

Opinion Paper

Collective opinion paper on findings of the 2010 convocation of experts on laboratory quality

Greg Cooper¹, Niels DeJonge², Sharon Ehrmeyer³, John Yundt-Pacheco⁴, Rob Jansen⁵, Carmen Ricós⁶ and Mario Plebani^{7,*}

¹ W. Gregory Cooper LLC, Denton, TX, USA

² Haga Teaching Hospital, Clinical Chemistry Hematology Laboratory, The Hague, The Netherlands

³ University of Wisconsin School of Medicine and Public Health, Madison, WI, USA

⁴ Scientific Fellow, Bio-Rad Laboratories Inc. (Hercules, CA), Quality Systems Division, Plano, TX, USA

⁵ SKML, NL-NEQAS, Nijmegen, The Netherlands

⁶ Biochemistry Department, Valle de Hebron General Hospital, Barcelona, Spain

⁷ Department of Laboratory Medicine, University Hospital of Padova, Padova, Italy

Abstract

As a part of a series of yearly meeting, in May 2010 over 40 medical laboratory opinion leaders, pathologists, clinical biochemists and physicians from Europe, Israel and South Africa gathered together in Bardolino, Italy to discuss issues and current challenges for laboratory medicine, including a) the use of biological variation 10 years after the Stockholm Conference; b) achieving quality in point-of-care testing; c) assessing risk and controlling sources of error in the laboratory; d) determining the appropriate frequency of quality control; and f) putting laboratory medicine at the core of patient care. The intended goal of the convocation was to give laboratory professionals from different countries and backgrounds the opportunity to share ideas, concerns and experiences in previously mentioned areas of interest. This paper provide a synopsis of the reports from each working group.

Keywords: accreditation; biological variation; communication; laboratory management; laboratory responsibility; patient outcomes; point-of-care testing (POCT); quality control; risk.

Introduction

This collective opinion paper is intended to document the proceedings and findings from a round of discussions held May 10–12, 2010 in Bardolino-Lago di Garda (Verona), Italy on quality in laboratory medicine; in particular regarding currently debated topics. These include: a) the use of biological variation 10 years after the Stockholm Conference; b) achieving quality in point-of-care testing (POCT); c) assessing risk and controlling sources of error in the laboratory; d) determining the appropriate frequency of quality control (QC); and f) putting laboratory medicine at the core of patient care.

This was part of yearly meetings sponsored by Bio-Rad, with the aim of offering laboratory professionals from different countries and backgrounds the opportunity to share ideas, concerns and experiences in previously mentioned areas of interest. After a plenary session with introductory remarks and presentations by the leaders of each Working Group, the experts were subdivided into five working groups (WG) according to their specific background and main interest. Each WG discussed current problems and challenges, and made a proposal for further initiatives and improvements. Finally, the proposals of the individual WGs were presented and discussed in a plenary session. The main results are reported below.

Results

The use of biological variation 10 years after the Stockholm Conference

In the Stockholm Conference, a hierarchy of models was accepted to set quality specifications for the analytical phase of medical laboratories. In particular, it was recognized the existence of five models structured in a hierarchical order related to fulfillment of medical needs. The first of these being the satisfaction of specific clinical situations and the second being the identification of general needs for diagnosis and monitoring purposes derived from biological variation (BV) estimates (1). The aim of the Bardolino working group was to identify consolidated advances on quality specifications and to propose necessary improvements. To accomplish this, five topics were discussed among the group members and these are reported as follows.

*Corresponding author: Prof. Mario Plebani, Department of Laboratory Medicine, University Hospital of Padova, Via Giustiniani 2, Padova, Italy
E-mail: mario.plebani@unipd.it

Received November 17, 2010; accepted December 27, 2010; previously published online March 3, 2011

1) Use of biological variation (BV) in internal quality control (IQC) The use of BV over the last 10 years has been recently revised by Hyltoft Petersen and Fraser (2) and include method selection and assessment (3), definition of common reference intervals in a geographic area (4), analysis of the consequences of poor calibration on populations being evaluated (5), integration into laboratory quality management programs (6, 7) and evaluation of laboratory results in external quality assurance programs (EQAP) (8).

Integration of BV into laboratory quality management implies adherence to internal quality control (IQC) procedures and the evaluation of analytical performance. Burnett et al. insisted on using quality specifications as key concepts for managing quality. Setting QC rules based on these specifications is a major improvement for daily practice (7). Most of the participants in the discussion group use BV to define total allowable error and use information from the BV database (9) for designing IQC. However, there were some concerns regarding the robustness of data reported in this database, as inaccurate information may derive from simply calculating the mean of several BVs published in the literature. Therefore, it would be desirable to perform a careful revision of publications from which the data and their “translation” in the database to demonstrate that they are really “evidence-based”. Depending on the analyte and the medical purpose, the participants choose desirable, minimum or optimum quality specifications derived from BV to manage bias, imprecision and inaccuracy. A majority of the participants use various commercial QC software products (e.g., Unity Real-Time® from Bio-Rad) to select the appropriate control rule for each analyte on the basis of the ratio $(TE_{bias})/CV_A$, where CV_A equals the analytical coefficient of variation. Regarding the evaluation of laboratory performance, all participants monitor their CV_A from their IQC; approximately half of the participants estimate bias from IQC and the other half from EQAPs. However, guidelines for estimating bias and imprecision from IQC and EQAP would be highly welcome. All participants monitor TE from EQAP.

2) Limitations of biological variation (BV) The participants recognized no limitations of the BV concept; however, participants did recognize three major limitations of the database, including: a) poor estimates of bias and/or imprecision for a number of analytes due to a small number of published data compiled for the database; b) data are available only for a limited number of analytes (the 2010 update includes 310 analytes whereas test menus of many hospital laboratories includes approximately 1000 tests); c) total allowable error derived from BV seems too restrictive in some cases compared with technological capacities (albumin, chloride, HbA_{1C} , sodium, etc.). To increase the viability of BV for analytes with poor information, the group believed that a standardized method to estimate BV using serial patient results from the Laboratory Information System (LIS) should be developed. With respect to this point, the general opinion was that routine methods (i.e., the same methods applied to test patient samples) with proven analytical specificity

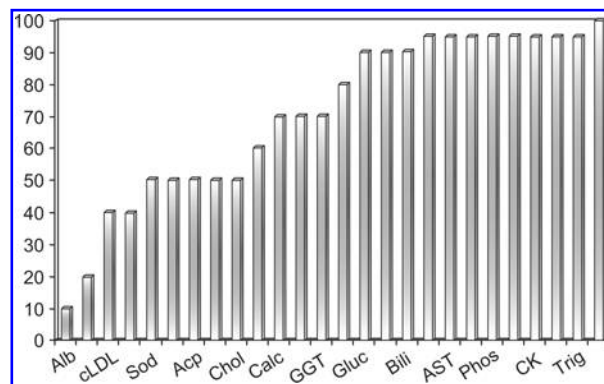


Figure 1 Percentage of results achieving the goals of BV-based quality specifications in the SEQC-EQAP (2008).

SEQC: Spanish Society of Clinical Biochemistry and Molecular Pathology. Y-axis: analytes in ascending order according to the allowable TE value.

should be used to estimate components of BV. Regarding the narrower specifications identified for certain analytes, various group members (e.g., The Netherlands and Spain) declared that a high percentage of their laboratories are able to achieve the apparently difficult goals in their national EQAP (Figure 1). In addition, the participants emphasized that some aspects for practical application of BV should be considered: in certain pathologies where CV_I (within-subject coefficient of variation) is higher than in healthy states for certain analytes (10), and in the case of using alternative instruments to monitor patients, achieving BV requirements already defined (11) may be an unrealistic goal; thus, other criteria should be defined.

3) Use of the reference change value (RCV) The use of the Reference Change Value (RCV) was discussed by participants of working groups 1 and 5 together. The concept of the RCV was first introduced by Harris and Brown (12). In recent years, other data has been added (13). The RCV is calculated according to the following formula:

$$RCV = z \times [(CV_A)^2 + (CV_I)^2]^{1/2}$$

RCV is the change in value over time that denotes a significant rise or fall in the concentration of the analyte measured. z is a factor of statistical significance.

There are a number of assumptions in the use of RCV, including a) random variation follows a Gaussian distribution, b) pre-analytical variation is negligible, c) the z -score for statistical significance is usually 1.96, d) analytical variation is constant and independent of the analyte concentration, and e) biological variation, independent of the value measured and independent of health status, is constant.

Arguments in favor of the use of the RCV are: a) clinicians express a need for the concept to differentiate physiological change from analytical variation, b) data is available for approximately 300 analytes, c) RCV is independent of

the study population, d) RCV is valuable for clinical validation.

In contrast, arguments against the use of RCV are: a) statistical information overwhelms clinicians, b) the z-factor denies clinical judgment, c) RCV is dependent on test frequency, d) some biological variation may be dependent on health status; namely intercurrent diseases, e) proper application requires a sophisticated LIS, f) education of laboratory staff and clinicians is needed, and g) terminology may be confusing.

The working group concluded that RCV is an appealing concept, with high potential for use in monitoring disease or treatment. The name, RCV, may give rise to some confusion. Therefore, the discussion group suggested significant change value (SCV) as a better alternative. Most participants indicated they would like to include information on RCV in the test information they provide to clinicians (e.g., in a laboratory test handbook or on the internet). If RCV is to be reported with test values, it should be implemented slowly in a stepwise fashion and under certain restrictions, such as adequate information technology support, education and acceptable analytical variability.

4) Is the state-of-the-art still in the hierarchy? Clearly, a majority of EQAP used in the countries represented by the members of the discussion group (Belgium, Denmark, France, Israel, Spain, The Netherlands and UK) still use the state-of-the-art as the criterion to indicate a good result to the participant laboratory (result within the peer group mean ± 2 standard deviation). In some countries this concept is combined with a BV-derived boundary. It was agreed that: a) the state-of-the-art is very useful to define quality specifications for non-analytical processes (pre- and post-analytical, as well as strategic and support processes); b) indicators for the non-analytical processes in laboratory medicine still require better standardization and harmonization; c) the Stockholm hierarchy is still valid, but has to be driven by management; d) some examples to satisfy medical requirements for specific clinical situations (14) are available today, but this experience needs to be further developed for the pathologies with the most impact in the healthcare system; e) the ultimate goal is to satisfy clinical needs (patient's requirements) and, consequently, laboratories need to pressure the industry to produce systems that achieve this goal.

5) Should particular specifications be recommended?

The combined group debated the quality needed for POCT, and agreed that the specifications for routine methods in the central laboratory apply. Concerning ordinal scale tests, all members of the group agreed that models published to date are theoretical (15, 16), and still require further studies on a practical basis to set quality specifications. The combined group participants agreed on two steps: a) first, record intra-laboratory stable "state-of-the-art" performance (e.g., record the number of out of control results for a period of at least 6 months for each test obtained every month, and observe the trend over time), and b) second, organize EQAP to establish the current state-of-the-art within a geographical area.

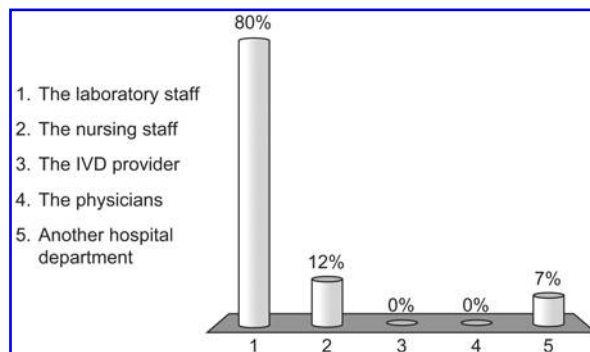


Figure 2 Management responsibilities regarding POCT.

Achieving quality in point-of-care testing

In the ISO 22870 standard (17), POCT is defined as "testing that is performed near or at the side of the patient with the result leading to a possible change in care of the patient". The requirements in ISO 22870, which is specific for POCT, are in close relationship with those of ISO 15189, the standard for quality and competence of medical laboratories, and a clear role for the central laboratory is defined. The use of POCT equipment is advocated, claiming the elimination of errors in sample collection, transport of samples, the distribution of results, and reduction in excessive turn-around time. It should not be considered as solution for excessive or mistimed ordering.

Questions that were addressed in the discussions included: a) Should the main laboratory be responsible for POCT? b) Is oversight by the central laboratory necessary for non-traditional testing sites? c) Does the location of testing require special precautions? d) Does operator competence affect results? e) What are the effects of strip, slide, or cartridge batch changes? f) Are on board QC checks a sufficient guarantee of quality? g) What role does information technology play in the management and performance of POCT?

1) POCT in the hospital The question whether POCT in the hospital and in other healthcare organisations should be performed under the control of the main laboratory was discussed extensively. In France, Germany and the Netherlands this is regulated. In the other countries represented (Finland, Italy, Switzerland, UK and South Africa) this is voluntary. The opinion of the discussion group was that POCT should be done under the responsibility of the accredited central laboratory was supported in practice in the hospitals of the conference participants (Figure 2).

2) Implications for the clinical laboratory A careful evaluation of true clinical and organizational needs should be performed before introducing POCT. This applies to resource management, including personnel training, in vitro diagnostics (IVD) device (18) selection and acceptance testing, inspection of environment and location of the equipment, and the desirability of informatics. Furthermore, the

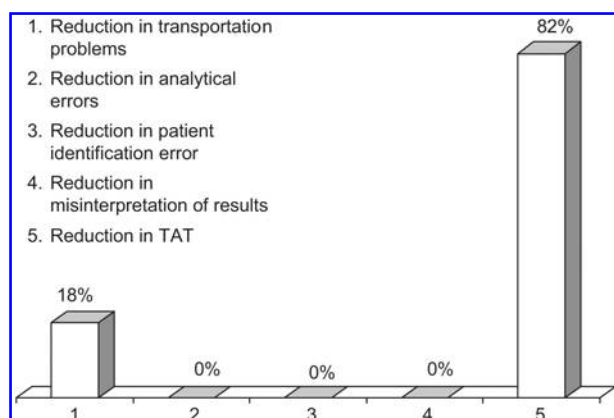


Figure 3 Major advantages of POCT.

on-going quality of POCT measurements should be evaluated, and continual improvement of measurement and staff competency should be in place.

3) Evaluation of the need The decision to introduce POCT should be taken by a multidisciplinary group, including clinicians, laboratorians and medical directors. The working group and the general assembly of the conference were of the opinion that the reduction in turn-around time is the major advantage of POCT (Figure 3). The discussion of whether POCT is really required should consider: a) the need of faster turn-around times; b) specimen transportation within the institution; c) the higher costs associated with POCT; d) the potential decrease in analytical quality; e) the importance of training and retraining; and f) the need for information technology.

4) Resource management – personnel training and competence testing The training of personnel (nursing staff) as well as assurance of their competence should be managed by the laboratory. The training could be performed by the laboratory, the IVD provider or the nursing staff. However, the laboratory is the preferred option, since: a) the laboratory can offer the expertise; b) the training is automatically part of the laboratory accreditation, and c) laboratory training establishes contact between nurses and technologists, which improves communication between the laboratory and medical wards on many other aspects. The training should result in evidence of competence via IQC results including testing of IQC samples but also comparison of POCT patient results with simultaneous laboratory results. If evidence of competence is lacking or competence is insufficient, retraining is indicated.

5) Resource management – IVD selection and acceptance testing The selection of the IVD POCT device should have a rational basis. The CE marking of IVD devices is not necessarily adequate nor does it provide sufficient evidence for fitness for purpose of the POCT device. Verification of the total allowable analytical error specification,

preferably based on the biological variation concept (19) is needed. Such verification was introduced on a national basis with the SKML Quality Mark for point-of-care glucose testing meters (20). In addition to an adequate selection procedure and verification process, there is the need for information on homogeneity of strips, cartridges etc. Requirements should be formulated to obtain specific lot/batch performance data from the manufacturer. Such information could facilitate acceptance and verification testing. The limitations of the IVD device should also be taken into account, including that for glucose meters: a) sensitivity to maltose (device not to be used on units where patients are dialyzed); b) sensitivity to oxygen tension (caveat for pneumology and intensive care departments); c) ascorbic acid or acetaminophen sensitivity.

6) Resource management – role of informatics Online connection of the IVD device to the LIS is highly desirable, if not mandatory. It assures correct identification of the operator (e.g., by barcode), and correct identification of the patient (barcode). Transmission of data to the LIS introduces the possibility of remote management of the POCT device, e.g., for internal quality control management, locking the device in case of malfunction, and traceability of the process, the instrument and the operator. The test result should be identified as a POCT test result in the LIS and in the hospital information system. Available evidence demonstrates that the lack of connectivity translates into an unacceptable number and frequency of errors (21).

7) Examination issues For internal quality control of POCT devices, Westgard rules are applicable, just like in the main laboratory. Electronic controls are insufficient, and the efficacy of on-board IQC depends on risk assessment and the results of device verification. In any case, third party IQC (e.g., by the main laboratory) or EQA is necessary. It is essential that POCT results are comparable with the laboratory method, e.g., for plasma glucose concentrations. The opinion of the working group is that IQC should be performed by the person performing the test. If nurses perform the test, they should perform IQC. This was supported by 83% of the general assembly of the conference.

8) Evaluation and continual improvement Retraining of personnel is an important issue for maintaining quality. Also, participation in an external quality assessment scheme or in a main laboratory based scheme is important. Such EQA should play a role in continuous competence testing of the personnel performing the tests.

Assessing risk and controlling sources of error in the laboratory path of workflow

Despite our best efforts to ensure quality throughout the total testing process (TTP), non-conformities, mistakes, or blunders can occur that can affect the quality of laboratory results and, potentially, cause harm to patients. The idea of risk management is to identify potential risks throughout the TTP that

can affect the quality of the test result, and to develop strategies to control quality and mitigate potential failures. Specifically, risk is defined as the probability for patient harm when a reported test result affected by undetected “error” is acted upon. Risk analysis and management by laboratories is intended to minimize and, hopefully, avoid these errors. Unfortunately, there is no one universal strategy for all situations to optimally mitigate risks in the TTP. The potential risks are many, and vary with a variety of factors, including the local environment and personnel, residual risks of the testing device, analysts training and competence, quality control schemes, reporting systems, etc.

Prior to the meeting, each participant in the working group reviewed two CLSI Risk Management Guidelines (22, 23) that are very useful for further improvements in clinical practice.

1) What factors, activities or conditions in the total testing process contribute to risk of harm to the patient? The group started with a lively discussion on what sources of error in the TTP potentially pose the greatest risk to patients when the errors are not detected and the test results are acted upon. Ultimately, the group unanimously agreed with the most common non-conformities listed in Table 3 of CLSI GP32:2007 *Management of Non-conforming Laboratory Events*. Francisco Ramon Bauza and Angel Salas shared this document with the group because they thought it complimented EP18 and EP23 (24). Table 3 in GP32 lists for the preanalytical phase of the TTP, six non-conforming events: a) ordering the test; b) sample collection; c) sample labeling/patient identification; d) sample transport; e) sample accession/handling processing; and f) sample quality. The analytical phase non-conforming events include: a) quality control errors; b) testing and instrumental errors; c) reagent and calibration problems; and d) delays in testing. The post-analytical errors comprise: a) result interpretation, which also includes calculation errors, b) data entry, and c) transmission and communication of results. To develop risk management strategies, organizations need to start with detailed mapping of the TTP to gather information on the essential steps and weaknesses in these steps. The information can then be used to rethink the TTP and focus on what really is important, so that the process can be simplified through LEAN activities, standardized and automated whenever possible. The information is also valuable in providing staff and all the “actors” in the TTP their importance and roles. All participants agreed that the most problematic area in risk management is tackling the unknown, the “people” or human factor. Despite all of our best efforts – appropriate policies and procedures, knowledgeable staff, training, utilization of technology and the best methods, information technology, etc., things still occur, primarily due to the human factor. As a consequence, education along with awareness of what can go wrong in the TTP and the impact of the “wrong” need to be key components of any risk management strategy.

2) Because even one bad result issued by a virology laboratory or blood bank may compromise both

patient health and laboratory credibility, how should labs manage risk in these laboratories? Are there any specific special precautions? Special precautions are needed for virology and blood bank laboratories to assure the quality of test results that frequently impact patient care.

Additional thoughts from the group on this question include: a) Consider not only risk of harm to patients, but also to the reputation of the entire organization. b) Since risks must be known before they can be addressed, a patient safety culture that ties together medical error, quality, and patient safety, must be instituted, as “*the biggest challenge to moving toward a safer health system is changing the culture from one of blaming individuals for errors to one in which errors are treated not as personal failures, but as opportunities to improve the system and prevent harm.*” (25). c) Gain the cooperation of all stakeholders – decision makers, departments, clinicians, patients, staff, etc.; continually solicit feedback so risks are identified and improvements made. d) Standardize and simplify the process; use technology wherever possible; design quality into the TTP. e) Validate steps in TTP, when necessary, e.g., tube system; challenge the system, e.g., data transfer. f) Continually monitor activities in TTP/collect and assess data/implement quality improvement. g) Need more confidence in the CE label to minimize some of the many required validations, etc. h) Use “right” QC and careful auto-validation (tools) to detect analytical error. i) Include pertinent information and uncertainty when reporting patient results; use SI units to minimize confusion.

What frequency of QC is enough?

The frequency of executing a QC event is a necessary component in a QC strategy, but neglected in conventional QC design methodologies. The QC Workgroup discussion focused on what impact this frequency has on patient risk, what challenges there are to implementing an optimal QC frequency, and what basic guidelines should be followed with respect to this issue.

1) The frequency of laboratory test system malfunctions Laboratory test system malfunctions can be characterized into those that are detected and those that are not. Metrics should be collected on detected malfunctions and what corrective actions were taken to mitigate them. It is unknown how many undetected malfunctions occur, but detected malfunctions should be regarded as the minimum number of malfunctions occurring. For error conditions that persist until detected by a QC event, the number of unacceptable patient results produced is a function of QC frequency.

2) Risk of harm to the patient and QC frequency A risk-based approach to determining QC frequency is useful (26, 27). The testing process should be evaluated to identify where there is a risk of failure – such as changing reagents, and checking the quality of the system with controls at these points. As the potential for harm to patients increases, the

frequency of QC should also increase. Important factors for determining frequency of QC include: a) high-risk tests – tests where there is a large patient impact for a wrong result; b) tests that support clinical decisions in isolation; c) tests that do not perform well (low process capability); d) tests that are acted upon immediately; e) tests performed on specimens that are difficult/painful to collect (or difficult – may-be impossible to recollect).

3) Time, the number of patient samples tested, and QC frequency For the most part, patient volumes differ by the day of the week, but have consistency from week to week. Thus, time can be used as a surrogate for the number of patient samples tested. Using only the number of patients to determine QC frequency may result in problems with reagent stability if the patient volume is low. When the workflow is light, time should be used to determine the QC interval. When there is a large volume of patients, controlling batch size is the main consideration and the number of patients should be used to determine the QC interval.

4) Six Sigma and QC frequency Use sigma (σ) to divide tests into groups. The following is an example of the approach – the specifics should be adjusted for patient volume and other relevant factors.

$>6\sigma$ (excellent tests) – evaluate with one QC per day (alternating levels between days) and a 1:3.5 s rule.

4σ – 6σ (suited for purpose) – evaluate with two levels of QC per day and the 1:2.5 s rule.

3σ – 4σ (poor performers) – use a combination of rules with two levels of QC twice per day.

$<3\sigma$ (problems) – maximum QC, three levels, three times a day. Consider testing specimens in duplicate.

Using sigma metrics for QC design should be modulated with other considerations like: a) risk assessment, b) clinical utility, c) number of tests performed (volume), d) level of education of staff performing the test, and f) external minimal legal requirements.

5) Recommendations for determining QC frequency

- Start with the legal minimum requirements.
- Next, use a 6σ approach (process capability)/Expected number of unacceptable patient results, to design an initial strategy.
- Do risk assessment to identify circumstances requiring modification of the control frequency.
- Use other factors to determine what is the appropriate frequency of QC:
 - Stability of reagents/controls/specimens/analytes
 - Quality and support of supplier
 - Expertise of staff
 - Supporting infrastructure like patient statistics
- Any circumstances, there is an upper limit to the amount of time that it is acceptable to go between QC – our working group feels this limit is 24 h when testing is being done.

Putting laboratory medicine at the core of patient care

Laboratory medicine has a great impact on patient care. Laboratory errors may have a direct negative impact. However, many aspects of an underperforming laboratory will not be visible directly. Poor quality management, high employee turnover and poor cost effectiveness are hidden costs.

Positive impact of the laboratory also can be seen directly and indirectly. Examples of direct positive impact are its important contribution to prevention, screening, diagnosis, and monitoring of disease. Accurate testing and short turn around times (TAT) contribute to efficient patient care. Less visible is the positive impact of a well-organized laboratory, which not only contributes to cost effectiveness, but also often is an example for the health care organization with respect to quality management.

The impact of laboratory service on health care could be identified by outcome studies. Another, yet hypothetical means of demonstrating the impact of laboratory medicine would be to close the laboratory on some days. It is clear that this not only be unethical, but also impossible. In the same way that modern society cannot function without electricity, health care could not function without laboratory services. Case reports very often clearly illustrate the high impact of laboratory medicine on patient outcome and health care. It would be helpful to demonstrate the importance of the laboratory by publishing case reports, not only in peer reviewed scientific journals, but also in local papers.

The negative impact of the laboratory seems to be modest, as can be learned from the review of malpractice cases.

1) How labs can make laboratory service more visible to the patient and hospital management? The visibility of the laboratory very much depends on the perspective of the different stakeholders. For the patient, the laboratory quite often is not more than a request form, the phlebotomy service, and a brief summary of the results of testing being addressed by the physician. For the doctor, the laboratory is seen as a test menu, a telephone number and a laboratory report. The laboratory professional may play an important role in the interaction with the doctor. Health care management may see the laboratory either as a cost factor, or as a strategic asset. For the laboratory professional, the laboratory is primarily an attractive work place.

The working group concluded that there are striking differences between health care systems and cultures in different countries. It was agreed that the visibility of laboratory services should be increased, but the target groups may be different, depending on the local situation.

Measures to increase the visibility of the laboratory were discussed by the working group. Sound suggestions for improvement were as follows:

- To increase the visibility for the doctor, laboratory professionals should pay more attention to their consultant functions and attend grand patient rounds.
- Towards the patient, the visibility of the laboratory could be greatly enhanced by open laboratory days, but also

by providing information directly to patients, e.g., via informative websites, such as www.labtestsonline.org. In some countries, initiatives have been taken to create an 'Ask the expert' service. Patients can direct questions to a laboratory professional via email, who will respond within 2–3 days. Reporting to patients is not allowed in all countries, but studies have shown that this not only contributes to patient awareness, but also may help to remind the doctor about patient results (28). Direct access testing may also be effective for increasing the visibility of laboratory services towards patients (29).

- c. Visibility towards health care management could be increased by reporting both quality aspects and cost effectiveness. Where possible, management participation was seen as a positive attribute.
- d. Towards the future workforce, the laboratory needs to be seen as an attractive workplace. Visibility needs to be raised, but professional branding is necessary. Examples of such initiatives are LabsAreVital™ by Abbott and the 'Laboratory Professionals Get Results' action by a number of American professional societies [the American Society for Clinical Laboratory Science, American Society for Clinical Pathology, the American Association of Clinical Chemistry (AACC), AABB, American Medical Technologists, American Society of Cytopathology, Association of Public Health Laboratories, Clinical Laboratory Management Association (CLMA), College of American Pathologists, and National Society for Histotechnology]. Considering branding, the laboratory seems to have already fulfilled some of the prerequisites. However, it will be a large and long standing effort to improve the branding of laboratories. Branding should be specific to the different target groups (patients, doctors, future employees, management), but also specific for different countries with different health care systems and cultures.

A brand (as adapted from en.wikipedia.org) should preferably: a) be protected under trademark law, b) be easy to pronounce; c) be easy to remember, d) be easy to recognize, e) be easy to translate into all languages, f) attract attention, g) suggest product benefits or usage, h) suggest the company or product image, i) distinguish the product's positioning relative to the competition, l) be attractive and, m) stand out among a group of other brands.

2) How can the lab mine information/data to improve patient care? Data mining can be a powerful instrument to provide information retrospectively, in real time or prognostically. Examples of fields of application are shown in Table 1.

Discussion

While the discussion topics of the conference were diverse, two themes (communication and responsibility) emerged that resonate universally.

Participants felt that in some cases, lines of communication need to be implemented or reinforced. It was observed

Table 1 Field of application of data mining. Some examples.

- a) Validation of analytical tests
- b) Interference studies
- c) Epidemiological studies
- d) Outcome studies
- e) Preparation of guidelines
- f) Decision support system (DSS)
- g) Real time monitoring of process indicators
- h) Cost effectiveness
- i) Key performance indicators of health care

Prerequisites for simultaneous data mining in different information systems are among others: standardization [semantic (e.g., LOINC), calibration].

that errors can and often do occur in all three phases of testing (pre-examination, examination, post-examination) particularly when communication is non-existent or suboptimal. Communication would include preparing the patient for the examination, insuring that the patient 'understands' instructions; gaining knowledge of the diagnosis or medical condition of the patient at the time that testing is taking place; putting the test result in medical context preventing gross errors; sharing key information between work shifts and awareness of communications and agreements made by the laboratory management with other departments in the organization or with individuals. These represent a small sample of communication examples and each is key to coherent laboratory operations.

Professional ethics enforce an additional requirement that is individual responsibility. Participants suggested that the human element of laboratory operation is its weakest link, and emphasized that each laboratory staff person from the lowest to the highest levels must understand and appreciate the role each plays in the total testing process. Simply put, laboratory staff must take full responsibility for the patient. They must ensure that they: a) Be familiar with and adhere to laboratory procedures. b) Be competent to perform testing and maintain their competency through continuing education and/or training – the key to preventing hazards. c) Take responsibility for point-of-care testing that occurs within the organization rather than delegating the responsibility to non-laboratory staff; thereby minimizing the risk of producing a test result that could harm the patient if acted upon immediately.

Managing risk of harm to the patient should a test result with an unacceptable amount of analytical error be reported and acted upon is a key responsibility that was the focus of one discussion group. Risk management in the clinical laboratory is a new concept for clinical laboratories, but something laboratories have done informally for years. Standards organizations, such as the Clinical and Laboratory Standards Institute (CLSI, Wayne, PA, USA) have commissioned a voluntary standard that formalizes risk management activities starting with identification of potential hazards attributable to laboratory operations followed by ranking of these hazards based on risk information and concluding with a formal management protocol. Of course, QC is the classic risk management activity engaged in by most laboratories. A contempo-

rary issue still unresolved related to this activity is the appropriate frequency that quality control testing should occur and whether control materials and recommendations made by the manufacturer are sufficient to assure quality.

General guidance for risk, quality, competence and communication can be found in ISO 15189 *Medical Laboratories: Particular Requirements for Quality and Competence* and an update of the work on the next version of this ISO document was delivered by David Burnet (Consultant, Lindens Lodge, Bradford Place, Penarth, Great Britain). A second key-note lecture was delivered by Claude Giroud (Marketing Manager – Europe, Quality Assurance Programs, Bio-Rad Laboratories, Marnes, France) on the work currently underway regarding the calculation of uncertainty of measurement for medical laboratory test results. After the key-notes, the participants broke up into five working groups to commence discussions on the various assigned topics.

Acknowledgments

1. Ten Years after the Stockholm Conference

Carmen Ricós PhD (CHAIR), Spanish Society of Clinical Biochemistry (SEQC), Plaza Gala Placidia, 2 àtico, Barcelona, Spain, carmen.ricos@terra.es; **Dimitri Baetens Apr. Biol.**, Klinisch Laboratorium ZNA, Lindendreef 1, Antwerpen, Belgium, Dimitri.Baetens@zna.be; **Mira Barak PhD**, Clalit Health Services, Haifa and Western Galilee Labs., Hataasia 47 Nesher, Haifa, Israel, miraba@clalit.org.il; **Jean-Pierre Bouilloux MD**, LABM LxBio, Quality Management, 5,7 boulevard d'estourmel, Rodez, France, jp.bouilloux@lxbio.com; **Ivan Brandslund MD**, DMSc, Lillebaelt Hospital, Laboratory Center, 25 Kabbeltøft, Vejle, Denmark, ivan.brandslund@slb.regionsyddanmark.dk; **Pilar Fernández Calle MD, PhD**, La Paz University Hospital, Emergency Laboratory, Paseo de la Castellana 261, Madrid, Spain, pfernandez.hulp@salud.madrid.org; **Jean Pierre Dehorne PhD**, Laboratoire Réseau Bio, Biochemistry Microbiology, 8 rue de l'Europe, Chapelle sur Erdre, France, jp.dehorne@mac.com; **Arnaud Dupuis PhD**, Haute-pierre Hospital, Haematology Laboratory, Avenue Molière, Strasbourg, France, arnaud.dupuis@chru-strasbourg.fr; **Marc Thelen PhD**, IJsselland Hospital, Clinical Laboratory, PO box 690, Capelle aan den IJssel, Netherlands, mthelen@ysl.nl; **Nudar Jassam MRC Path**, Leeds Teaching Hospital Trust, Clinical Biochemistry, Old Medical School, Leeds, Great Britain, LS1 3EX, nuthar.jassam@leedsth.nhs.uk; **Guillaume Lefevre PhD**, Hopital Tenon, Biochemistry, 4 rue de la Chine, Paris, France, guillaume.lefevre@tnn.aphp.fr; **Carmen Perich PhD**, Institut Català de la Salut, Laboratori Bon Pastor, C/Mollerusa s/n, Barcelona, Spain, cperich.bcn.ics@gencat.cat; **Anne Vassault PhD**, Hôpital Necker, Biochemistry, 149 rue de Sevres, Paris, France, anne.vassault@nck.aphp.fr

2. Achieving quality in point-of-care testing

Mario Plebani MD (CHAIR), Azienda Ospedaliera-Università di Padova, Via Giustiniani 2, 35128 Padova (PD), Italy, mario.plebani@unipd.it; **Rob Jansen PhD** (CO-CHAIR), SKML, Director General, Postbox 9101 huispost 488, 6500 HB Nijmegen, Netherlands, RJansen@skml.nl; **David Burnett PhD**, Consultant in Quality and Accreditation System, Lindens Lodge, Bradford Place, Penarth, CF64 1LA, Great Britain, davidburnett4@btinternet.com; **Roman Fried MD**, Verein f. medizinische Qualitätskontrolle, Institut für Klinische Chemie, Universitätsspital Zürich, Zürich, Switzerland, roman.fried@usz.

ch; **Maria Stella Graziani PhD**, Azienda Ospedaliera Universitaria Integrata di Verona, Laboratorio di Analisi Chimico Cliniche ed Ematologiche, Piazza Stefani, 1, 37126 Verona (VR), Italy, mariastella.graziani@ospedaleuniverona.it; **Hannele Kangas PhD**, Hospital District of Helsinki and Uusimaa, Huslab, Peijaksen sairaalan laboratorio, Sairaalakatu 1, Vantaa, Finland, hannele.kangas@hus.fi; **David Rambau FFPath**, Lancet Laboratories, Stanley and Menton Rd, Richmond, Johannesburg, South Africa, rambau@lancet.co.za; **Berndt Zur MD**, Universitätsklinikum Bonn, Institut für Klinische Chemie und Pharmakologie Siegmund-Freud-Straße 25, Bonn, Germany, berndt.zur@ukb.uni-bonn.de; **Michel Vaubourdolle PhD**, Hôpital Saint-Antoine, Biologie-Imagerie, 184, rue du Fb St Antoine, Paris, France, michel.vaubourdolle@sat.aphp.fr

3. Assessing risk and controlling sources of error in the laboratory path of workflow

Sharon Ehrmeyer PhD (CHAIR), University of Wisconsin, Pathology and Laboratory Medicine, 6175 University Ave., Madison, WI, USA, ehrmeyer@wisc.edu; **Norbert Blanckaert MD, PhD, MBA**, Catholic University of Leuven, Laboratory Medicine, Herestraat 49, Leuven, Belgium, norbert@uzleuven.be; **Peter Declercq PhD**, Jessa Ziekenhuis Laboratoriumneeskunde, Stadsomvaart 11, Hasselt, Belgium, peter.declercq@jessazh.be; **Brendan Fitzpatrick FIBMS, CSci, MSB, CBiol, MSc**, Bon Secours Hospital, Haematology Dept., Glasnevin, Dublin, Ireland, bfitzpatrick@bonsecours.ie; **Monika Fritzer-Szekeres MD**, General Hospital/Medical University, Clinical Institute for Medical and Chemical Laboratory Diagnostics, Waehringer Guertel 18-20, Vienna, Austria, monika.fritzer-szekeres@meduniwien.ac.at; **Dagmar Kessler MD, CSCQ**, 2, Chemin du Petit-Bel-Air, Chêne-Bourg, Switzerland, dagmar.kessler@hcuge.ch; **Solveig Linko PhD**, Helsinki and Uusimaa Hospital District, Huslab, P.O. Box 340, Helsinki, Finland, solveig.linko@hus.fi; **Matthias Orth MD, PhD**, Vinzenz von Paul Kliniken, Institut für Laboratoriumsmedizin, Adlerstr. 7, Stuttgart, Germany, orth@vinzenz.de; **Francisco Ramón Bauza PhD**, Hospital Universitari Sant Joan de Déu, Biochemistry, Passeig Sant Joan de Déu, 2, Esplugues, Barcelona, Spain, framon@hsjdbcn.org; **Ángel Salas MD**, Consorci Sanitari Terrassa, Direcció Qualitat, Ctra. Torrebonica, s/n, Terrassa, Spain, asalas@cst.cat; **Maria Adelina Gomes MD**, Instituto Nacional, Controlo da Qualidade, Avenida Padre Cruz, Lisboa, Portugal, m.adelina.gomes@insa.min-saude.pt; **Jaya Thomas BMBCH, FCPPath**, National Health Laboratory Service, Chemical Pathology, 7, York Road Parktown, South Africa, jaya.george@nhls.ac.za

4. What frequency of QC is enough?

John Yundt-Pacheco BS (CHAIR), Bio-Rad Laboratories, Quality Systems Division, 3201 Technology Drive, Plano, TX, USA, john_yundt-pacheco@bio-rad.com; **Maguy Bernard PhD**, GH Pitie Salpetriere, Biochimie Endocrinienne et Oncologique, 47 bd de l'Hopital, Paris, France, maguy.bernard@psl.aphp.fr; **Ferruccio Ceriotti MD**, Diagnostica e Ricerca Raffaele, Via Olgettina 60, 20132 Milano (MI), Italy, ceriotti.ferruccio@hsr.it; **Christa Cobbaert PhD**, Leiden University Medical Center, Department of Clinical Chemistry, Albinusdreef 2, 2300 RC Leiden, Netherlands, c.m.cobbaert@lumc.nl; **Jeremie Gras MD**, UCL Saint-Luc University Clinics, Clinical Biology, 10 Avenue Hippocrate, Brussels, Belgium, jeremie.gras@gmail.com; **Daniella Harell PhD**, Clalit Health Fund, Central Laboratory, 27 Benjamin (Home address), Ramat-Gan, Israel, dharell@smile.net.il; **Adrian Holt PhD**, Manchester Royal Infirmary, Biochemistry Department, Oxford Road, Manchester, Great Britain, adrian.holt@cmft.nhs.uk; **Michael Hubmann PhD**, Med. Zentrallaboratorium GmbH, Carinagasse 41,

Feldkirch, Austria, mhubmann@mzl.at; **Douwe van Loon PhD**, Sint Antonius Ziekenhuis, Clinical Chemistry, Postbus 2500, Nieuwegein, Netherlands, d.vanloon@antoniusziekenhuis.nl; **Rui Pimentel MD**, LAC Joaquim Chaves, Core Laboratory, Av. General Norton de Matos, 71, R/C Miraflores, PRT, rui.pimentel@gjc.pt; **Anne Rauhio MSc**, Pirkanmaa Hospital District, Centre for laboratory medicine, PO Box 2000, Tampere, Finland, anne.rauhio@pshp.fi

5. Putting laboratory medicine at the core of patient care

Niels de Jonge PhD (CHAIR), Haga Teaching Hospital, Clin Chem Hematol Laboratory, P.O. Box 40551, The Hague, Netherlands, n.dejonge@hagaziekenhuis.nl; **Jos Van Acker MD**, AZ Sint-Lucas Gent, Laboratory, Groenebriel 1, Gent, Belgium, jos.vanacker@azstlucas.be; **Francisco A. Bernabeu PhD**, Hospital Universitario Príncipe de Asturias, Department of Quality, Ctra. Alcalá-Meco, s/n, Alcalá de Henares, Spain, fbernabeu.hupa@gmail.com; **Eirini Leimoni PhD**, Euromedic International Company, Laboratory Development Officer, 50 Agiou Konstantinou, Athens, Greece, irini.leimoni@euromedic.gr; **Dirk Peetz MD**, Universitätsmedizin der Johannes Gutenberg-Universität Mainz, Institut für Klinische Chemie und Laboratoriumsmedizin, Langenbeckstraße 1, Mainz, Germany, peetz@uni-mainz.de; **Rudi Ravasio PhD**, Ospedali Riuniti di Bergamo, USC Laboratorio Analisi Chimico Cliniche, Via Largo Barozzi 1, 24128 Bergamo (BG), Italy, rravasio@ospedaliuniti.bergamo.it; **Evangelos Vogiatzakis MD, PhD**, Gen. Hospital Polykliniki Athens, Microbiology – Biochemistry Laboratory, 10 Thironos Str, Athens, Greece, vogial@otenet.gr.

Conflict of interest statement

Authors' conflict of interest disclosure: The authors stated that there are no conflicts of interest regarding the publication of this article.

Research funding: None declared.

Employment or leadership: None declared.

Honorarium: None declared.

References

- Kenny D, Fraser CG, Hyltoft Petersen P, Kallner A. Introduction: Strategies to set global analytical quality specifications in laboratory medicine. *Scand J Clin Lab Invest* 1999;59:477–8.
- Hyltoft Petersen P, Fraser CG. Strategies to set global analytical quality specifications in laboratory medicine: 10 years on from the Stockholm consensus conference. *Accredit Qual Assur* 2010;15:323–30.
- Fraser CG, Hyltoft P, Ricós C, Haeckel R. Quality specifications for the acceptability of analytical systems in for clinical chemistry. *Eur J Clin Chem Clin Biochem* 1992;30:311–7.
- Rustad P, Felding P. Translational biological reference intervals. *Scand J Clin Lab Invest* 2004;64:263–441.
- Gallagher MP, Mobley LR, Klee GG, Schryver P. The impact of calibration error in medical decision error. NIST 2004.
- Ricós C, Álvarez V, Cava F, García-Lario JV, Hernandez A, Jiménez CV, et al. Integration of data derived from biological variation into the quality management system. *Accredit Qual Assur* 2004;9:128–131.
- Burnett D, Ceriotti F, Cooper G, Parvin C, Plebani M, Westgard J. Collective opinion paper on findings of the 2009 convocation of experts in quality control. *Clin Chem Lab Med* 2010;48:41–52.
- Ricós C, Baadenhuijsen H, Libeer JC, Hyltoft Petersen P, Stöckl D, Thienpont L, et al. Currently used criteria for evaluating performance in EQA in European countries and a proposal for harmonization. *Eur J Clin Chem Clin Biochem* 1996;34:159–65.
- Ricós C, Alvarez V, Cava F, Garcia-Lario JV, Hernandez A, Jiménez CV, et al. Desirable specifications for total error, imprecision, and bias, derived from intra- and inter-individual biologic variation. The 2010 update. <http://www.westgard.com/biodatabase1.htm>.
- Ricós C, Iglesias N, García-Lario JV, Simón M, Cava F, Hernández A, et al. Within-subject biological variation in disease: collated data and clinical consequences. *Ann Clin Biochem* 2007;44:343–52.
- Fraser CG, Hyltoft Petersen P. Desirable performance standards for imprecision and bias in alternate sites. The views of laboratory professionals. *Arch Pathol Lab Med* 1995;119:909–13.
- Harris E, Brown S. Temporal changes in the concentration of serum constituents in healthy men. Distributions of within-person variances and their relevance to the interpretation of differences between successive measurement. *Ann Clin Biochem* 1979;16:169–75.
- Ricós C, Doménech MV, Perech C. Analytical quality specifications for common reference intervals – review. *Clin Chem Lab Med* 2004;42:858–62.
- Jorgensen L, Hyltoft Petersen P, Brandslund I. Clinical outcome estimated bases on treatment target limits of laboratory tests: proposal for a plot visualizing effects and differences of medical target setting exemplified by glycemic control in diabetes. *Clin Chem Lab Med* 2006;44:327–32.
- Petersen HP, Christensen GN, Sandberg S, Nordin G, Pedersen M. How to deal with a dichotomous tests? Application of a rankit ordinal scale model with examples from the Nordic ordinal scale project on screening tests. *Scan J Clin Lab Invest* 2008;68:298–311.
- Petersen PH, Christensen NG, Sandberg S, Nordin G, Pedersen M, Nordic Control Organizations. How to deal with semi-quantitative tests? Application of an ordinal scale model to measurements of urine glucose. *Scand J Clin Lab Invest* 2009;69:662–72.
- ISO 22870:2006. Point-of-care testing (POCT) – Requirements for quality and competence.
- Lex EU. Directive 98/79 EC on in vitro medical devices. *Off J L* 1998;331:1–37.
- Fraser CG, Petersen PH. Desirable standards for laboratory tests if they are to fulfill medical needs. *Clin Chem* 1993;39:1447–53 [discussion], 1453–5 [review].
- Jansen R, Slingerland R. SKML – Quality mark for point-of-care test (POCT) glucose meters and glucose meters for home-use. *Clin Chem Lab Med* 2010;48:1021–7.
- Carraro P, Plebani M. Post-analytical errors with portable glucose meters in the hospital setting. *Clin Chim Acta* 2009;404:65–7.
- EP18-A2, Risk Management Techniques to identify and control Laboratory Error Sources. Clinical and Laboratory Standards Institute, Wayne, PA, 2009.
- EP23-P, Laboratory Quality Control based on Risk Management. Clinical and Laboratory Standards Institute, Wayne, PA, 2010.
- GP32-A, Management of Non-conforming Laboratory Event. Clinical and Laboratory Standards Institute, Wayne, PA, 2007.
- Institute of Medicine. Crossing the quality chasm: a new health system for the 21st century. Washington, DC: National Academy Press, 2001.

26. Parvin CA. Assessing the impact of the frequency of quality control testing on the quality of reported patient results. *Clin Chem* 2008;54:2049–54.
27. Yundt-Pacheco J, Parvin CA. The impact of QC frequency on patient results. *MLO Med Lab Obs* 2008;40:24, 26–7.
28. Sung S, Forman-Hoffman V, Wilson, MC, Cram P. Direct reporting of laboratory test results to patients by mail to enhance patient safety. *J Gen Intern Med* 2006;21:1075–8.
29. Soloway HB. Establishing a direct laboratory access program. *Clin Chem* 1995;41:809–12.