by Amukele *et al*. in 2017, drone transport of blood products in controlled conditions and in a duration of 26.5 minutes had no effect on their quality according to the parameters measured[21]. Our research is the first attempt ever to study the impact of air transport conditions on the quality of blood samples, including a longer and more demanding transport with great atmospheric and temperature differences, as well as analyzing a larger number of hematologic parameters.

Conclusion

To the best of our knowledge, a study like this on the impact of air transport conditions on the blood sample quality has never been conducted before. Results obtained by comprehensive multidisciplinary research indicate the importance of the impact of transport and microclimate on the blood sample quality.

A statistically significant difference in test results compared to control samples was observed for several parameters and in both shipping modules (flights to Brussels and London). The same was observed when different transport conditions (packages with and without cooling elements) were applied.

Changes due to the possible effects of outdoor temperatures were also recorded, that is, between the tests performed in the winter and summer period. By comparing test results of WBC count obtained in the case of transport during the colder and warmer period, an inversion of results was observed. On both flights during colder weather, test results of the samples transported without cooling elements showed lower WBC values than of the samples transported with cooling elements, whereas the results were reverse during warmer weather.

According to the results obtained, we can conclude that microclimate in conditions with cooling elements is obviously insufficient to preserve storage conditions which exist in a controlled laboratory refrigerator. The research conducted suggest the need of a new study, which should include measurement of other parameters, and which would require an interdisciplinary cooperation and a more comprehensive study design.

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Sažetak

UTJECAJ ZRAČNOG PRIJEVOZA NA KVALITETU UZORAKA KRVI

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Cilj ovog istraživanja bio je utvrditi utjecaj zračnog prijevoza na uzorke krvi pakirane s rashladnim elemenatima i bez njih, kao i utjecaj vanjske temperature na kvalitetu uzorka. U venskim uzorcima 38 darivatelja krvi tijekom zime i njih 36 tijekom ljeta određeni su stupanj hemolize i kompletna krvna slika. Jedan uzorak po ispitaniku ostavljen je u kontroliranim uvjetima na +4 ˚C. Dva seta uzoraka poslana su zrakoplovom iz Zagreba u Bruxelles, jedan s rashladnim elemenatima i jedan bez njih, a druga dva seta poslana su u London po istom načelu. Pakovanja s rashladnim elementima čuvana su u kontroliranim skladišnim uvjetima u zračnim lukama (+2 ˚C do +8 ˚C), dok su pakovanja bez rashladnih elemenata čuvana u ambijentnim skladišnim uvjetima. Uređaji za kontinuirano mjerenje temperature korišteni su za nadzor temperature tijekom transporta. Naše istraživanje otkrilo je statistički značajne razlike u nekoliko hematoloških parametara kada se uspoređuju uzorci pohranjeni u kontroliranim laboratorijskim uvjetima i oni koji se transportiraju zračnim prijevozom. Te su razlike bile izraženije u uzorcima transportiranim tijekom ljeta. Uvjeti transporta bez rashladnih elemenata imali su dodatni negativni utjecaj na kvalitetu uzoraka. Transport uzoraka pomoću rashladnih elemenata i kontrolirani uvjeti skladištenja u zračnim lukama ponekad nisu dovoljni za održavanje laboratorijskih uvjeta skladištenja.

Ključne riječi: *Kvaliteta uzoraka krvi; Uvjeti transporta; Hematološki parametri*