Quality standards and internal quality control practices in medical laboratories: an IFCC global survey of member societies

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Abstract

Objectives: The trueness and precision of clinical laboratory results are ensured through total quality management systems (TQM), which primarily include internal quality control (IQC) practices. However, quality practices vary globally. To understand the current global state of IQC practice and IQC management in relation to TQM the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) Task Force on Global Laboratory Quality (TF-GLQ) conducted a survey of IFCC member countries on IQC practices and management.

Methods: The survey included 16 questions regarding IQC and laboratory TQM practices and was distributed to IFCC full and affiliate member countries (n=110). A total of 46 (41.8 %) responses were received from all regions except North America.

Results: Of the responding countries, 78.3 % (n=36) had legislative regulations or accreditation requirements governing medical laboratory quality standards. However, implementation was not mandatory in 46.7 % (n=21) of responding countries. IQC practices varied considerably with 57.1 % (n=28) of respondents indicating that they run 2 levels of IQC, 66.7 % (n=24) indicating they run IQC every 24 h.

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and 66.7% (n=28) using assay manufacturer IQC material sources. Only 29.3% (n=12) of respondents indicated that every medical laboratory in their country has written IQC policies and procedures. By contrast, 97.6% (n=40) of responding countries indicated they take corrective action and result remediation in the event of IQC failure.

**Conclusions:** The variability in TQM and IQC practices highlights the need for more formal programs and education to standardize and improve TQM in medical laboratories.

**Keywords:** global survey; IFCC; internal quality control; International Federation of Clinical Chemistry and Laboratory Medicine; medical laboratories; quality assurance; quality management

**Introduction**

The medical laboratory provides critical information to clinicians for disease screening, diagnosis, monitoring, prevention, and treatment, especially in this era of evidence-based medicine. The trueness and precision of the results produced by the medical laboratory is often poorly understood by clinicians who generally consider results to be definite as they review them in the medical record. As a consequence, laboratories must develop and maintain robust quality management systems to ensure the reliability of results necessary to meet these expectations are preserved.

Early quality management efforts in the medical laboratory focused on analytical quality as the important first step in providing consistent results [1]. Despite advances in automation which reduce human intervention and errors, there are still many areas that must be consistently monitored for quality excursions [2, 3]. Total quality management systems (TQM) in the medical laboratory now seek to minimize risks of erroneous results and must necessarily monitor all parts of the testing process [4]. Identification of erroneous results from medical laboratory processes throughout the total testing process and thoughtful application of quality metrics is an important control measure to minimize risk [2, 4]. Recent work by the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) has provided consensus harmonized quality indicators (QI) and provided both studies and guidance on implementation [5–7]. Unfortunately, implementation of comprehensive QI and appropriate follow-up is resource intensive in a time when medical laboratories are already resource stretched [6, 7] and medical laboratories may be forced to implement minimum required QI only.

Internal quality control (IQC) is a central tenet in analytical quality assessment and is a mainstay of medical laboratory testing, being required by international quality standards, regulatory, and accreditation agencies [8, 9]. Ideally, IQC allows the medical laboratory to monitor both trueness (through the mean IQC value) and precision, (through the evaluation of reproducibility by standard deviation of IQC values) [10, 11]. This traditional IQC model of monitoring assumes that analytical errors will be reflected by IQC excursions due to a shift in the underlying Gaussian distribution of IQC results [10, 11]. Assessment of current and future possibilities for IQC and analytical quality monitoring reflect the continued evolution of laboratory medicine with rules advocating for performance specifications centered around imprecision [12] as well as a traceability approach where bias can also be considered [13, 14].

In current practice IQC is assumed to monitor for variables in instrumentation, lot-to-lot variability, and other possible sources of analytical error. IQC practices vary in the number of levels of material used, frequency of analysis, type and source of material, acceptance criteria, practices in handling out-of-range IQC, and procedures for evaluation of IQC. A survey on statistical global IQC practices in 2017 indicated that the primary reason cited for setting levels of materials and frequency of performance were regulatory and accreditation requirements [15], highlighting the need for appropriate regulatory and accreditation guidance.

Global practices in IQC seem to vary considerably, as global surveys and within country assessments have indicated [15–17]. To clarify the current state of IQC practice and IQC management in relation to TQM, the IFCC TF-GLQ conducted a survey of IFCC full and affiliate members on IQC practices and management. The goal of this survey was to determine the current state of global laboratory quality systems and to assess the need for additional education programs for IQC in medical chemistry and laboratory medicine.

**Materials and methods**

**Survey design**

A two-part survey was drafted by an IFCC TF-GLQ subcommittee of members as previously outlined [18]. Briefly, this survey addressed global quality management and IQC as well as EQA programs in clinical chemistry (including immunoassays), hematology, and serology. We have previously reported on the EQA findings in this survey and present here the quality management and IQC findings. The survey included 16 questions regarding IQC and laboratory quality management with an emphasis on providing simple, multiple-choice responses to limit language barriers and increase participation.

**Survey deployment and participation**

On February 10, 2021 the final survey was sent via Survey Monkey to IFCC National Member Societies through their National Representatives
and remained available until March 15, 2021. The survey request included the statement that “This survey’s intention is to determine your country’s current quality laboratory system and assess the need for implementation or expansion of IQC and EQA programs for Clinical Chemistry and Laboratory Medicine.” There were 110 recipients (93 full members and 17 affiliate members) resulting in 66 responses received. Accounting for duplications there were a total of 52 countries that responded to the survey (47.3 %). Of the 52 countries, 46 (41.8 %) provided responses to questions regarding IQC and quality management (Table 1). Only countries that provided responses to IQC and quality management questions were included in this survey result assessment. Incomplete responses were not evaluated. Countries submitting multiple responses were combined to create a single response per country.

Survey analysis

Survey results were exported to a comma separated file and compiled in Excel (Microsoft, Redmond, WA, USA). Tables, figures, and calculations were performed in Excel. To understand geographic variability, where pertinent, responses were stratified by IFCC region: African Federation of Clinical Chemistry (AFCC), Arab Federation of Clinical Biology (AFCB), Asia-Pacific Federation for Clinical Biochemistry and Laboratory Medicine (APFBCM), European Federation of Clinical Chemistry and Laboratory Medicine (EFLM), Latin American Federation of Clinical Biochemistry (COLABIOLCI). No responses were received from members of the North America Federation of Clinical Chemistry (NAFCC).

Results

Laboratory quality management systems

We first assessed if there were legislative regulations or accreditation requirements that governed medical laboratory quality standards and found that only 36 of 46 reporting countries (78.3 %) had these requirements (Figure 1A). 36 of 42 countries indicated that they have an agency that is responsible for supervising the application of quality standards (Figure 1B). Interestingly, two countries without regulations for medical laboratory quality standards did have an agency available to supervise the application of standards, and two countries with regulations for medical laboratory quality standards did not respond to the survey question regarding availability of a supervisory agency. Despite a lack of official requirements for medical laboratory quality standards in 21.7 % of responding countries (10/46), 40 of 44 (90.9 %) responding countries indicated that quality standards are in use for medical laboratories in their country (Figure 1C).

Legislative regulations or accreditation requirements governing medical laboratory quality standards can vary considerably and almost half of the responding countries indicated that application of quality standards was not mandatory (21 of 45, 46.7 %; Figure 1D). While application of quality standards was not mandatory for many countries, almost all countries 97.6 % (40 of 41) responded that there were qualification requirements to be a quality manager. Respondents indicated that required qualifications varied considerably with 12 countries requiring a certification, 25 requiring a degree, 17 requiring a diploma, and 2 requiring a specialist.

Internal quality control

A vital pillar of total laboratory quality management is IQC and we surveyed countries for an estimate of the percentage of medical laboratories within the country that perform IQC. More than half of respondents indicated that IQC is run in all laboratories in their country (23 of 40, 57.5 %), however 17 of 40 (42.5 %) respondents indicated that IQC is run in 50–99 % of medical laboratories (Figure 2A). One country in this response indicated that IQC was run ‘as appropriate’ and this response was excluded from this analysis. Frequency of IQC performance indicated that medical laboratories primarily performed IQC every 24 h (24 of 42 respondents, 57.1 %), though 6 respondents had varying IQC frequency which might be expected as IQC frequency may vary depending on assay performance (Figure 2B). IQC every 24 h reflects a minimum standard best practice [8, 9] and we found the response of the majority of countries to the number of IQC levels usually performed also reflected a minimum standard best practice with 28 of 42 (66.7 %) respondents indicating that they run 2 levels of QC (Figure 2C). Many countries ran a variable number of IQC levels (11 of 42, 26.2 %), reflecting the

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<td>Total countries</td>
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Figure 1: Medical laboratory quality standards. (A) Response indicates if there are regulations and/or requirements that govern medical laboratory quality standards in a country (n=46). (B) Response indicates if there is an agency available to supervise the application of clinical laboratory quality standards in the respondent’s country (n=42). (C) Response indicates if quality standards are in use for medical laboratories in the country (n=44). (D) Response indicates if application of quality standards are mandatory in the country (n=45).

Figure 2: Internal quality control Execution. (A) Response indicates the percentage of laboratories within a country that perform IQC (n=40). (B) Response indicates how often QC is run in the respondent’s country (n=42). (C) Response indicates the number of QC levels utilized by countries (n=42). (D) Response indicates the source of QC materials utilized by countries (n=42), responses are stratified by IFCC region. AFCC, African Federation of Clinical Chemistry; AFCB, Arab Federation of Clinical Biology; APFCB, Asia-Pacific Federation for Clinical Biochemistry and Laboratory Medicine; EFLM, European Federation of Clinical Chemistry and Laboratory Medicine; COLABIOCLI, Latin American Confederation of Clinical Biochemistry.
variability in IQC needs for different assays. The majority of responding countries indicated that they used assay manufacturer IQC materials (28 of 42, 66.7%) rather than third party IQC (16 of 42, 38.1%) with two countries reporting use of both IQC sources.

**Internal quality control performance**

Running IQC material is only the first step utilizing IQC for quality management and a detailed procedure is necessary for effective management of IQC. While all countries indicated that at least some of their labs had written IQC policies and procedures, there were only 12 of 41 (29.3%) respondents that indicated every medical laboratory in their country had written IQC policies and procedures (Figure 3A). The steps following running IQC material require assessment against a defined set of rules that reflect if the assay is performing as expected. We found that most countries indicated that they used Westgard IQC rules (23 of 42, 54.8%; Figure 3B). Only one country reported use of 3 standard deviation (SD) rules, and 8 countries (19%) reported use of a combination of rules.

IQC data are primarily displayed by software (26 of 42, 61.9%), though a large number of countries still use a manual display of IQC data (12 of 42, 28.6%) while some use both (4 of 42, 9.5%; Figure 3C). Those IQC data are reviewed by multiple people for many labs with Supervisor (25 of 40) and Medical Directors (24 of 40) being the most commonly reported reviewers, while 17 of 40 countries reported that

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**Figure 3:** Internal quality control evaluation. (A) Response indicates if laboratories in a country have written policies and procedures for IQC (n=41). (B) Response indicates the IQC rules utilized in the respondent’s country (n=42). (C) Response indicates the method for displaying QC data by countries (n=42), responses are stratified by IFCC region; AFCC, African Federation of Clinical Chemistry; AFCB, Arab Federation of Clinical Biology; APFCB, Asia-Pacific Federation for Clinical Biochemistry and Laboratory Medicine; EFLM, European Federation of Clinical Chemistry and Laboratory Medicine; COLABIOCLI, Latin American Confederation of Clinical Biochemistry. (D) Response indicates who reviews QC in the countries (n=40). (E) Response indicates how often QC is reviewed in the countries (n=42). (F) Response indicates if corrective actions are taken if QC is unacceptable (n=41).
bench level personnel reviewed IQC (Figure 3D). Responding countries reported that IQC data were primarily reviewed daily (32 of 42), though several countries review IQC data at multiple timepoints including weekly and monthly, which is a frequent practice to identify trends and verify appropriate decision making by frontline staff (Figure 3E). Most responding countries (40 of 41) indicated that their medical laboratories take corrective action and result remediation in the event of IQC failure (Figure 3F).

The complexity of IQC and appropriate management of IQC results to maintain laboratory quality is underscored by the response of 22 of 39 (56.4 %) countries that would be interested in participating in an IQC pilot training program organized by the IFCC TF-GLQ (Figure 4).

**Discussion**

Effective laboratory TQM is critical to ensuring trueness and precision in the medical laboratory. The medical laboratory provides results that directly impact patient care and clinician decision-making, ensuring quality results is of utmost importance. As a result, most countries have legislative or governmental regulations and requirements around multiple aspects of quality within the medical laboratory. This survey provides a reasonable sampling of current quality management systems among IFCC member and affiliate countries across the globe with a 42 % participation rate. The largest representation was from the EFLM encompassing 27 of 46 (58.7 %) of the respondents. While there was notably no representation of NAFCC countries, participation from AFCB, AFCC, APFCB, and COLABIOCLI encourage consideration of this survey as a reasonable estimate of current practices in TQM and IQC practices globally. Interestingly, even within the EFLM there was marked diversity in the responses which underscores the lack of global standardization in application of TQM and IQC practices [15, 16, 19].

Despite a lack of participation by the NAFCC, both members, Canada and the United States of America (USA), have rigorous governmental requirements for laboratory quality management which are stringently enforced, though a survey of academic medical institutions within the USA indicated significant variability in many aspects of IQC [16]. While 78.3 % (36 of 46) of countries had legislative regulations or accreditation requirements that governed medical laboratory standards, 85.7 % (36 of 42) of respondents have an agency available for supervision of the application of laboratory quality standards, perhaps providing some indication that there may be future requirements or regulations instituted in countries that do not currently have them. Encouragingly 90.9 % of respondent countries had medical laboratory quality standards in use, though this was only mandatory in 53.3 % of respondent countries underscoring the need for more formal programs to standardize and improve TQM in the medical laboratory. The fact that 42.5 % of responding countries indicated that at least some medical laboratories in their country did not perform IQC highlights the need for increased mandatory minimum global TQM standards.

IQC continues to be a central tenet in TQM, though there are different viewpoints on its optimal implementation and utility [12–14]. It is generally accepted that even minimum implementation of IQC aids in defining imprecision to ensure reproducibility, while more advanced implementation can provide additional information on trueness and precision [3, 11–14]. Assessing ongoing assay reproducibility necessitates defining the IQC frequency and levels. This survey was limited in that it queried these questions as a composite of laboratory practice, though frequency and levels of IQC should be assay specific. We therefore consider that the responses illustrate minimum frequency and levels. The most common IQC practice appears to be 2 levels of IQC run every 24 h. Many respondents indicated that both frequency and levels were variable, which is an accurate
reflection of a medical laboratory with robust TQM in place. Two levels of IQC run every 24 h would be sufficient for high performance assays but inadequate for other assays [9, 20]. IQC material is an important consideration as analytically assigned values can allow for higher level evaluation of bias and drift [21], though this has not been well adopted. Most respondent countries (66.7 %) indicated that they use manufacturer IQC possibly reflecting the financial implications of running third party IQC. Third party IQC can be costly and also logistically prohibitive for some countries where IQC material costs are an issue and supply chains are regularly disrupted. These practical considerations are relevant when assessing guidance and training for standardization of IQC practices. Shared coordination between medical laboratories and manufacturers will continue to be important as we work to improve IQC globally [13].

Running appropriate IQC materials, at appropriate concentrations and intervals is only the first step in truly utilizing IQC for quality management. Establishing performance criteria and follow-up processes for unacceptable results is also critical [3]. This is best provided through formal policies and procedures that will ensure regular and appropriate analysis and action on IQC results [8, 9, 22]. Unfortunately, 60 % of respondents indicated that not all medical laboratories in their country had IQC policies and procedures. This emphasizes an important gap which should be addressed. When queried what IQC rules were used in assessing IQC performance 54.8 % of respondents indicated their country primarily used Westgard rules, with 19 % of respondents indicating the use of a combination of rules. How Westgard or other IQC rules were implemented was not assessed in our survey, however, implementation of Westgard rules can take many forms and does not guarantee appropriate IQC assessment. Interestingly, at 19 of 21 academic medical centers surveyed in the USA Westgard rules were not in explicit use and most IQC was assessed using 2 or 3 standard deviation (SD) limits [16]. An informal survey by the Westgard group with 980 responding laboratories (33 % from the USA), 55 % of respondents indicated that they use 2SD limits for all assays, while 73 % of respondents indicated that they are using Westgard Rules [15]. These findings imply that many within the laboratory community may consider 2SD limits to be an application of Westgard Rules. The likely variability in application of IQC rules coupled with the gap in implementation of policies and procedures represents an important area of future education and work to improve laboratory TQM. This work can be aided by improved technology for assessing IQC and we found that 28.6 % of respondents were still using manual display of IQC data in their IQC assessment, which severely limits implementation of more advanced IQC assessments.

Best practices in IQC vary [16, 23, 24], however, most literature and ISO 15189 indicate that results should be assessed daily by those running the testing, and at less frequent regular intervals by supervisory personnel to determine if assays are functioning appropriately [8, 9, 22, 25]. Surprisingly, only 42.5 % of respondents indicated that bench level personnel reviewed IQC, though most (76.2 %) indicated that IQC was reviewed daily. Supervisors and medical directors were the most commonly reported reviewers, which may reflect that this question was interpreted as querying who performs the final review of IQC or that some countries rely on supervisors or directors to review QC prior to reporting patient results. Despite variations in IQC review intervals and reviewers, 97.6 % of responding countries indicated that their medical laboratories take corrective action in the event of IQC failure. However, without policies and procedures in place as noted above, these corrective actions and result remediations may not be consistent between personnel. The complexity of IQC results and management to improve TQM is highlighted by the variability in responses to this survey and reinforced by the response of 56.4 % of countries interested in participating in an IQC pilot training program organized by the IFCC TF-GLQ.

The purpose of this survey was to improve our understanding of global TQM and IQC practices within medical laboratories. Due to distribution of this survey to 110 National Representatives with diverse languages we chose to use multiple choice rather than open ended questions, which may have limited the information we collected. Additionally, this survey was designed to assess basic TQM and IQC current global practices, which may under report more advanced approaches to TQM and IQC which are present globally. We observed some discrepancies in question responses, which may be due to difficulties in question interpretation. As this survey was sent only to the National Representatives, the responses were necessarily an approximation of national practice and cannot capture the variations in individual laboratory practice. Despite these noted limitations, this survey represents the current state of global TQM and IQC practices and provides insight into areas where further improvement would be beneficial.

This survey represents the current state of global TQM and IQC practices. It demonstrates variability in practices globally, and together with our previously published results regarding global EQA (17), it shows that there is ample room for improvements in the quality management of medical laboratories. These survey results lay the groundwork for the IFCC TF-GLQ to develop training and education programs to increase harmonization and improve quality practices in medical laboratories around the world. Moreover, this highlights an opportunity for the IFCC and other laboratory
professional societies to develop guidance on medical laboratory quality strategies and practical approaches with the ultimate goal of improving patient care and outcome.

Acknowledgements: The IFCC TF-GLQ would like to thank Silvia Cardinale for her help and expertise in survey distribution and collation.

Research ethics: Not applicable.

Informed consent: Not applicable.

Author contributions: All authors have accepted responsibility for the entire content of this manuscript and approved its submission.

Competing interests: JL is an employee of Abbott Labs, RB owns rbaisconsulting, KC is an employee of Bio-Rad Laboratories, JMG is an employee of Technical Direction Biogroup and Labac, EA owns Amann Consulting. All other authors state no conflict of interest.

Research funding: None declared.

References