



## Improved quality of samples and laboratory turnaround time using 3.5 mL low vacuum BD Vacutainer<sup>®</sup> Barricor tubes in the emergency department

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### ABSTRACT

**Background:** Centrifugation is a consuming time step which participates to increase the turnaround time (TAT) in laboratories, likewise hemolysis sample that needs a re-sampling could delay management of patients. Recently, it has been postulated that BD Barricor<sup>™</sup> tube could allow to decrease the centrifugation time and prevent hemolysis, two key feature to ensure high-quality results.

Aim of the study was to evaluate the impact of replacing 4 mL BD vacutainer heparin lithium tube by low vacuum 3.5 mL BD vacutainer Barricor<sup>™</sup> tube in an emergency department (ED) on hemolysis rate and TAT.

**Methods:** Data of hemolysis index (HI) and TAT were compared between the first period of 15 days using 4 mL BD vacutainer heparin lithium tubes with 15 min at 2000xg as centrifugation setting and a second period of 15 days using BD vacutainer Barricor<sup>™</sup> tube centrifuged 3 min at 4000xg.

**Results:** A significantly reduced time duration between reception of sample and available results in informatics lab system was observed with the reduction time of centrifugation allowed by use of Barricor<sup>™</sup> tube compared to regular heparin lithium tubes ( $p < 0.001$ ). A significative decrease in hemolysis rate also occurred in the second period as samples with HI < 10 reached from 52.5% in the first period to 68.5% ( $p < 0.001$ ) in the second.

**Conclusion:** Low vacuum Barricor<sup>™</sup> tubes allowing a higher speed of centrifugation improve lab TAT without impairment of sample quality as a significant reduction of hemolysis was observed, a double advantage which is of particular interest for ED.

## 1. Introduction

Providing results with a reduced turnaround time (TAT) is a major challenge for laboratories, especially when working for emergency department (ED). As a critical parameter, TAT is a key indicator of laboratory performance and should be monitored as a part of quality management. Overall TAT is defined as the duration time between sampling and the availability of results for prescribers that include the blood transport, centrifugation step, analytical measurement and post-analytical step. Lab TAT could be defined as the

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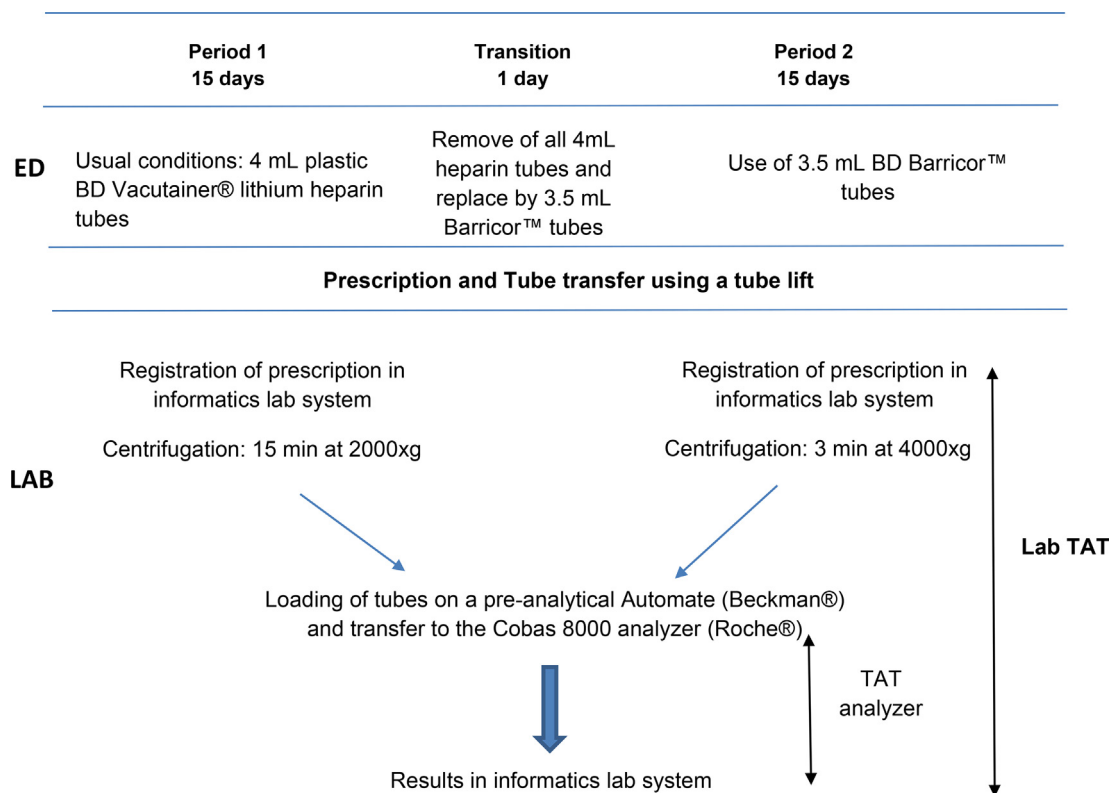


Fig. 1. Study design.

duration time between reception of sample and available results in lab system. Among process involved in lab TAT, the centrifugation is one of them that can be modulated. Indeed, new BD Barricor™ tubes (Becton Dickinson, NY, USA) allow a higher speed of centrifugation and therefore reduced the time of centrifugation without altering results [1,2]. So, it could be hypothesized that reduction of centrifugation time could reduce the lab TAT.

Beyond TAT management, laboratories must also reduce laboratory errors that could be due to pre-analytical, analytical or post-analytical steps. Today, pre-analytical errors remain the main source of errors reaching up to 60% [3] and could be related to the external laboratory pre-analytical step named pre-pre-analytical that include the blood sampling and transport [4]. Indeed, blood sampling is the cornerstone of pre-pre-analytical step as errors in anticoagulant type, defect in fulfilling tubes or generation of hemolysis can alter the quality of laboratory results and efficient work-up of patients. Moreover, during the pre-analytical step in the lab, centrifugation setting could also generate hemolysis according to a higher speed or higher time used. In all case, hemolysis sample should need a re-sampling and delayed management of patients. So, the absence of hemolysis is one of the most important quality indicators for biochemistry as many analytes are influenced at the up or at the down with sample hemolysis [5]. Hemolysis index (HI) is easily measured through pre-analytical automate or within the analytical step and is now implemented in external quality control. Hemolysis as the main cause of unsuitable samples [5] is even more frequent in ED compared to other units [6,7]. Type of sampling is highly involved in the occurrence of hemolysis especially intravenous catheter [6,7]. Several studies identified a benefit using low vacuum tube compared to regular tubes in order to decrease hemolysis rates [8,9] although contradictory results remain [10]. More recently this advantage was confirmed with the use of new reduced vacuum BD Barricor™ tubes [11].

The aims of our study were to compare i) the hemolysis rate on samples from ED using either BD 4 mL heparin lithium tubes or BD low vacuum 3.5 mL Barricor™ heparin tubes and ii) the lab TAT defined as time duration between reception of samples from ED and releasing results in informatics lab system.

## 2. Material and methods

### 2.1. Study design

Prior to the start of the study, a reminder of recommendations of art to perform blood sampling was given in the adult ED. Thereafter, all samples received to the lab from ED were included in the Period 1 consisting of 15 days of observational study without change of usual conditions. As illustrated in Fig. 1, blood sampling for biochemistry were all performed using 4 mL plastic BD Vacutainer® lithium heparin tubes (Becton Dickinson, NY, USA) during the first period. Samples were transferred to the lab through a tube lift and order

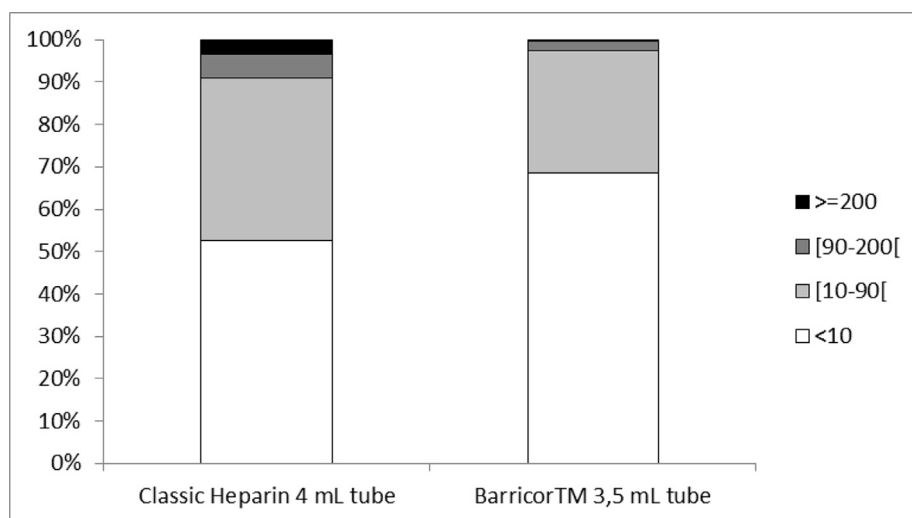


Fig. 2. Percentage of samples according to HI values and type of tubes.

prescription was registered in the informatics lab system. Tubes were then centrifuged during 15 min at 2000xg in an emergency dedicated Multifuge X3 FR Centrifuge (Heraeus, Germany) and loaded on a pre-analytical Automate (Beckman<sup>®</sup>) to be sorted to an emergency area. Then tubes were loaded on a Cobas 8000 analyzer (ISE Module, c701, c502, e601, Roche<sup>®</sup>). After this first period, all 4 mL BD Vacutainer<sup>®</sup> lithium heparin tubes were removed from the ED and replaced by 3.5 mL BD Vacutainer Barricor<sup>™</sup> lithium heparin tubes during the one day of transition. The second period consisted of 15 days with use of Barricor<sup>™</sup> tubes for all biochemistry requests from the ED. The transfer of samples from ED and registration of prescriptions were done in the same settings as the first period. Barricor<sup>™</sup> tubes were then centrifuged for 3 min at 4000xg in an emergency dedicated Multifuge X3 FR Centrifuge (Heraeus, Germany) prior to be treated with the same process than in the first period.

## 2.2. Methods

HI was measured in the conventional unit (free hemoglobin mg/dl) on all tubes using the Cobas 8000 Roche<sup>®</sup> test SSI-2 on a c701 module. According to HI interference claimed by manufacturers and analyzer flag, we studied HI distribution between the range <10; [10–90[; [90, 200[; ≥200 mg/dL. For example, HI value of 10 is the first interference step for haptoglobin, while 90 is the cut-off for potassium. In our routine practice, for all analytes with HI higher than manufacturer's claim, results are provided with the comment "hemolysis interference" on the lab report. We further compared the theoretical rate of re-sampling needing in accordance with a higher HI index than manufacturer's data for eight analytes of importance in ED that are sodium, potassium, bicarbonate, creatinine, Alanine Aminotransferase (ALAT), Aspartate Aminotransferase (ASAT), C-Reactive Protein (CRP), and high sensitive Troponin T (hs-cTnT).

Lab TAT was calculated from the sample reception in the lab to the report dispatch in the informatics lab system. The eight chemistry analytes were measured on the four different Cobas 8000 modules: Sodium and potassium on ISE module; ALAT, ASAT, creatinine, and CRP on c701 module, bicarbonate on c502 module and hs-cTnT on an e602 module. In addition, analyzer's TAT was recorded for each parameter as the time duration between the scan of the tube by the Cobas 8000 analyzer and return of results in the middleware.

## 2.3. Statistical analysis

Results of eight biochemistry analytes and HI were extracted from the lab system for the two periods. Lab TAT was provided by the informatics lab, while analyzer TAT was recorded on the middleware. Comparison of HI distribution among the range <10; [10–90[; [90, 200[; ≥200 between the two periods was performed using Chi<sup>2</sup> square test with Yate's correction. Comparison of TAT between the two periods was performed using a Wilcoxon test. Comparison of percent of results available at 30 min between the two periods was performed using Chi<sup>2</sup> square test with Yate's correction. The level of significance was set at  $p < 0.05$ .

## 3. Results

1243 samples on regular 4 mL BD Vacutainer<sup>®</sup> lithium heparin tubes were received in the lab from ED during the first 15 days period while 1269 samples on 3.5 mL BD Vacutainer Barricor<sup>™</sup> lithium heparin tubes were collected during the second period.

### 3.1. Hemolysis rate

A significant difference of HI distribution between the two periods was observed (global  $p$ -value  $< 0.001$ ) as illustrated in Fig. 2. The

**Table 1**Comparison of re-sampling need according to Roche<sup>®</sup> values for hemolysis interference for each analyte during the two periods.

	Roche <sup>®</sup> values mg/dl	Period 1	Period 2	p value
		HI over the limit	HI over the limit	
		(%)	(%)	
ALAT	90	8.5	2.2	<0.001
ASAT	40	16.7	5.6	<0.001
Bicarbonate	600	0.2	0	0.48
Creatinine	800	0.2	0	0.52
CRP	1000	0.1	0	0.99
Potassium	90	8.6	2.4	<0.001
Sodium	1000	0.1	0	0.99
Hs-cTnT	100	7.0	2.3	<0.001

ALAT, Alanine Aminotransferase; ASAT, Aspartate Aminotransferase; CRP, C-Reactive Protein (CRP); Hs-cTnT, High sensitivity Troponin T.

**Table 2**

Lab turnaround time (TAT) 95% and percent of results available at 30 min according to the period.

	n	Period 1	TAT 95% (min)	n	Period 2	TAT 95% (min)
		% of results at 30 min			% of results at 30 min	
ALAT	448	8	77	502	40*	70*
ASAT	448	7	79	502	39*	75*
Bicarbonate	1053	9	71	1057	51*	62*
Creatinine	1081	3	76	1101	39*	65*
CRP	1038	3	75	1053	40*	64*
Potassium	1094	15	75	1103	58*	61*
Sodium	1084	16	70	1099	59*	59*
Hs-cTnT	673	2	88	703	14*	77*

ALAT, Alanine Aminotransferase; ASAT, Aspartate Aminotransferase; CRP, C-Reactive Protein (CRP); Hs-cTnT, High sensitivity Troponin T.

\*, p &lt; 0.001: comparison of period 2 versus period 1.

proportion of sample without hemolysis (HI < 10) was improved from 52.5% with the use of regular 4 mL heparin tube to 68.5% (p < 0.001) when using low vacuum Barricor<sup>TM</sup> tube. This increase of sample quality was associated with a significantly decreased percentage of hemolyzed samples with low vacuum Barricor<sup>TM</sup> tube in each categories. For example for HI ≥ 90 mg/dl, we observed a reduction from 9.2% to 2.5% between the first vs the second period (p < 0.001). Furthermore, the percent of samples with a theoretical need of re-sampling according to HI values provided by Roche<sup>®</sup> were significantly lower with the use of Barricor<sup>TM</sup> tube compared to classical 4 mL Heparin tube, as illustrated in Table 1. For example 2.4% vs 8.6% for potassium (p < 0.001) and 2.3% vs 7.0% for Hs-cTnT (p < 0.001) for period 2 vs period 1 respectively.

### 3.2. Lab TAT

Duration time between the reception of samples from ED and available results in informatics lab system was significantly reduced with the use of BD Barricor<sup>TM</sup> lithium heparin tube compared to BD regular lithium heparin tube for all parameter studied. Analyzer's TAT was similar for all the eight analytes studied between the two periods (data not shown). The lab TAT 95% was reduced to more than 10 min for some analytes such as creatinine, CRP, potassium, sodium, and Hs-cTnT in the second vs the first period (Table 2). Furthermore, considering a fixed duration time of 30 min, the number of samples with available results increased for every analyte such as from 15% to 58% for potassium. Comparison of lab TAT for each parameter was reported in Fig. 3.

## 4. Discussion

Our study showed that the use of low vacuum BD Barricor<sup>TM</sup> tube in ED reduce lab TAT because allowing high-speed centrifugation and reduce hemolysis occurrence in samples. In consequence, these results demonstrated an improvement in the quality of specimen and laboratory performance. These findings are important for ED in particular, which is known to have the highest hemolysis rate compared to other clinical departments and are regularly overcrowded. Taking together, reduction of TAT and prevention of re-sampling due to less hemolysis could shorten the length of stay and improve the fluidity in ED.

Several studies evaluated factors attributed to the hemolysis of blood samples particularly from ED. Causes and nature of hemolytic specimen are multiple [5] but the collection techniques in the ED appeared to be the origin of the increased hemolysis rate problem [12, 13]. Recently, Phelan study confirmed previous findings that straight stick and antecubital location are significantly associated with reduced hemolysis and indicated that shorter tourniquet time and larger gauge for IV draws were significantly associated with lower hemolysis [14]. In this context, a regular teaching of pre-analytical recommendation in the medical unit is of great importance, even more in ED. In accordance with this and in order to optimize the sampling a reminder of recommendation was performed on the ED staff

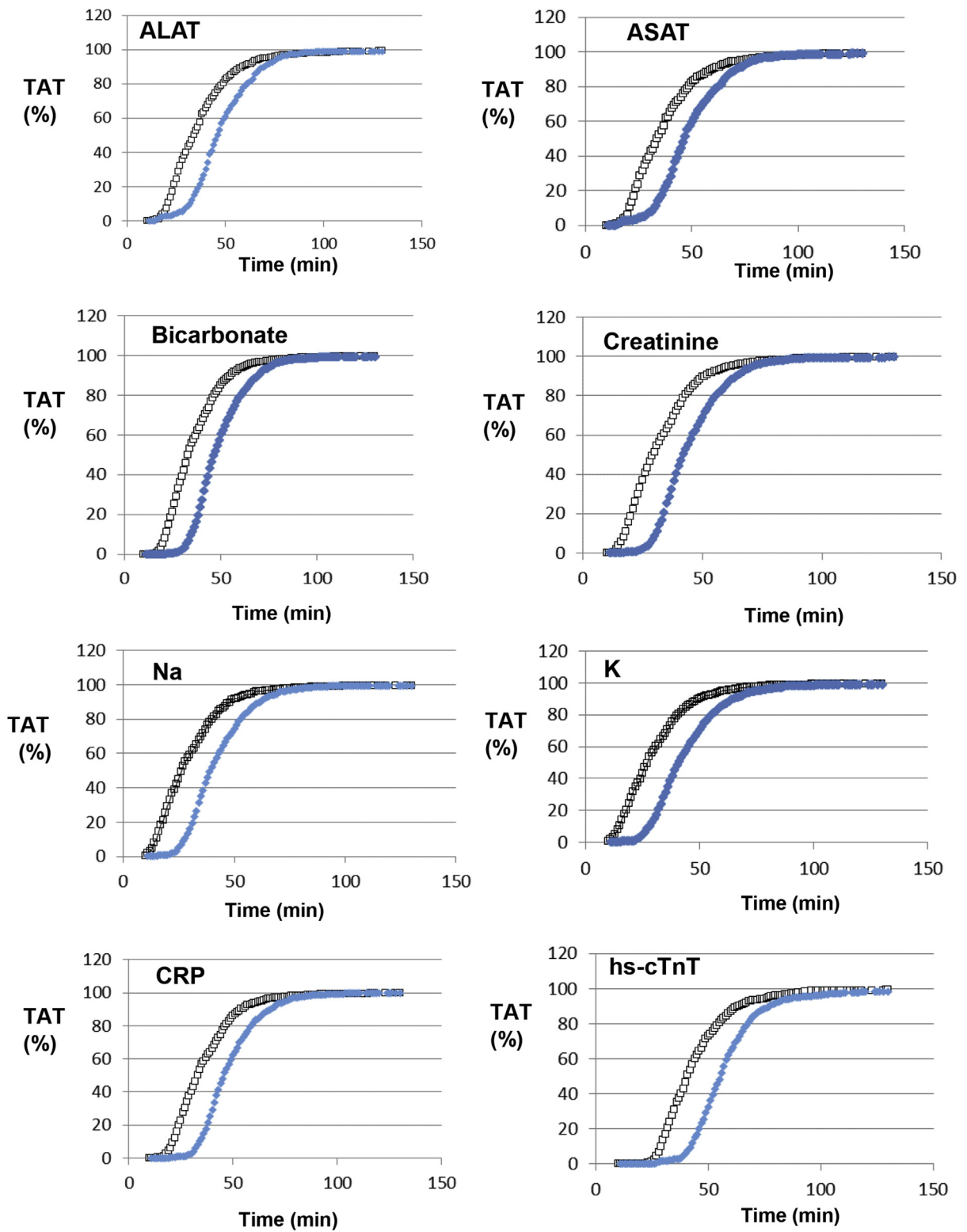


Fig. 3. Graphical representation of lab TAT between the two periods (Black: use of Barricor™ tube, Blue: Use of regular Heparin lithium tube).

before the start of the study.

The Barricor™ tube combines three innovative features. First, it has a mechanical separator instead of a gel barrier, allowing cells to pass across the separator while gels occlude this pathway. Concordant previous studies reported an acceptable correlation between Barricor™ tube results for many biochemical analytes with those of tubes used routinely such as regular lithium heparin [2], plasma separator tube (PST) or serum with (SST) or without gel barrier [1,15], although another study reported some bias when compared to tube without additive [16]. Second, the shortened centrifugation time with high speed as recommended by BD (4000xg for 3 min for Barricor™ tubes vs 2000xg for 10 min for lithium heparin tubes), does not seem to affect the results as shown by several studies [1,17]. Reducing centrifugation time is an opening way to improve TAT. Some author's [1] reported no difference in biochemistry analytes levels using heparin lithium gel tube centrifuged at 2000xg for 10 min versus 3000xg for 5 min. Identical results are observed using Barricor™ tube with these two conditions of centrifugation. In this latter study, comparison of Barricor™ tube and PST II heparin gel demonstrated no bias for many of routine biochemistry analytes excepted for lactate dehydrogenase (LDH) level which was lower with Barricor™ tube. This difference was confirmed by applying two centrifugation settings of 10 min at 2000xg or 5 min and 3000xg for each type of tube [1]. According to our results showing reduced hemolysis rate, it could be hypothesized that decreased in LDH levels with Barricor™ tube is related to an improvement in the quality of samples. In agreement with this, free hemoglobin is also reduced with the Barricor™ tube in the same study [1]. A recent study aiming to compare speed and time centrifugation demonstrated that for Barricor™ tube, 4000xg for 3 min achieve a high quality of sample without benefit to more increase in time or speed [17]. Third, the Barricor™ tube has a partial draw with reduced vacuum which has been suggested to decrease hemolysis rate. Although controversial [10], several studies [8,9] including the use of low vacuum Barricor™ tubes [11], in accordance with our study, confirmed this statement.

To this time, the Barricor™ tube quality was evaluated at different usage conditions. Our study provides additional data since it was performed on the real-life situation for 15 days on a large number of samples allowing to calculate TAT and HI distribution. The significant decrease of hemolysis rate with Barricor™ tube is of particular importance in ED as high HI should be associated to re-sampling and delay of patient management. The analytes mostly altered by hemolysis with false elevation include haptoglobin, LDH, ASAT, ALAT and potassium for which the HI of manufacturer is 90. When comparing the two periods of our study, HI  $\geq$  90 was significantly reduced from 9.2% to 2.5%. Hs-cTnT is also altered by hemolysis at a close HI value (100) leading to a decreased level that could be deleterious for interpretation of troponin level in single or kinetic assessment. The improvement of lab TAT for all analytes with use of Barricor™ tube is even more of interest for decision biomarkers such as troponin. Indeed, the release of troponin results quickly allows an appropriate treatment which is crucial to minimize myocardial injury. In addition, the trend for the diagnostic of myocardial injury is based on kinetic changes of troponin at 3 h and even at 1 h [18]. So, shorten the TAT in ED is a major challenge for physicians and biologists especially since the troponin assays on point of care instrument do not perform sensibility yet as well as those available in the central laboratory [19]. As the majority of ED are afflicted by overcrowding with a negative impact on patient care [20], improvement in the quality of sample and lab TAT with Barricor™ could help to the fluidity of ED.

## 5. Conclusion

This study highlighted two advantages when using low vacuum Barricor™ tubes which are a reduction of centrifugation time allowing improvement of lab TAT and a reduction of hemolyzed samples that improve sample and result quality. Consideration could be given to replacing regular tubes with the low vacuum BD Barricor™ tube, especially in departments known to have high hemolysis rate and overflow of patients such as the ED, although it remains to evaluate the cost of such implementation.

## Conflict of interest

None declared.

## Acknowledgements

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## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.plabm.2019.e00128>.

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