Stability of Biochemical Components in Blood Samples Transported by Tempus600®/GLP Robot Loader

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Introduction

Department of Clinical Immunology and Biochemistry, Lillebaelt Hospital, Denmark and TIMEDICO A/S, Denmark have developed Tempus600®, a pneumatic tube system (PTS) consisting of long pipes with a diameter of 2.5 cm. It transports blood tubes by air pressure, around 10 m/s, from hospital wards, emergency departments or outpatient clinics to laboratory. The tubes can be sent directly, without need of packing them before transport and without the need to enclose request forms, since the samples are labeled with patient and barcode ID. At the end of the Tempus-pipes a robot receives and place the tubes onto a Sysmex GLP transportsystem after the principle ”first in first out” (FIFO). The GLP system then delivers the tubes to centrifuges and analytical equipment. The whole system has decreased the total turnaround time (ToTAT) from sampling the patient to the doctor receiving the result from 2-3 hours to less than 60 min.

Objectives

Validate the Tempus600® system in combination with the FIFO Sysmex GLP robot reception system as a technical validation on the 89 most frequent or critical components.

Conclusion

The Tempus600®/FIFO GLP robot reception system can be used for transport of the majority of routinely used analytical tests. This is especially important for troponin for the diagnosis of acute myocardial infarction and lactate for detection of septicemia.

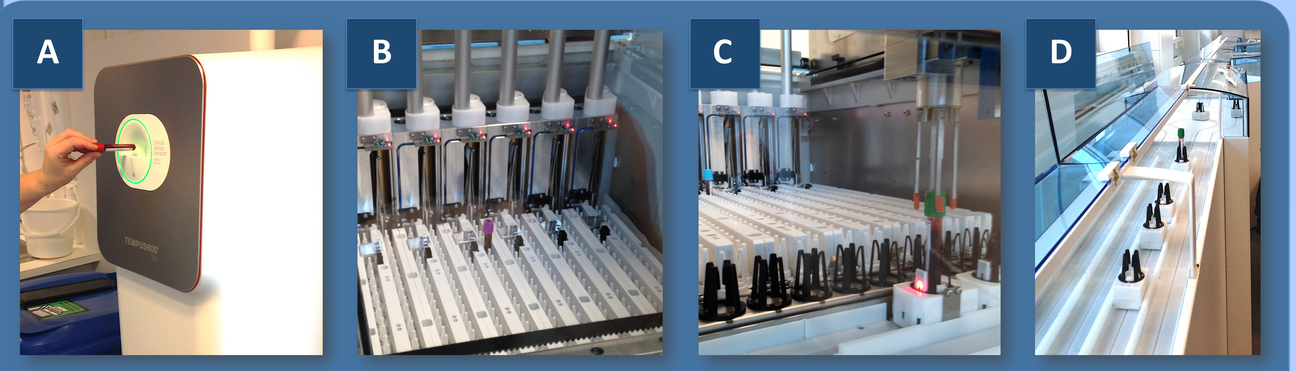
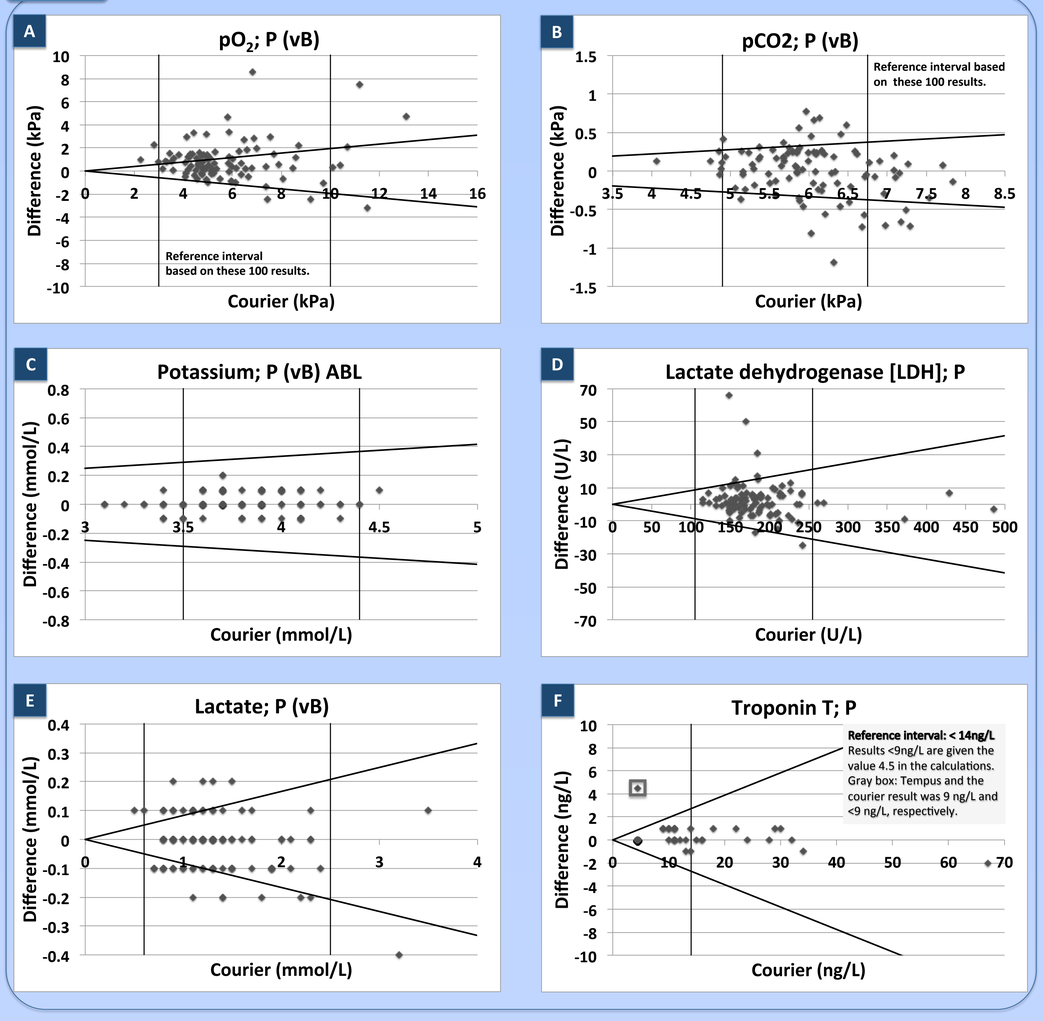


Figure 1 A blood tube is sent off through a Tempus Vita-sending station at Vejle Hospital (A). The sending station works the same way as a reverse vending machine. The tube is delivered through the pipes to the receiving-module in the laboratory (B). It is placed onto the GLP transportsystem by the GLP FIFO robot (C) and delivered to the centrifuges and/or analysis machines using small “cars” (D).

Figure 2



Results and discussion

Table 1 shows statistics from the comparison of the transport forms for all 89 analysis. Only results from patients where both tubes were available (Tempus and courier) were included.

Difference plots for selected analysis are shown in fig. 2A-F. O_2 saturation, oxyhemoglobin and pO_2 deviated too much from a clinical point of view (only pO_2 is shown, fig. 2A). pO_2 could deviate as much as 4 kPa at the value of 8, which at least in arterial blood is considered critical.

pCO_2 though exceeding limits might be clinical acceptable for accessing patients with obstructive lung disease for hypercapnia based on the rather low differences in measurements between courier and Tempus transported venous blood (fig 2B). Supported by measurement of HCO_3^- in venous blood patients status could be sufficiently good evaluated for daily clinical practices.

For K^+, previously reported sensitive to temperature, time and transport, the transport forms were equally good and poses no problems from a clinical point of view (fig. 2C). As the fig. 2D shows there are a few outliers in the reference range which are probably patient specific and in general it can be concluded that lactate dehydrogenase can be transported by the Tempus system though if values are critical within the reference range a sample should be transported manually for immediate measurement in the lab. In cases of high values, this could be repeated on a special sampling. The same applies to lactate (fig. 2E). There is no problems in transporting Troponin T (fig. 2F).

Table 1

Analysis	Courier		Tempus		Difference (Temp-courier)		n	CV_{anal}%	Unit	Within acceptance lines
	Mean	SD	Mean	SD	$Mean_{diff.}$	$SD_{diff.}$				
25-Hydroxy-Vitamine D3;P	64.43	33.79	64.09	33.60	-0.34	-0.19	100	10	nmol/L	+
Activated partial thromboplastin time [APTT];P	25.38	4.21	25.38	4.01	0.00	-0.19	99	2	s	+
Alanine aminotransferase [ALAT];P	32.93	15.37	32.70	15.29	-0.23	-0.07	100	4	U/L	+
Albumin;P	44.23	3.10	43.93	3.07	-0.30	-0.03	100	3	g/L	+
Alkaline phosphatase;P	77.16	30.60	77.02	30.86	-0.14	0.26	100	4	U/L	+
Amylase, pancreatic type;P	28.64	15.29	28.60	15.55	-0.04	0.26	100	6	U/L	+
Antithrombin;P	1.05	0.12	1.05	0.12	0.00	0.00	98	3	10E3 IU/L	+
Antitrypsin;P	1.36	0.36	1.36	0.37	0.00	0.01	100	4	g/L	+
Base excess (aktuel);P(vB)	1.42	2.07	1.25	2.04	-0.17	-0.03	100	0.05*	mmol/L	+
Basophils;B	0.04	0.02	0.04	0.02	0.00	0.00	100	0.007**	10E9/L	+
Bilirubins;P	7.69	3.71	7.71	3.69	0.01	-0.02	100	6	µmol/L	+
C-reaktivt protein [CRP];P	7.00	18.37	6.92	18.20	-0.08	-0.18	100	14	mg/L	+
Calcium, free ionized (unbound), pH=7.4;P(vB)	1.12	0.04	1.12	0.04	0.00	0.00	100	2	mmol/L	+
Calcium, free ionized (unbound);P(vB)	1.13	0.04	1.13	0.04	0.00	0.00	100	2	mmol/L	+
Calcium;P	2.34	0.08	2.33	0.08	-0.01	0.00	100	2	mmol/L	+
Carbon monoxide hemoglobin;Hb(B)	0.02	0.01	0.03	0.01	0.00	0.00	100	5	mol fr.	+
Chloride;P(vB)	107.86	3.72	108.01	3.69	0.15	-0.03	100	1	mmol/L	+
Cholesterol HDL;P	1.51	0.54	1.50	0.54	-0.01	0.00	100	6	mmol/L	+
Cholesterol LDL;P	3.06	1.03	3.05	1.03	0.00	0.00	100	4	mmol/L	+
Cholesterol;P	4.91	1.15	4.90	1.15	-0.01	0.00	100	3	mmol/L	+
Cortisol;P	265.58	126.38	263.49	125.20	-2.09	-1.18	100	6	nmol/L	+
Creatine kinase;P	106.95	57.97	107.03	57.69	0.08	-0.28	100	5	U/L	+
Creatinine;P	81.49	38.16	81.50	38.87	0.01	0.71	100	4	µmol/L	+
Creatinine;P(vB) ABL	77.96	37.86	77.87	37.96	-0.09	0.10	100	4	µmol/L	+
Digoxin;P	0.10	0.00	0.10	0.00	0.00	0.00	100	7	nmol/L	+
Eosinophils;B	0.17	0.13	0.17	0.13	0.00	0.00	100	10.0	10E9/L	+
Erythrocyte volume fraction;B	0.41	0.04	0.41	0.04	0.00	0.00	100	1.8	vol. fr.	+
Erythrocyte volume fraction;B(vB) ABL	0.43	0.05	0.43	0.05	0.00	0.00	100	2	vol. fr.	+
Erythrocytes;B	4.64	0.58	4.66	0.58	0.01	0.00	100	1.6	10E12/L	+
Estradiol;P	0.22	1.10	0.21	1.10	0.00	0.00	100	8	nmol/L	+
Ethanol;P	2.57	0.65	2.50	0.00	-0.06	-0.65	100	5	mmol/L	+
Ferritin;P	235.66	373.52	233.77	367.32	-1.89	-6.20	100	7	µg/L	+
Fibrin D-Dimer;P	0.70	2.04	0.70	2.04	0.00	0.00	100	5	mg/L FEU	+
Follicle-stimulating hormone [FSH];P	29.71	34.95	29.65	34.75	-0.06	-0.19	100	5	IU/L	+
gamma-Glutamyl transferase;P	52.59	66.29	52.43	65.86	-0.16	-0.43	100	4	U/L	+
Glucose;P	6.90	3.43	6.93	3.42	0.03	-0.01	100	3	mmol/L	+
Glucose;P(vB) ABL	6.68	3.43	6.67	3.35	-0.01	-0.08	100	5	mmol/L	+
Haptoglobin;P	1.50	0.94	1.50	0.95	0.00	0.01	100	4	g/L	+
Hemoglobin [MCHC]; Erc(B)	20.86	0.67	20.90	0.66	0.04	-0.01	100	2.9	mmol/L	+
Hemoglobin;B	8.50	1.00	8.51	1.01	0.01	0.01	100	1.5	mmol/L	+
Hemoglobin;B(vB) ABL	8.61	0.98	8.53	1.25	-0.09	0.27	100	2	mmol/L	+
Hemolytic index [HI];P	3.26	1.79	3.83	4.15	0.57	2.36	100	3	µmol/L	(+)
Hydrogen carbonate (standard);P	25.05	1.75	25.04	1.73	-0.01	-0.02	100	0.13***	mmol/L	+
Icterus;P	12.66	5.05	12.66	5.17	0.00	0.12	100	3	µmol/L	+
Immunglobulin A (g/l);P	2.31	1.08	2.31	1.07	-0.01	-0.02	100	4	g/L	+
Immunglobulin G;P	9.53	2.59	9.49	2.54	-0.04	-0.05	100	3	g/L	+
Immunglobulin M;P	0.92	0.55	0.92	0.55	0.00	0.00	100	6	g/L	+
INR;P	1.12	0.46	1.12	0.46	0.00	-0.01	99	3	INR	+
Iron;P	16.02	6.80	16.10	6.80	0.08	0.00	100	5	µmol/L	+
Lactate dehydrogenase [LDH];P	186.57	54.25	189.28	53.73	2.71	-0.52	100	3	U/L	+ (see discussion)
Laktate;P(vB)	1.34	0.51	1.33	0.50	-0.01	-0.02	100	3	mmol/L	+ (see discussion)
Leukocytes;B	7.50	2.76	7.50	2.78	0.00	0.02	100	3.0	10E9/L	+
Lipide index;P	17.28	14.66	18.49	14.72	1.21	0.07	100	6	A.U.	+
Lutropin [LH];P	15.53	15.33	15.47	15.35	-0.07	0.02	100	5	IU/L	+
Lymphcytes;B	1.94	0.82	1.93	0.83	-0.01	0.01	100	5.1	10E9/L	+
Magnesium;P	0.79	0.06	0.79	0.06	0.00	0.00	100	4	mmol/L	+
Mean corpuscular hemoglobin [MCH];Erc(B)	1.84	0.13	1.84	0.13	0.00	0.00	100	2.2	fmol	+
Mean cell volume [MCV];Erc(B)	88.10	5.25	87.96	5.24	-0.14	-0.01	100	2.1	fL	+
Methemoglobin;Hb(vB)	0.01	0.00	0.01	0.00	0.00	0.00	100	3	mol fr.	+
Monocytes;B	0.59	0.23	0.59	0.24	0.00	0.01	100	7.0	10E9/L	+
Neutrophils;B	4.69	2.27	4.71	2.28	0.02	0.01	100	5.0	10E9/L	+
Orosomucoid;P	0.93	0.39	0.93	0.39	0.00	0.00	100	3	g/L	+
Oxygen saturation.;Hb(vB)	0.70	0.17	0.76	0.15	0.06	-0.02	100	1	mol fr.	÷
Oxyhemoglobin;Hb(tot.;vB)	0.68	0.16	0.73	0.14	0.05	-0.02	100	1	mol fr.	÷
pCO2;P(vB)	6.02	0.72	6.03	0.71	0.00	-0.01	100	2	kPa	(+) (see discussion)
pH;P(vB)	7.39	0.03	7.38	0.03	0.00	0.00	100	0.1		+
Phosphate;P	1.02	0.18	1.02	0.18	0.00	0.00	100	3	mmol/L	+
Platelets, PDW;B	11.92	2.15	11.92	2.11	0.00	-0.04	99	2.2	vol. fr.	+
Platelets;B	268.68	98.34	267.81	95.92	-0.87	-2.42	100	3.0	10E9/L	+
pO2;P(vB)	5.73	1.99	6.55	2.71	0.83	0.72	100	7	kPa	÷ (see discussion)
Potassium;P	3.97	0.33	3.97	0.31	0.00	-0.01	100	2	mmol/L	+
Potassium;P(vB) ABL	3.81	0.31	3.82	0.30	0.01	-0.01	100	3	mmol/L	+
Progesterone;P	3.65	19.44	3.64	19.42	-0.02	-0.02	100	8	nmol/L	+
Protein;P	72.44	4.65	72.37	4.59	-0.07	-0.06	100	2	g/L	+
Red cell distribution width [RDW];Erc(B)	0.14	0.02	0.14	0.02	0.00	0.00	100	3.0	vol. fr.	+
Reticulocytes;B	70.66	27.95	70.00	28.41	-0.66	0.46	100	10.0	10E9/L	+
Rheumatoid factor;P	7.50	8.40	7.28	8.23	-0.22	-0.17	100	4	10E3 IU/L	+
Sex hormone-binding globulin;P	61.33	39.44	61.19	39.36	-0.14	-0.07	100	5	nmol/L	+
Sodium;P	138.61	2.99	138.60	2.97	-0.01	-0.02	100	1	mmol/L	+
Sodium;P(vB) ABL	136.30	3.34	136.19	3.33	-0.11	-0.02	100	2	mmol/L	+
Thyrotropin [TSH];P	2.05	4.17	2.05	4.20	0.00	0.03	100	5	10E-3 IU/L	+
Thyroxine [T4];P	15.72	3.34	15.72	3.46	0.00	0.12	100	4	pmol/L	+
Transferrin;P	31.85	5.61	31.72	5.54	-0.13	-0.07	100	3	µmol/L	+
Triglyceride;P	1.71	1.45	1.71	1.44	0.00	0.00	100	3	mmol/L	+
Triiodothyronine [T3];P	4.44	0.71	4.44	0.71	0.00	0.00	100	7	pmol/L	+
Troponin T;P	8.42	8.91	8.53	8.83	0.12	-0.08	100	7	ng/L	+
Urate;P	0.31	0.09	0.31	0.09	0.00	0.00	100	4	mmol/L	+
Urea/Carbamide;P	5.45	2.36	5.51	2.34	0.05	-0.02	100	4	mmol/L	+
Vitamin B12;P	376.36	213.44	376.81	213.51	0.45	0.07	100	6	pmol/L	+

*SD: 0.5mmol/L **SD: 0.007 x 10E9/L ***SD: 0.5mmol/L

Methods

100 patients from the hospitals outpatient clinic were included without consideration to diagnosis and with a usual mix of diseases. Duplicate blood samples (A and B) were obtained by a trained phlebotomist. The A samples were sent by Tempus600® and the B samples were manually transported by a courier technologist who carried the blood samples to the laboratory. In the laboratory, all samples (A and B) were treated in parallel and the paired samples were analyzed at the same time, to avoid analytical variation. The five different blood tubes (1 pink, 1 purple, 1 blue and 2 green tubes per set) were treated after the guidelines required by the analytical methods.

Comparisons between the two transportforms were made using difference plots as described by Altman and Bland, using the reference methodology courier transport, as the abscissa, and Tempus result minus courier result as the difference. Limits mark the combined 95% uncertainty, based on only analytical CV. They are calculated using the formula:

$$expected\ difference < 1.96 * v2 * CV_{anal}$$

If more than 5% of the results exceed the limits, it indicates that there is a difference between the transport forms.

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