Original Article

A Path to Clarity: Systematic Assessment of Slide Quality in Daily Laboratory Practice

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Abstract

Background: The aim is to evaluate and analyse the defined quality control parameters used in the daily assessment of internal quality control (IQC) slides in cytopathology, histopathology, and peripheral smear examination in haematology to highlight the significance of structured, criterion-based evaluations in strengthening slide quality monitoring and reducing the technical flaws and subjective bias. **Material and Methods:** This was a retrospective observational study conducted in the Department of Pathology, Madras Medical College, Chennai, a tertiary care centre[2]. The study period extended over two years, from June 2020 to June 2022. The objective was to assess the internal quality control (IQC) parameters followed in the evaluation of slides prepared in cytopathology, histopathology, and peripheral smear examination in haematology. **Results:** Daily IQC registers and archival slide records maintained in the laboratory were reviewed[4]. Quality control assessments were conducted by two pathologists using predefined technical parameters for each slide type[5]. The slides were scored for the presence or absence of errors in each parameter, and the data were compiled and analysed to assess the frequency and types of errors in the technical part and to determine the effectiveness of structured parameters in minimizing technical flaws[6]. **Conclusion:** The paper sheds light on the importance of specified quality parameters in the day-to-day assessment of internal quality control (IQC) slides in pathology. With slide systemic evaluation in cytopathology, histopathology, and peripheral smear analysis using structured criteria, variation in slide interpretation resulting from technical variability was greatly reduced in the study [8]. Furthermore, objective parameter-based scoring systems also greatly reduced interobserver variance. The results confirm the necessity of the systematic use of standardized quality control procedures to achieve consistency, improved diagnostic accuracy, and the maintenance of ambitious standards of laboratory practice[1].

Keywords: Slide Quality Assessment, Laboratory Practice, Microscopy, Histopathology, Cytology, Quality Control, Staining Techniques.

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Introduction

Effective laboratory diagnostics takes quality assurance seriously, specifically in pathology, where microscopic analysis of slides directly affects decision-making and, as a result, the analysis of slides as a whole is required to establish this quality assurance (Porter, 2016; Porter, 2017). The whole pathology process can be sufficiently divided into three stages: pre-analytical, analytical, and post-analytical.[12] All these steps will improve the accuracy of the diagnostic procedures' results. Among them, the pre-analytical stage- those stages which involve sample collection, fixation, processing, and slide preparation- is usually the most susceptible to variability, but through the years, the least open to examination historically.[13]

Analysis of the available literature suggests that the majority of quality assessment research in the field of pathology has focused more on the analytical stage, examining diagnostic accuracy and interpretation.[1,14] Nonetheless, mistakes created by some pre-analytical steps, including ineffective fixation, improper staining, or technical defects on the slide preparation, may negatively affect the quality of the diagnosis even prior to the slides proceeding into the reporting phase by a huge margin, including improper fixation, inadequate staining, or technical glitches on the slide preparation stage.[15]

Daily internal quality control (IQC) of slides is an effective method to ensure uniformity in slide preparation and staining methods.[16] In areas such as cytopathology, histopathology, and haematology, it is possible to systematically assess IQC slides against specific quality parameters to identify technical failures early and maintain high diagnostic standards.[17] Nevertheless, there are few standardized guidelines for such assessments, and interobserver reliability is a problem area.[8]

Against such a backdrop, the purpose of the present study will be to evaluate the quality parameters applied during testing of daily

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IQC slides in cytopathology and histopathology, and during the examination of peripheral smears in haematology. The paper highlights that structured scoring systems should be based on criteria to improve objectivity and minimize inconsistencies in observer quality control ratings.

Materials and Methods

This was a retrospective observational study conducted in the Department of Pathology, Madras Medical College, Chennai, a tertiary care centre[2]. The study period extended over two years, from June 2020 to June 2022. The objective was to assess the internal quality control (IQC) parameters followed in the evaluation of slides prepared in cytopathology, histopathology, and peripheral smear examination in haematology.[3]

Daily IQC registers and archival slide records maintained in the laboratory were reviewed[4]. Quality control assessments were based on predefined technical parameters for each slide type.[5] The parameters evaluated were as follows:

Peripheral Smear Slides:

- Smear shape and thickness
- Smearing artifacts
- Smear fixation quality
- Background staining
- Colour and appearance of cellular components, including red blood cells (RBCs), platelets
- White blood cell (WBC) evaluation based on nuclear staining, cytoplasmic clarity, and granule staining, staining uniformity

Cytopathology Slides:

- Smear fixation
- Nuclear staining
- Cytoplasmic staining
- Differentiation of staining
- Presence of stain precipitate
- Uniformity of staining
- Mounting quality

Histopathology Slides:

- Tissue fixation
- Tissue processing and embedding
- Tissue sectioning quality (thickness, uniformity, folds, presence of floaters)
- Staining evaluation (nuclear and cytoplasmic staining, uniformity, differentiation, and stain precipitate)
- Mounting and slide labelling

The slides were scored according to the presence or absence of errors in each parameter, and consistency in scoring between observers was also analysed based on adherence to the defined criteria[6]. Data were compiled and analysed to assess the frequency and types of errors in the technical part and to determine the effectiveness of using structured parameters in minimising technical flaws and inter-observer variation[7].

Results

A total of 485 histopathology and cytopathology slides and 700 peripheral smear slides were evaluated under Internal Quality Control (IQC) using standardized assessment criteria.

Histopathology Slides (n = 485)

Histopathology slides showed the highest frequency of technical errors. The most common errors identified were:

Section error – 42 slides

Under-processing – 38 slides

Staining defects – 30 slides

Incomplete fixation – 18 slides

Mounting errors – 10 slides

Improper embedding – 8 slides

Cytopathology Slides (n = 485)

The predominant errors observed were:

Staining errors – 23 slides

Fixation errors – 15 slides

Peripheral Smear Slides (n = 700)

Peripheral smears demonstrated the highest number of errors per slide. The most frequent issues included:

Thick smears – 50 slides

Background precipitate – 47 slides

Smear lines/holes – 28 slides

Staining defects – 18 slides

Overall, technical errors were more frequent in histopathology slides in absolute numbers, while peripheral smears exhibited the highest error rate per slide.

Discussion

Internal Quality Control (IQC) plays a pivotal role in maintaining the consistency and reliability of diagnostic slides in pathology laboratories[8]. The study aimed to identify general technical mistakes in histopathology, cytopathology, and peripheral smear slides, and to design specific remedial measures for these based on standardised assessment criteria eleven. The evaluation of 485 histopathology and cytopathology slides, each with 700 peripheral smears, showed that a variety of recurrent technical problems influence the overall quality of the diagnoses.

Histopathology had the highest rate of errors: the most common error was sectioning defect (42 slides), then came under-processing (38 slides), and finally staining defect (30 slides) [11]. Such problems are caused by the following: inappropriate use of equipment (e.g., microtomes), poor maintenance of reagents, and non-optimised procedures.[12] The unfinished fixation (18 slides) and the incorrect embedding (8 slides) highlighted shortcomings in tissue handling during the pre-analytical stage.[13] The other error was mounting errors (10 slides), but this was less prevalent, and the majority of them were caused by improperly used mountant or coverslips. The remedial measures for such mistakes included strengthening training procedures, periodic calibration of equipment, and process standardisation.[14]

Staining errors were more prevalent in cytopathology (23 slides), followed by fixation errors (15 slides). These may have a very deleterious effect on nuclear and cytoplasmic detail, thus affecting cytological interpretation to the detriment of the latter in a very severe manner. Staining solutions must be filtered regularly, staining protocols must be established, and fixation materials must be available at the location where the smear is made. This was also proposed to be used as a corrective measure, which has been proven to be effective on many occasions.[11]

On a per-slide basis, there was the largest number of technical

errors in peripheral smears compared to all other types of slides examined.[1] The most frequent problems were thick smears (50 slides) and background precipitate (47 slides), both of which interfere with the assessment of cell morphology.[1] Smear lines or holes (28 slides) and staining defects (18 slides) also contributed to the inferior quality of slide 1. Such mistakes were attributed to other causes, including poor smear technique, poor slide cleaning, the use of poorly maintained staining solutions, and others.[20]

The introduction of a set of standardised criteria for evaluating IQC became a critical intervention in this study.[21] Such a systematic procedure enabled the objective evaluation of each slide against the stated parameters. Consequently, the fundamental causes of errors might be revealed promptly, and certain, effective corrective actions might be undertaken efficiently.[2] Unified standards were also used to provide clear guidelines that technicians could understand and correct their errors, thereby helping ensure continuous quality improvement.[23]

Moreover, another significant effect of employing standardised evaluation criteria was the decrease in inter-observer variation.[24] Objectivity and personal bias were reduced by having consistent rules used to apply the same method to all evaluators. The number of discrepancies during slide evaluation was reported to be rare, with the greatest proportion caused by external sources of variability, such as variations in microscope illumination or incomplete scanning of a slide zone.[25] All these were controlled by setting up a microscope in a standard manner and by thoroughly systematically screening the slide.[26]

Histopathology Slide Errors (n = 485)

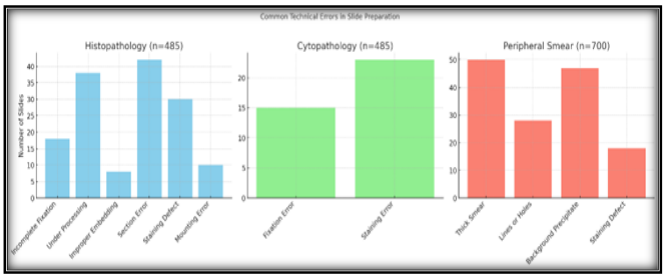
Error	Number of Slides	Corrective Action
Incomplete Fixation	18	Ensure timely transfer of specimens to fixative; use adequate volume (10:1 ratio of fixative to tissue); train staff to check fixation status before processing.
Under Processing	38	Review and optimise processing schedules (time/temperature/dehydration); verify reagent quality and change cycles; introduce pre-processing checklist.
Improper Embedding	8	Provide hands-on training for correct tissue orientation; monitor embedding under supervision; use labeled templates for orientation-sensitive tissues.
Section Error	42	Calibrate microtomes regularly; train technicians on optimal thickness; monitor blade condition and replace as needed; implement double-checking during sectioning.
Staining Defect	30	Standardize staining protocols; monitor reagent freshness; implement slide rotation for even staining; document staining times and temperatures.
Mounting Error	10	Ensure proper coverslip size and adhesive usage; dry slides adequately before mounting; check for air bubbles or excess mountant before cover slipping.

Cytopathology Slide Errors (n = 485)

Error	Number of Slides	Corrective Action
Fixation Error	15	Train staff on immediate fixation after smear preparation; use spray fixatives where appropriate; ensure availability of fixative at collection points.
Staining Error	23	Regularly filter and replace staining solutions; ensure strict adherence to staining protocol (timing, pH, temperature); prevent drying artefacts during staining.

Peripheral Smear Slide Errors (n = 700)

Error	Number of Slides	Corrective Action
Thick Smear	50	Retrain staff on correct smear technique (angle, speed, pressure); use fresh, non-coagulated blood; perform periodic practical assessments.
Lines or Holes	28	Ensure clean, grease-free slides; avoid excessive anticoagulant; inspect spreaders for rough edges or chipped surfaces.
Background Precipitate	47	Filter stains regularly; rinse slides thoroughly between steps; avoid drying between stain changes; ensure distilled water use in washes.
Staining Defect	18	Standardize stain preparation and timing; use control smears daily; ensure even immersion and proper drying of slides post-staining.



The use of standardised criteria for assessing internal quality control (IQC) slides has proven highly effective in identifying the root causes of technical errors, clearly [27]. This method provides an objective assessment by defining quality parameters at each stage of slide preparation, whether in histopathology, cytopathology, or peripheral smear examination, allowing timely and specific corrective measures to be taken 28. Additionally, it can serve as a handy guide to teach laboratory technicians to identify and correct mistakes, thereby further enhancing the quality of slides and, more generally, diagnostic processes.[2,3]

Significantly, inter-observer variance in rating IQC slides is greatly reduced when the standardised assessment 30 is used. Equalised criteria ensure that evaluators agree on their judgments and reduce subjectivity. There were only a few instances of discrepancies observed, which were mostly explained by either the difference in illumination under the microscope or not all the slide screening being done.[31] Such results confirm the

importance of standardising procedures to improve the consistency, accuracy, and reliability of quality control practice.[3]

Conclusion

These findings, in general, emphasise the significance of the structured quality monitoring, including practical practice in work and effective communication between the members of laboratory staff. The results support the idea that establishing and applying universal IQC parameters would lead to better technical quality, as well as greater reproducibility, diagnostic precision, and overall laboratory performance.

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Conflicts of interest

There are no conflicts of interest.

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