Opinion paper

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Colour coding for blood collection tube closures – a call for harmonisation

DOI 10.1515/cclm-2014-0927
Received for publication September 19, 2014

Abstract: At least one in 10 patients experience adverse events while receiving hospital care. Many of the errors are related to laboratory diagnostics. Efforts to reduce laboratory errors over recent decades have primarily focused on the measurement process while pre- and post-analytical errors including errors in sampling, reporting and decision-making have received much less attention. Proper sampling and additives to the samples are essential. Tubes and additives are identified not only in writing on the tubes but also by the colour of the tube closures. Unfortunately these colours have not been standardised, running the risk of error when tubes from one manufacturer are replaced by the tubes from another manufacturer that use different colour coding. EFLM therefore supports the worldwide harmonisation of the colour coding for blood collection tube closures and labels in order to reduce the risk of pre-analytical errors and improve the patient safety.

Keywords: blood specimen collection; harmonization; quality of health care; standards; venipuncture.

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Introduction

Healthcare errors are not rare. The annual incidence of premature patient deaths associated with some kind of preventable medical error was recently estimated to over 400,000/year in the USA [1]. The unacceptably high error rate in the healthcare environment has also been acknowledged by the World Health Organization (WHO) [2]. According to WHO, one in 10 patients suffer from some kind of error during hospitalisation in developed countries and the risk of error is even higher in developing countries. Further, the European Commission (EC) has also recognised patient safety as one of its issues of global concern across Europe. It has been estimated that 8%–12% of patients in the EU countries experience adverse events while receiving hospital care [3]. Those errors are preventable and are classified into healthcare-associated infections, therapeutic errors, surgical errors, medical device failures and diagnostic errors.

Laboratory errors make a significant contribution to the overall risk of error in healthcare. Laboratory test results are reported to be important in around 70% of

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medical decisions [4, 5]. Errors in laboratory medicine can therefore lead to diagnostic errors (missed diagnosis, misdiagnosis and delayed diagnosis) [6]. It has been shown that almost 40% of diagnostic errors are attributable to problems in the area of laboratory medicine or radiology [7]. The majority of these laboratory errors occur in the pre-analytical phase, the most vulnerable part of the total testing process [8]. Although 'pre-analytical phase' as a concept has been introduced in the biomedical literature in the early 1970s, it still represents one of the greatest challenges for specialists in laboratory medicine [9, 10]. Pre-analytical errors can occur at any step of the pre-analytical phase from, in chronological order, test requesting and ordering, patient preparation, to blood sampling, transport, handling and storage [11, 12]. Probable reasons for high error rate in the pre-analytical phase are:

- many steps are performed outside the laboratory and are not under the direct supervision of the laboratory staff;
- many individuals are involved in various pre-analytical steps. Those individuals have a different type and level of educational backgrounds (i.e., different professions);
- safe practice standards for many activities and procedures are either not available, or are available but are not evidence-based;
- safe practice standards do exist, but there is a low level of compliance to those standards.

Due to the abovementioned reasons, the current pre-analytical phase practices and policies are very heterogeneous, so that immediate and urgent activities for standardisation and harmonisation are of vital importance.

Standardisation and harmonisation has been considered exclusively in the context of measurement procedures over the past few decades. Only recently, attention has been focused on steps outside the analytical part of the total testing process, such as patient preparation, blood sampling, transport of samples, detection and management of interfering substances, assay units and terminology, reference intervals, decision levels, critical results, etc. [13–17].

The EFLM is aware that harmonisation initiatives are essential to improve the quality of procedures and processes within the pre-analytical phase [18]. Effective and successful error reduction strategy must involve all stakeholders in the healthcare sector: government, healthcare workers, professional associations, industry and patients. This is a challenging task. Nevertheless, only by engaged and concerted action can the error rates further be reduced.

The EFLM feels it has a special obligation to address the harmonisation of the total testing process including the pre-, post- and clinical levels. By this effort we wish to contribute to the improvement of the quality of the service delivered by laboratory medicine.

More specifically, with this document we wish to address the unresolved and ongoing issue of non-standardised colour coding for blood collection tube closures produced by different manufacturers and call for the harmonisation of this important source of pre-analytical error.

Background

The first standard published by International Organization for Standardization (ISO) on single use blood specimen containers up to 25 mL capacity (ISO 4822:1981) was published in 1981. This standard has later been withdrawn and replaced by ISO 6710:1995 Standard on single-use containers for venous blood specimen collection. The ISO 6710:1995 standard was prepared by the Technical Committee ISO/TC 76 Transfusion, infusion and injection equipment for medical use and its aim was to define requirements for evacuated and non-evacuated single-use venous blood collection tubes [19]. This document acknowledges the lack of international agreement on colour coding for tube closures and tube labels, and provides a recommendation for letter codes and colour codes for identifying different additives, to facilitate international standardisation among blood collection tube manufacturers and harmonisation of tube closure colour coding. Closure colours recommended by ISO 6710:1995 are presented in Table 1, with other standards shown for comparison. Moreover, the ISO 6710:1995 standard states that if colour coding is used, it is recommended that the closure colour is similar to the colour of the tube or the tube label.

The ISO 6710:1995 was subsequently withdrawn in Europe and replaced by document EN 14820:2004 Single-use containers for human venous blood specimen collection [20]. So, whereas ISO 6710:1995 was only superseded in Europe by EN 14820:2004, it is still extant outside of the EU. Unfortunately, the recommendation on closure colour coding has been omitted from EN 14820:2004 though it still acknowledges the lack of international agreement on colour coding stating that whatever the coding system is in use, the colour of the closure should be similar to the colour of tube label or the tube itself.

In 2003, the National Committee for Clinical Laboratory Standards (NCCLS) published the document H1-A5

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Table 1 Overview of the past and present tube closure colour coding recommendations.

Specimen type	Additive	ISO 6710 (1995) [19]	CLSI H1-A5 (2003) [21]	EN 14820 (2004) [20]	CLSI GP41-A6 (former H03-A6) (2007) [22]	CLSI GP39-A6 (former H01-A6) (2010) [23]	SS-872805 (2011) [24]
Serum	Clot activator	Red	Red	NA	Red	NA	Red
Serum with gel	Gel, clot activator	NA	NA	NA	Red	NA	Yellow
Plasma	Heparin	Green	Green	NA	Green	NA	Light green
Plasma with gel	Gel, heparin	NA	NA	NA	Green	NA	Dark green
Plasma	Citrate (1:9)	Light blue	Blue	NA	Blue	NA	Light blue
Whole blood	Citrate (1:4)	Black	Black	NA	NA	NA	Black
Whole blood	EDTA	Lavender	Lavender	NA	Lavender, Pearl	NA	Lavender
Plasma EDTA with gel	Gel, EDTA	NA	NA	NA	Lavender, Pearl	NA	White or pearl
Plasma	Glycolytic inhibitor	Grey	Grey	NA	Grey	NA	Grey

NA, recommendation on tube closure colour not specified or not available.

Tubes and additives for venous and capillary blood specimen collection; approved standard – fifth edition [21] [author note: *NCCLS has officially changed its name on January 1st, 2005 to Clinical and Laboratory Standards Institute (CLSI)*]. The first edition of this document was published in August 1977. The purpose of this document was to serve as a performance standard for blood collection tube manufacturers by providing recommendations and requirements for serum, plasma, and whole blood tubes and additives. This standard particularly addressed the recommended type of materials for tubes and tube closures, system specifications, such as compatibility with centrifuge carriers, construction requirements (strength, exterior texture), and requirements for draw and fill accuracy, tube labels and tube assemblies, etc. Under section 11 on additives (pages 5–6), the approved Fifth Edition of the Standard provides recommendation for colour coding for some most commonly used plastic tubes (Table 1). This standard was prepared by a working group of eight experts, three of which were representatives of the three major blood collection tube manufacturers: Sarstedt Inc. (Newton, NC, USA), Greiner Bio-One (Vacuette North America, Inc.) and BD Vacutainer Systems (Franklin Lakes, NJ, USA). Obviously, the proposed closure colour coding was a consensus agreement by three major manufacturers at that time. This was indeed encouraging.

The CLSI document GP41-A6 (former H3-A6) Procedures for the collection of diagnostic blood specimens by Venipuncture: approved standard – sixth edition (2007) defines the standardised procedure for venipuncture and is aimed at facilitating the global harmonisation of venous blood sampling, reduce the number or errors and increase the safety of patients and healthcare workers. This standard does not provide any specific recommendation on the colour of the tube closures, but it does mention the colours of the tube closures within the section on the Order of draw (Table 1) [22]. The three major companies (Sarstedt Inc., Greiner Bio-One and BD Diagnostics – Preanalytical systems) were again members of the working group which prepared the document by joint consensus.

Unfortunately, in the next edition of the CLSI H1-A5 document published in 2010, GP39-A6 (former H01-A6) (Tubes and additives for venous and capillary blood specimen collection; approved standard – sixth edition), which has replaced the previous H1-A5 version, the recommendation on closure colours is omitted [23]. CLSI GP39-A6 document states that due to the large variety of colours and colour combinations in use worldwide, a tube manufacturer should be consulted for colour closure coding specifications related to each blood collection tube. Representatives from two major blood collection tube manufacturers: Sarstedt and BD Preanalytical Systems were members of the document revision subcommittee.

Current situation

At the moment there is significant heterogeneity in the available colours of the tube closures in the market. Table 2 illustrates the existing differences in the tube closure colours supplied by different phlebotomy tube manufacturers as taken from their website or catalogue. Colours in the table are listed as standards or manufacturers' core colours. However, tube suppliers will produce whatever coloured tube caps the customer requires on request. This table cannot serve as a comprehensive information of all available tube colour standards, but rather an example of a number of different types of test tubes a large reference laboratory could receive for the same test from satellite laboratories or when there is a mix up of samples in delivery destinations if tubes are purchased from the

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Table 2 Standard colours or manufacturers' core tube closure colours currently provided by several major tube manufacturers.

	Additive	1	2	3	4	5	6	7
Serum (clotting activator)	Clot activator	White	Red	Red	Red/Black ring	Brown	Red	Red
Serum-gel (clotting activator)	Gel, clot activator	Brown	Brown	Gold	Red with Yellow ring	Red Gold	Yellow	Gold
Plasma	Heparin	Orange	Green	Dark green	Green with black ring	Dark green	Dark green	Green
Plasma gel	Heparin	Orange/Brown	Green/Brown	Mint green	Green with yellow ring	Light green	Green	Green
Plasma	Citrate	Green	Blue	Blue	Blue with black ring	Pale blue	Blue	Blue
Whole blood	Citrate	Purple	Black	Black	Blue with yellow ring	Black	Black	Black
Whole blood	EDTA	Red	Purple	Purple	Purple with black ring	Purple	Light lavender Lavender	Lavender
Plasma gel	EDTA	Red	Purple/Brown	White	Purple with yellow ring		White	
Glucose (fluoride)	Glycolytic inhibitor	Yellow	Grey	Grey	Grey with black ring	Grey	Grey	Grey
Trace element tube	EDTA	Orange	Orange	Dark blue	Dark Blue with black ring			
Source		Catalogue	Catalogue	Catalogue	Website	Catalogue	Website	Catalogue

same supplier producing different colours for different hospitals. We hope that this might help in reinforcing our message, considering the absence of published evidence.

Several efforts have already been undertaken in the past to achieve standardisation of the tube cap colours. Unfortunately, all efforts have failed due to the difficulty in reaching a consensus among manufacturers. The most probable reason for the lack of consensus is the expected cost associated with changes in the technological process necessary to meet the requirements of any proposed standardisation, this can therefore only be achieved through consensus and shared efforts and costs by all involved blood collection tube manufacturers so that none of them is disadvantaged. Recent implementation of a national standard in Sweden (SS-872805:2011), defining the additive based colour code is an excellent example, thus showing the possibility of reaching a broad consensus among manufacturers [24]. Possible implementation of the Swedish standard has now just been discussed in Norway and Denmark, and it was also presented as a model at the meeting of the CEN/TC140 in vitro diagnostics medical devices held in Berlin in October 2013.

Another probable barrier to the proposed standardisation could also be the overall perception by manufacturers, laboratory professionals and other healthcare providers that patient safety is not necessarily compromised by the present situation. Different colour codes currently used present an obvious potential risk for confusion and hence a direct impact on patient safety especially when a laboratory receives samples from multiple sampling locations, if they used tubes from different manufacturers, or when junior medical staff rotates through several different institutions each of which may use different tube suppliers. The chance of mismatching the tubes during blood collection may be further increased in facilities where sample labels containing specific information about the colour of the tube stopper are used. Although literature reports on the error rate associated with the different tube closure colours is lacking, unpublished data show that the change of tube manufacturer [25] may lead to four times the increase of frequency of the samples drawn in the wrong container (from 0.2% to 0.8%) in the first 3 weeks after change was implemented (data not published, personal communication with Prof. Giuseppe Lippi, Parma, Italy).

The utmost significance of this pre-analytical problem has also been recently acknowledged by the Working Group on 'Laboratory Errors and Patient Safety' of the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC), with the inclusion of a specific, high priority indicator (i.e., 'Incorrect sample type') among the list of quality indicators in laboratory medicine [26].

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One important issue that also needs to be acknowledged is the use of different closure colours for tubes with the same additive to distinguish the laboratory section(s) for which the tubes will be referred internally or externally to the laboratory. This is usually a laboratory driven requirement in order to efficiently manage the sample tracking in large laboratories. Thus, one laboratory could potentially be using even five or more specific closure colours for one additive type, to recognise the different section of the laboratory that will be using the sample. Whilst this high number may be unusual the practice certainly is not: this adds to the overall risk for errors and its impact on patient safety.

The way forward

In addressing harmonisation of pre-analytical phase in laboratory testing, a recent report [17] states that this is currently not coordinated on an international basis. EFLM and its WG-PRE wishes to lead in catalysing various European and possibly global standardisation and harmonisation projects in the field. Clinical laboratory science has made extraordinary developments over the last decade; however, the overall benefit of those changes to the quality of the healthcare will not reach its full potential if pre-analytical, analytical and post-analytical phases of the total testing process are not harmonised. Whereas the American Association for Clinical Chemistry (AACC) harmonisation project prioritises the analytical phase [27], it is EFLM wish to raise awareness about the need to also harmonise the pre- and post-analytical phases of testing. To fulfil this goal, EFLM has recently established a new Working Group for Harmonization of the total testing process (WG-H), with the aim to improve the level of harmonisation along the total testing process of laboratory medicine, by identifying most critical areas that need harmonisation as well as by being the facilitator and coordinator for existing initiatives at national level in various countries. The activities of WG-H will be linked with other existing WG within EFLM, such as WG-Guidelines, WG-Preanalytical Phase, WG-Postanalytical Phase and WG-Accreditation and ISO/CEN standards.

With this opinion paper EFLM through WG-PRE wish to express its support to the worldwide harmonisation of colour coding for blood collection tube closures. We believe that such harmonisation would reduce the potential risk of pre-analytical errors and substantially improve patient safety. We also believe that harmonisation is feasible. This paper is our open call for a joint action by all manufacturers, regulatory bodies and laboratory professionals to support the definition of a universally applicable standard for tube closure colours and its worldwide implementation. EFLM WG-PRE and WG-H are willing to take responsibility to act as a convener for a dialog between interested parties. Particularly, we propose the following roadmap:

- All stakeholders, including all manufacturers working in the field, should be invited to join a dialogue to establish a universally acceptable colour coding standard for blood collection tube closures;
- Standard writing bodies (ISO, CLSI) should add the colour coding standard agreed on to the existing recommendations;
- Manufacturers should implement the agreed colour coding standard.

The goal of EFLM is to facilitate a dialog leading to consensus and harmonisation of this important pre-analytical factor and not to impose any particular solution.

Author contributions: All the authors have accepted responsibility for the entire content of this submitted manuscript and approved submission.
Financial support: None declared.
Employment or leadership: None declared.
Honorarium: None declared.
Competing interests: The funding organisation(s) played no role in the study design; in the collection, analysis, and interpretation of data; in the writing of the report; or in the decision to submit the report for publication.

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