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TURNAROUND TIME IN HISTOPATHOLOGY LABORATORIES: DETERMINANTS OF DIAGNOSTIC EFFICIENCY

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ABSTRACT
Histopathology turnaround time (TAT) is an important measurement of quality in laboratories that has an impact on how patients are treated and how therapies may be made available for the patient, as well as on the clinical outcomes of that therapy. Delays and/or waiting for a histopathology report increases the anxiety of a patient, as well as compromises the treatment plan for the patient due to delays in starting therapy.
Literature published between January 2010 and December 2025 was included in this systematic review using PubMed, Scopus, Google Scholar, and institutional quality reports assessing TAT in histopathology and surgical pathology. Twenty studies relevant to workflow efficiency, TAT, digital pathology, artificial intelligence (AI), lean methodology, telepathology, and quality improvement were selected. Study selection followed PRISMA guidelines. Due to heterogeneity, no meta-analysis was performed; instead, descriptive statistical analysis and thematic synthesis were used. The systematic review assesses the primary factors that delay histopathology TAT, types of interventions that increase productivity in the laboratory and improve the quality of the reports to clinicians based on workflow efficiencies.
Analytical delay (85%) had the highest reporting of delay to TAT, followed by delay in the pre-analytical phase (65%), staffing availability (55%), post-analytical phase delays (45%), and lack of clinical information (40%). The average TAT for routine biopsy specimens was reported as 2–3 days; for large surgical specimens, as 5–7 days; for immunohistochemistry, as 7–10 days. Digital pathology, telepathology, use of lean methodology, and use of AI tools will create opportunities to improve TAT.

KEYWORDS: diagnostic errors; efficiency; histological techniques; pathology; telepathology; time factors.

INTRODUCTION
The turnaround time (TAT) for histopathology specimens is an important measure of quality, as delays can significantly impact the timely diagnoses, treatment planning and outcomes for patients.[1,2] Long delays in the reporting of histopathologic specimens may lead to clinical decision-making delays, increased anxiety and diminished prognosis; this is particularly the case within the realm of oncology where timely reporting is particularly necessary for accurate clinical decision making.[1,2] The variation seen across laboratories in TAT may be attributed to differences in workflow, available staffing, complexity of specimens being evaluated, and reporting systems used by each of the laboratories.[1] The pre-analytical phase of TAT is often compromised by issues such as improper specimen labelling, delayed transport of specimens to laboratories, poor fixation of specimens, and incomplete clinical information about the patient; the pre-analytical issues often play a significant role in delays for TAT.[5,13] TAT delays also occur during the analytical phase, to include time spent in completing the processing steps of a specimen and the pathologist's workload.[6,2] The TAT for developing nations are often prolonged due to limitations within the country's infrastructure and workforce.[7,14] The use of digital pathology, telepathology, and lean methodologies help to increase efficiency.[15,20,18]

OBJECTIVES
PRIMARY OBJECTIVE
To systematically review factors affecting turnaround time in histopathology laboratories.

SECONDARY OBJECTIVES
1. To identify workflow barriers contributing to delayed pathology reporting
2. To evaluate interventions used for TAT improvement
3. To assess the role of digital pathology, AI, and telepathology in workflow optimization
4. To identify research gaps for future histopathology quality improvement studies

METHODS
This review was reported in accordance with the PRISMA guidelines, Cochrane handbook for systematic reviews of interventions, JBI manual for evidence synthesis, Newcastle-Ottawa Scale (NOS). [21-25]

REVIEW QUESTION

What are the major factors affecting turnaround time in histopathology laboratories, and how do these factors influence laboratory efficiency, reporting quality, and patient management?

SEARCH STRATEGY

A systematic literature search was performed to identify studies published between 2010 and 2025 evaluating turnaround time (TAT) in histopathology laboratories and factors influencing reporting efficiency. The Electronic databases searched included PubMed, Google Scholar, Scopus, Web of Science (Thomson Reuters, New York, NY, USA), and Embase (Reed Elsevier PLC, Amsterdam, Netherlands). Additional relevant studies were identified through manual screening of reference lists, journal archives, institutional quality reports, and conference abstracts where available. Medical Subject Heading (MeSH) and keyword searches limited to English language articles were carried out to identify studies investigating turnaround time in the histopathological laboratories.

The search strategy included at least one MeSH term or keyword related to the following keywords and combinations of terms: histopathology turnaround time, surgical pathology TAT, pathology workflow efficiency, histopathology laboratory quality indicators, digital pathology turnaround time, telepathology and laboratory efficiency, and lean methodology in pathology laboratories. Additional terms such as diagnostic delay, laboratory information system, workflow optimisation, quality improvement, automation, and artificial intelligence in pathology were also included.

Boolean operators (AND, OR) were used to refine the search. A representative search strategy was: ("histopathology" OR "surgical pathology" OR "anatomic pathology") AND ("turnaround time" OR "diagnostic delay" OR "reporting delay") AND ("workflow" OR "efficiency" OR "quality improvement" OR "digital pathology" OR "telepathology" OR "laboratory information system" OR "artificial intelligence").

Only English-language original studies involving surgical pathology and histopathology workflow were included. Studies limited to cytology, unrelated laboratory workflows, editorials, and non-original reports were excluded.

The full search terms for each database are available in the supplementary material and the review protocol was registered on the PROSPERO database (CRD 420261384611).

STUDY SCREENING AND SELECTION

Titles and abstracts were reviewed by the three authors independently (MB was involved in collection, and data extraction for all included studies, KR contributed to data verification and methodological review; YSR participated in data analysis) and any discrepancies were resolved by discussion with a third reviewer. The 'PECO' criteria was used to determine eligibility of included articles.

The screening and selection of studies for this systematic literature review, were done in a systematic, structured and stepwise way in accordance with PRISMA guidelines. [21,22] First, the reviews searched databases for relevant studies to turnaround time (TAT) in histopathology laboratories, and diagnostic efficiency. After the removal of duplicates, the titles and abstracts of the studies that remained after duplicates were screened independently to determine the relevance of the studies to the objectives of the review.

All studies identified at the title and abstract screening stage that were found not to be relevant to histopathology (e.g. historical, methodological quality, non-research articles) or not to measure turnaround time (TAT) or laboratory efficiency, were excluded at this initial stage. Full text articles of the studies remaining after the title and abstract screening stage were identified and further assessed in detail for eligibility for inclusion in the review. In order to assess the eligibility of each study at this stage, each study was assessed against predetermined inclusion criteria, including appropriate study design (retrospective, prospective, cross-sectional, cohort, audit based studies), relevance to histopathology turnaround times, availability of complete data, and methodological quality.

Each study was then assessed for risk of bias using appropriate tools (e.g. Joanna Briggs Institute (JBI) checklist or Newcastle –Ottawa scale [24,25]). Any disagreement between the reviewers regarding the inclusion of each study was resolved through discussion and consensus. At the completion of the study review process, only those studies meeting the above inclusion criteria were included for review.

DATA EXTRACTION

The data was systematically extracted data using a consistent format; this helped us ensure uniformity and precision throughout the evaluation of all of the studies included in the review. Each eligible article was evaluated for relevant data in alignment with our systematic literature review objectives regarding histopathology turnaround time (TAT) and diagnostic efficiency determinants. The extracted information included author and publication year, country of origin, study design, sample size, and type of laboratory setting, e.g., hospital-based, academic pathology department or independent diagnostic centre. The outcome data included TAT average, percentage of diagnostic reports issued within agreed-upon timeframes, and major contributing factors influencing TAT. [1,6,7,19]

The common themes that were identified in all studies were related to employee shortages, specimen complexity, workload, specimens being delivered late, insufficient clinical information provided, institutional infrastructure limitations, laboratory information system effectiveness, immunohistochemistry use, and telepathology/digital pathology implementation. [5,9,11,13-18]

Additionally, final conclusions and recommendations that were made in each study were obtained to use as a foundation for narrative synthesis and for the purpose of comparison between the outcomes of the studies. This structured approach to data extraction allowed us to produce a complete assessment of the evidence available, and has helped us to identify

patterns and struggles experienced by histopathology laboratories that have prevented diagnostic efficiency and have allowed us to compile quality improvement strategies for histopathology laboratories. [2-4,8,10,15,18]

PECO

PARTICIPANTS

Histopathology laboratories that process surgical pathology specimens, biopsy samples, resection specimens, and cytology samples form the study population for this review. [1,9,19] These laboratories may be located in government hospitals, private diagnostic centers, teaching institutions, and tertiary care hospitals. [12,14] Since histopathology reports play a major role in confirming diagnosis and guiding treatment decisions, turnaround time (TAT) is considered an important indicator of laboratory quality and efficiency. [1,3]

EXPOSURE

The study focuses on the various factors that influence turnaround time in histopathology laboratories. [2,5] These factors may occur during the pre-analytical, analytical, post-analytical, and organizational stages of laboratory work. Pre-analytical factors include specimen collection, labeling mistakes, transportation delays, and improper fixation [5]. Analytical factors include delays in gross examination, tissue processing, embedding, section cutting, staining, microscopic examination, and report preparation. [9] Post-analytical factors include report verification, consultant review, final sign-out, and dispatch of reports. [3] Organizational factors such as shortage of staff, heavy workload, lack of automation, absence of laboratory information systems, and poor quality assurance practices also affect reporting efficiency. [8,14]

COMPARATORS

The comparison is made between laboratories with faster and more efficient turnaround times and those with delayed reporting. [1,10] It also compares manual workflow systems with automated systems, accredited laboratories with non-accredited laboratories, laboratories with sufficient staffing and those facing manpower shortages, and institutions with standardized protocols versus those without proper workflow systems. [10,15]

OUTCOME

The main outcome measured is histopathology turnaround time, usually calculated in hours or days from specimen receipt to final report release. [1,19] Additional outcomes include identifying the major causes of delayed reporting, understanding how delays affect diagnosis and patient treatment, evaluating methods used to improve laboratory efficiency, and assessing compliance with recommended standards provided by CAP, RCPath, and NABL. [4,11,17] Recent advances such as digital pathology, telepathology, lean management, and artificial intelligence have also shown improvement in reducing delays and improving laboratory workflow efficiency. [15,16,18,20]

INCLUSION CRITERIA

STUDY DESIGN

The guidelines for including studies in the systematic review were established to identify high-quality and high-relevance research evidence related to the turnaround time (TAT) of histopathology specimens and the factors affecting diagnostic efficiency. To be included in this systematic review, studies had to specifically assess histopathology TATs; examine processes related to surgical pathology workflow; assess delays in the reporting of histopathology results; examine indicators of diagnostic efficiency; and assess quality improvement initiatives in order to improve the quality of services provided by pathology departments. [6,12]

The types of studies that were considered for inclusion in the systematic review were original research studies (including retrospective studies, prospective studies, cross-sectional studies, cohort studies, observational studies, audit studies, and studies conducted for quality improvement), published in peer-reviewed journals, with all data available in English language and full text format.

This systematic review included studies conducted in hospital-based histopathology laboratories, academic pathology departments, and independent diagnostic centres, provided they reported measurable outcomes related to TAT or diagnostic efficiency, such as time to report, time to complete a workflow, and quality of service. [1,3,4,9,19]

The systematic review also included studies evaluating surgical pathology workflow analysis, interventions to improve the quality of pathology reporting, and the use of digital pathology systems, laboratory information systems (LIS), telepathology, and AI-based diagnostic tools, since these studies are directly related to improving TAT and overall laboratory efficiency. Methodological sources of literature pertaining to the synthesis of evidence and the guideline documents referenced throughout this systematic review included the PRISMA guidelines, Cochrane Handbook, JBI Manual for the Synthesis of Evidence, and methodologically sound studies were included in the systematic review.

EXCLUSION CRITERIA

The study did not accept studies that did not meet predetermined eligibility criteria for systematic literature review, nor considered studies related to histopathologic pathologic workflow and TAT. In addition, only those studies that used histopathologic and surgical pathologic workflow, which may have significant differences in turnaround time, and were excluded from consideration. This review also excluded radiology and other nonhistopathologic methods of diagnosing pathology because these are not specifically related to histopathologic laboratory methods and their reporting timeline; thus, it would not analyze these methods relative to histopathology. Editorials, commentaries and/or opinion pieces related

to the research studies could not be evaluated because they do not provide sufficient primary data to evaluate how long it takes to do a histological examination of tissue or establish TAT. Therefore, studies that included multiple publications that reported the same dataset and had overlapping results were eliminated to prevent redundancy of record and edit inaccuracies when compiling study results. The exclusion criteria provided the ability to evaluate all viable original study results with primary data that accurately address the TAT of histopathologic analysis, as well as supporting the technical rigor of the systematic review methodology.

RISK OF BIAS ASSESSMENT

A risk of bias assessment was performed to evaluate the methodology, validity, and reliability of studies included in this systematic literature review for turnaround time in histopathology labs and the determinants of diagnostic efficiency. Several appraisal tools were used to perform the assessment, including the Joanna Briggs Institute (JBI) checklist and the Newcastle–Ottawa Scale (NOS) for observational studies. [24,25]

Additional guidelines were followed according to the PRISMA statement and Cochrane Handbook to ensure adherence to methodology, rigor, and transparency throughout the study selection and reporting process. [21–23] The studies were carefully reviewed in order to evaluate selection bias, information bias, confounding variables, reporting quality, and methodological transparency for retrospective studies, as well as for issues with incomplete laboratory records, inconsistent definitions of turnaround time, insufficient sample size, and confounding variables associated with workload, staffing levels, specimen complexity, and laboratory infrastructure. [1,3,4,5,11,14] If the study had a high risk of bias that would have likely impacted the reliability of the findings, it would also have been excluded from the review, including those articles containing an incomplete methodology, unclear outcome measures, insufficient statistical analysis, selective reporting of results or that present data inadequately. [6,12,13] The following table 1, summarises the tool used for the study design.

Assessment Tool	Purpose	Reference Number
PRISMA Guidelines	Reporting transparency and study selection	[21,22]
Cochrane Handbook for Systematic Reviews of Interventions	Methodological guidance for systematic review conduct	[23]
JBI Critical Appraisal Checklist	Quality appraisal of observational studies	[24]
Newcastle–Ottawa Scale (NOS)	Risk of bias assessment for non-randomized studies	[25]

Table 1. Tools Used for Risk of Bias Assessment

PRISMA Methodology Overview

A structured PRISMA approach was used for study selection and synthesis was summarised in a flowchart given in Figure 1.

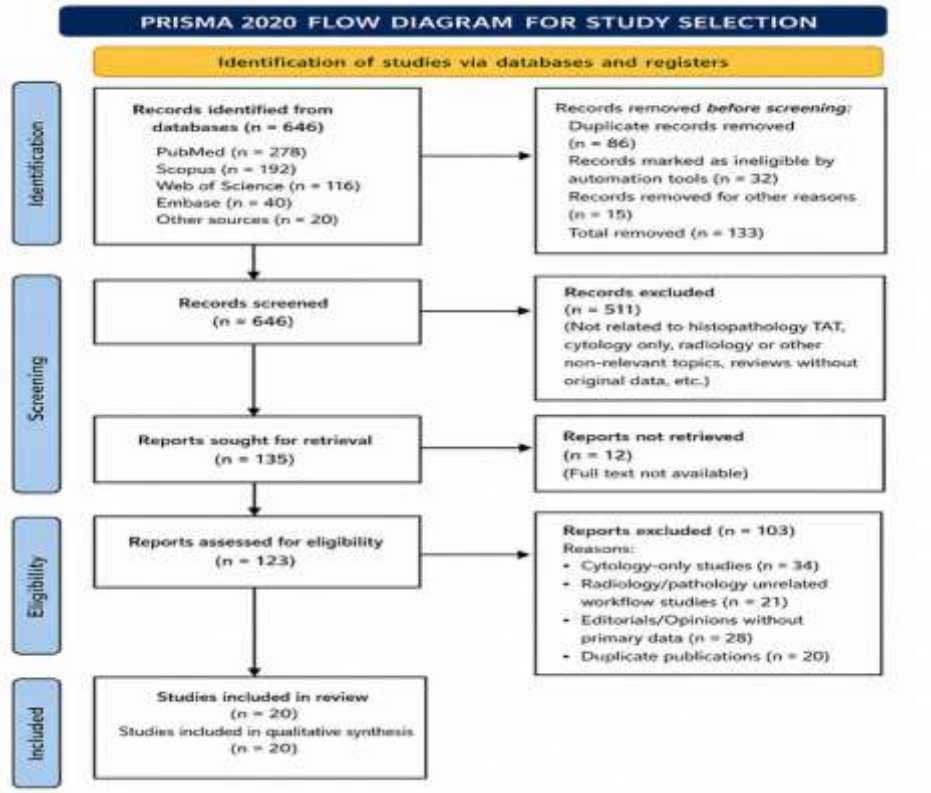

Figure 1: PRISMA Flow Diagram for study selection [22]

RESULTS

The PRISMA flow diagram [22] summarises study selection (Figure 1). A total of 646 records were identified through database searching and manual reference screening. Joanna Briggs Institute (JBI) checklist and the Newcastle–Ottawa Scale (NOS) for observational studies. [24,25]After removal of duplicates and screening of titles and abstracts, 135 full-text articles were assessed for eligibility. Finally, 20 studies published between 2010 and 2025 were included in the qualitative synthesis. [1–2] These included retrospective observational studies, multicentre institutional audits, quality improvement studies, and systematic reviews focusing on histopathology turnaround time (TAT), workflow efficiency, and laboratory quality indicators.

Across included studies, routine biopsies, complex surgical specimens, oncological resections, and workflow intervention studies were most frequently evaluated. The main determinants of TAT were categorised into pre-analytical, analytical, post-analytical, organisational, and technological domains. [3,5,15,18,20]

Analytical delays were the most commonly reported contributor (85%), mainly due to tissue processing, embedding, microtomy, staining, immunohistochemistry (IHC), and reporting workload.[6,8,9,19] Pre-analytical factors were reported in 65% of studies and included specimen transport delay, fixation issues, and incomplete requisition data. [5,12,13] Post-analytical delays (45%) were mainly related to verification steps, transcription errors, and delayed report release, often linked to inefficient laboratory information systems [10].

Included studies show that histopathology turnaround time (TAT) is a multifactorial outcome influenced by workflow, organisational, and technological factors. The systematic literature review provided thorough evidence regarding turnaround time (TAT) within histopathology laboratories as well as about factors that influence diagnostic efficiency.

Novis et al. [1] conducted an interinstitutional study on TAT of surgical pathology, demonstrating substantial differences between laboratories, with standardized workflows providing greater efficiency in TAT. Mubarak (2023), [2] discussed the importance of quality assurance programs, SOPs, and ongoing monitoring in enhancing histopathology laboratory performance. Nakhleh (2011), [3] mentioned that physician and pathologist communication can impact reporting timelines, thus improving the accuracy of cancer diagnoses. Raab and Grzybicki (2011), [4] indicated that delays in diagnosis present significant roadblocks to the management of cancer and suggested that improving workflow can help resolve TAT issues. Hawkins (2012), [5] examined the role of pre-analytical and post-analytical influences, such as specimen handling and reporting systems, on laboratory TAT.

Emmanuel I. et al. (2020), [6] discovered that increased time to report lab results exists in Nigerian labs due to a lack of staff and infrastructure. Jeyapal R. et al. (2021). [7] determined that developed countries typically have shorter reporting times because of the extensive use of automation and the maintenance of appropriate facilities for testing.

Zarbo R.J. et al. (2014), [8] showed that error-detecting systems increase the efficiency of workflows. Volmar K.E. et al. (2015), [9] provided evidence that complex specimens result in longer times to report results. Alshieban S. and Al Surimi K. (2015), [10] demonstrated through methodologies that when workflows are redesigned, there is a demonstrable reduction in the time to value of outcomes.

Patel S. et al. (2012), [11] identified three principal factors leading to delays: staffing shortages, high volume of specimens and ancillary testing being processed. Ebughe G. et al. (2017), [12] reported discrepancies regarding providers' perceptions of turnaround times compared with actual turnaround times. Ali S.M.H. et al. (2018), [13] confirmed that inadequate clinical information contributed to delays in reporting results. Gupta S. and Sodhani P. (2019), [14] noted that inadequate facilities and staff were problems that developing countries must overcome.

Pantanowitz L. et al. (2020), [15] demonstrated that utilizing digital pathology systems improved workflow between provider and laboratory. Sankarapandian S. et al. (2021), [16] reported that by applying artificial intelligence to assist in triaging patients, the delay in obtaining a test result could be significantly reduced. Petrov E. (2023), [17] stressed the need to receive rapid/early diagnosis for the effective treatment of patients in need of care. Cherie N. et al. (2024), [18] provided evidence that lean methodologies have been shown to greatly improve laboratory workflow efficiency. Sharma A. et al. (2025), [19] supported the contention that turnaround time is an essential measure when assessing quality and confirmed variability in institutional quality. Finally, Ly U. et al. (2025), [20] demonstrated that telepathology improves speed by providing diagnostic consultations and timeliness by reducing turnaround times for patients provided with test results.

Pre-analytical and post-analytical delays, including specimen transport issues, incomplete requisitions, and reporting inefficiencies, contributed significantly to prolonged TAT. [2,5,13] Analytical processes such as tissue processing, embedding, microtomy, staining, and immunohistochemistry were the major bottlenecks, especially with staffing shortages and complex cases. [19]. Large surgical specimens further prolonged reporting time and required case stratification for air benchmarking. [9]

Organisational limitations, including workforce shortages, poor infrastructure, and resource constraints, were frequently reported in low-resource settings. [14,12] Workflow redesign and quality improvement initiatives improved efficiency and reduced delays. [4,10]

Technological solutions such as laboratory information systems improved tracking and reduced errors. [8] while digital pathology, artificial intelligence, telepathology, and lean methodologies significantly enhanced workflow efficiency and reduced TAT. [15,16,17,18]

In accordance with PRISMA-guided synthesis, the included studies were analysed to identify determinants of turnaround time (TAT) in histopathology laboratories and were grouped into pre-analytical, analytical, post-analytical, organisational, and technological domains. Despite heterogeneity in study designs, consistent delays were observed across the diagnostic pathway, indicating that TAT is a multifactorial and interdependent outcome.

RISK OF BIAS ASSESSMENT

All of the studies reviewed were assessed for risk of bias using the Joanna Briggs Institute (JBI) critical appraisal checklist and the Newcastle–Ottawa Scale (NOS) for observational studies. [24,25] During this assessment process, the review adhered to the recommendations of PRISMA and the methodology outlined in the Cochrane Handbook for conducting systematic reviews so that the review process would be transparent, consistent, and methodologically rigorous. [21–23]

Overall, the included studies were rated as having moderate to good methodological quality since the majority of studies had clearly defined objectives, study populations, laboratory settings, and outcome measures related to the histopathology turnaround time (TAT) and diagnostic efficiency. [1–20] However, since most of the included studies were retrospective observational studies, audit-based studies, or institutional reviews; various sources of potential bias were identified.

Among the sources of potential bias that were identified, selection bias was noted among studies conducted at a single-center site with limited sample diversity (i.e., studies conducted among resource-limited countries) where limited workforce capacity and/or limited infrastructure may have affected how reported the efficiency and generalizability of study results. [6,12,14] In addition, in the retrospective studies, there were identified instances of information bias due to laboratory records being incomplete, laboratory records maintained inconsistently, and variation in the definitions and derivation of turnaround time. [5,11,13] Finally, almost all of the included studies were reported without having controlled for important confounders (e.g., availability of ancillary testing, staffing levels, laboratory workload & distribution, complexity of specimens, laboratory staff; laboratory automation).

According to Novis et al.[1], Zarbo et al.[8], Volmar et al.[9], Sharma et al.[19], the measurements of the risk of bias were lower as these studies used larger sample sizes, standardised outcome measures, clearly defined TAT benchmarks, and structured statistical analysis. Compared to other studies investigating the impact of digital pathology, telepathology, artificial intelligence and lean work processes relating to technological innovations, the findings show moderate levels of methodological quality with descriptive detail of the workflow interventions and measurable outcomes in the laboratory. [15-18,20]

Some of the reasons for a moderate risk of reporting bias across the studies included insufficient methodology description, incomplete statistical reporting or selective emphasis on positive workflow outcome measures. [6,12,13] Another limitation to the ability to compare the results quantitatively across the studies was the variability in study design, differences in laboratory structure, institutional protocols, and TAT benchmarks. However, trends can be identified across all of the studies regarding the major determinants of histopathology laboratory turnaround time and diagnostic effectiveness.

These studies as a whole provide sufficient and clinically applicable evidence to support narrative synthesis and the formation of conclusion regarding diagnostic effectiveness in histopathology laboratories, despite the limitations identified.

Overall, evidence indicates that effective reduction of TAT requires integrated optimisation of workflow processes, workforce capacity, digital technologies and risk of bias assessment. [1–20] was summarised in Table 2.

Author & Year	Study Design	Study Focus / Key Findings	Risk of Bias Level	Major Sources of Bias Identified
Novis DA et al., 2010 [1]	Multicenter observational study	Demonstrated variability in TAT across institutions; standardized workflows improved efficiency	Low	Minor institutional variability
Mubarak M, 2023 [2]	Review / quality assessment	Highlighted importance of QA programs, SOPs, and monitoring for efficiency improvement	Moderate	Limited primary quantitative data
Nakhleh RE, 2011 [3]	Observational review	Effective communication improves accuracy and reduces diagnostic delays	Moderate	Narrative interpretation bias
Raab SS & Grzybicki DM, 2011 [4]	Quality improvement review	Diagnostic delays impact cancer care; workflow optimization recommended	Moderate	Limited adjustment for confounders
Hawkins RC, 2012 [5]	Observational study	Pre- and post-analytical phases significantly affect TAT	Moderate	Variability in laboratory practices
Emmanuel I et al., 2020 [6]	Retrospective study	Prolonged TAT due to workforce and infrastructure limitations	Moderate–High	Small sample size; infrastructure limitations
Jeyapal R et al., 2021 [7]	Comparative observational study	Developed countries show shorter TAT due to better infrastructure and automation	Moderate	Institutional heterogeneity
Zarbo RJ et al., 2014 [8]	Multicenter audit study	Error monitoring improves workflow efficiency and reduces delays	Low	Minimal reporting bias
Volmar KE et al., 2015 [9]	CAP Q-Probes study	Complex specimens prolong reporting time	Low	Minor case-mix variability
Alshieban S & Al Surimi K, 2015 [10]	Quality improvement study	Workflow redesign reduced turnaround times significantly	Moderate	Single-center limitation

Patel S et al., 2012 [11]	Retrospective observational study	Staffing, workload, and testing volume influence TAT	Moderate	Confounding by workload and staffing
Ebughe G et al., 2017 [12]	Retrospective study	Differences between perceived and actual TAT in histopathology	Moderate–High	Incomplete records; reporting variability
Ali SMH et al., 2018 [13]	Retrospective study	Incomplete clinical data delays histopathology reporting	Moderate	Inconsistent clinical documentation
Gupta S & Sodhani P, 2019 [14]	Review article	Infrastructure and workforce shortages limit histopathology efficiency in developing countries	Moderate	Resource-setting variability
Pantanowitz L et al., 2020 [15]	Technological workflow study	Digital pathology improves accessibility and reduces TAT	Low–Moderate	Implementation heterogeneity
Sankarapandian S et al., 2021 [16]	AI workflow study	AI-assisted triage improves prioritization and workflow efficiency	Moderate	Limited long-term validation
Petrov E, 2023 [17]	Narrative review	Rapid diagnosis improves patient management and healthcare outcomes	Moderate	Limited primary data
Cherie N et al., 2024 [18]	Systematic review	Lean methodology significantly improves laboratory efficiency	Low	Minor publication bias
Sharma A et al., 2025 [19]	Observational study	TAT is a key quality indicator with institutional variability	Low	Minimal methodological concerns
Ly U et al., 2025 [20]	Telepathology workflow study	Telepathology improves consultation speed and reduces TAT		

Table 2: Studies Included in the Review with Risk of Bias Assessment

DISCUSSION

A major contribution of this systematic literature review is to assess the complex, multidimensional nature of histopathology turnaround time (TAT) as an indicator that is affected by interrelated pre-analytical, analytical, post-analytical, organisational, and technological factors. Delays in diagnostic results reported in all included studies were consistently encountered across the laboratory workflow phases; thus, inefficiencies found were not specific to one stage of the process, but are widespread and systemic.

The major contributing factor to delays in the pre-analytical phase is preventable losses, which were indicated as major sources of delay in systematic reviews of the tested literature. The studies include a number of factors that delay the accessioning and processing of specimens (e.g., incomplete requisitions, missing clinical information, specimen mislabeling, transport delays, and suboptimal fixation). [2,8,9] Underreported evidence from Hawkins (2012) [5] and Ali et al. (2018) [13] indicates that inadequate communication between clinicians and laboratories, and the absence of standard operating procedures for specimen processing are likely causes of numerous early process-related delays. Evidence also supports that a significant proportion of laboratory errors are attributed to the pre-analytical phase, providing a substantial impetus for the development of formal quality assurance (QA) and total quality management (TQM) systems.

The analytical phase continues to be the single most time-consuming and technically burdensome phase of histopathology reporting. Delays in reporting results were predominantly associated with tissue processing, embedding, microtomy, staining, and reporting workflow processes, particularly for complex oncological cases requiring the use of immunohistochemistry (IHC) or special stains. As demonstrated by Sharma et al. (2025) [19] these additional diagnostic procedures are also contributing to longer TATs. Staffing scarcity, and Equipment.

Delays in analyses are increased exponentially by shortages in the workforce, equipment failure, and disorganized workflows. Zarbo et al. (2014) [8] pointed out that systematic methods for error detection and structured approaches to laboratory operation will increase overall efficiency of the laboratory and decrease the amount of time taken from when a diagnostic examination is performed until a report is issued (TAT).

Post-analytical delays are associated with verification of reports - including potential errors in transcription and delays due to lab order verification - and ineffective integration of laboratory information system (LIS) within the laboratory's workflow. Research has shown that the implementation of electronic methods of reporting, as well as standardized formats for reporting of results will improve efficiency of turnaround times and decrease the human error component associated with generating reports. [12,13] The post-analytical phase comprises the examining and confirming report results, correlating to ancillary studies, and delivering the finished report to the requesting physician. Each of these components is critical to ensuring diagnostic accuracy as well as quality assurance of laboratory results.

Operational factors that have been consistently associated with increased turnaround times (TAT) include: staffing shortages, excessive workloads for pathologists, lack of sufficient infrastructure, and lack of standard protocols, particularly in resource-limited settings. [14] Gupta and Sodhani (2019) [14] further identified systemic issues (e.g., limited automation and inadequate/absent benchmarking) which may have a significant impact on laboratory performance.

There is a strong likelihood that the use of new technology will improve efficiency of the histopathology workflow. Laboratory Information Systems (LIS) allow for greater compliance (tracking) and improved communication. Digital Pathology allows for remote access to reports and quicker (via digital access vs. physical access) availability of slides for review. Artificial intelligence (AI) will assist with triaging specimens for evaluation by pathologists as well as telepathology will reduce the time pathologists spend waiting for slides from remote locations; the use of lean management methodologies will help eliminate inefficiencies associated with laboratory workflow. [15-18] Ultimately, these innovations lead to an identifiable reduction in TAT.

The goal of shorter TAT is of utmost importance, but it cannot jeopardize diagnostics; "the use of TAT for measuring and managing pathology service quality should not sacrifice, damage or reduce the diagnostic accuracy of the pathology service" (Nakhleh, 2011) [3] because "the potential consequences of placing an overly high priority on speed, without adequate quality assurance, could be detrimental to the safety of patients and the reliability of diagnosis".

Among included studies, the overall risk of bias was mainly considered moderate based on the observational/retrospective nature of most of the available evidence. Although there are several studies that have been rated as low risk of bias (particularly multicentre audits and systematic reviews). [8,18,19] These have also taken advantage of having a larger dataset than the majority of the studies included, and had a more robust methodology than many of the other studies. In addition to this, a number of studies were rated as moderate to high risk of bias based on several characteristics such as small sample size, single centre in design, incomplete documentation, and heterogeneity within institutions. [6,12]

Some common methodological issues resulted from variability in laboratory practices, reliance on retrospective data collection, and not controlling (or being able to control) for potential confounding variables, such as workload, staffing level and infrastructure differences. Review-based studies also have a risk of introducing potential bias in terms of narrative interpretation, while technology-driven studies demonstrated problems with implementation and limited long-term validation of the findings.

Nonetheless, despite these methodological issues, the consistency of findings across the various study designs supports the general validity of the evidence. However, the predominance of moderate risk studies continues to demonstrate the necessity for future well-organized, multicentre, prospective studies that reflect good design methodology, to enhance the overall reliability of evidence related to determinants and interventions associated with TAT.

A summary has been provided for further explanation of how histopathology TAT represents an interrelated system made up of a series of workflow, organisational capacity and technological systems; to improve TAT will require a "whole systems" approach; including standardisation of laboratory processes, improving communication systems, increasing workforce capacity and developing digital and automated technology. Multiple aspects of the above must occur to produce long term improvements in both diagnostic efficiency and patient care outcomes. The following Table 4,5 summarises the key factors and risk of bias assessment influencing on TAT.

Technology	Study	Effect on TAT	Reference No.
Digital Pathology	Pantanowitz et al., 2020	Improved slide accessibility and enabled faster remote reporting	[15]
Artificial Intelligence	Sankarapandian et al., 2021	Improved case triage efficiency and reduced diagnostic delays	[16]
Telepathology	Ly et al., 2025	Improved consultation speed and reduced turnaround time	[20]
Lean Methodology	Cherie et al., 2024	Eliminated workflow inefficiencies and improved laboratory efficiency	[18]

Table 4. Impact of Technological Interventions on Histopathology Turnaround Time (TAT)

Category	Factors	Reference No.
Pre-analytical	Specimen transport, requisition errors, fixation delays	[5, 11, 13]
Analytical	Processing delays, staining, workload, IHC	[1, 3, 6, 9]
Post-analytical	Report verification, LIS delays	[3, 4, 8]
Organizational	Staffing, infrastructure, workload distribution	[7, 14, 18]
Technological	LIS, AI, digital pathology, telepathology	[15, 16, 20]

Table 5: Factors Contributing to Laboratory Workflow Delays

Overall, the evidence supports a systems-based approach rather than isolated interventions. Sustainable improvement in histopathology TAT requires integration of workflow standardisation, workforce optimisation, and digital transformation supported by continuous quality monitoring.

LIMITATIONS OF REVIEW

There are significant limitations in interpreting the findings of this literature-based systematic review. First, because many of the included studies were significantly heterogeneous with regards to study design/laboratory settings/sampling sizes/defining turnaround time, [14] it was difficult to make direct comparisons between studies. In addition, a majority are retrospectively based on audit style studies, and therefore, are subjected to bias due to; selection bias, incompleteness in

data recording, inconsistent reporting, [6,11,12] and variability among institutional protocols, workload, staff patterns, and laboratory infrastructures across countries. [7,14]
Secondly, multiple limitations were seen in excluding non-English publications and studies without full texts, causing more publication bias. In addition, many studies were found to lack standardized outcome measures and did not control for confounding variables such as specimen complexity, the use of ancillary testing, and pathologist workload. [3,4,9]
Furthermore, limited high-quality prospective and multicentre studies exist for histopathology laboratory turnaround time. It was not possible to perform quantitative meta-analysis due to differences in methodology among studies, therefore the findings were synthesised primarily through narrative synthesis.

FUTURE DIRECTIONS

Research to date has focused on examining histopathology turnaround times through a variety of methods, with particularly little emphasis placed on multicentre prospective studies that use standardized definitions and benchmark measurements. More emphasis needs to be placed on studies that provide evidence for evaluating the effects of factors such as laboratory automation, digital pathology, artificial intelligence; and telepathology; and how those factors relate to the efficiency of diagnosis, and patient outcomes. Additionally, research should focus on how cost-effectiveness, workforce management, and implementation of lean, quality-improvement strategies will lead to improved efficiency in facilities with limited resources.
Developing international standards for defining and reporting histopathology turnaround times may assist with better comparisons across studies and facilities. Additionally, research should explore the relationship between turnaround time, diagnostic accuracy, clinician satisfaction, and how they impact patient care quality. Finally, quality assurance and standardization of laboratory information systems will improve workflow efficiency by helping to eliminate unnecessary delays between diagnosis and patient care.

CONCLUSION

The turnaround times for pathology labs are very important indicators of the quality of the laboratory results, and thus, they are critical to achieving efficient diagnostic time, making clinical decisions, and managing patients. This systematic literature review determined numerous different variables that can impact turnaround time in histopathology laboratories (analytical (pre-analytical, analytical, post-analytical); specimen handling; staffing levels; workloads; laboratory infrastructure; ancillary testing; communication methods.
A large body of evidence supports the use of systems that can improve laboratory efficiency and, therefore, decrease the time to completion of histopathology reporting; by improving workflow optimization (using workflow optimization systems); implementing quality assurance protocols (using quality assurance measurement systems); using digital pathology systems (using digital pathology systems); the use of telepathology systems (using telepathology systems); using lean management techniques; and using artificial intelligence based systems (using AI based systems) can significantly improve the efficiency of histopathology laboratories, and therefore decrease the time it takes to complete histopathology reporting.
Although the methods used to achieve this, as well as the use of different processes, were used are not always going to be the same, the overall body of evidence supports the use of standardized protocols, automation technology, and effective quality management systems to improve the quality of pathology reports. More research and development must be done to support the continued use of innovative technology in order to provide timely, accurate, and efficient pathology reports, which will ultimately improve patient care and the overall outcome of healthcare.

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AUTHOR CONTRIBUTIONS STATEMENT

For this manuscript, the author MB had the primary responsibility of collecting, analyzing and presenting the data, creating the first draft; the primary responsibility of author KR was designing the study; author YSK participated in helping with data analysis. All three authors have worked together on various aspects of this project. The final version of this manuscript was reviewed and approved by all three authors, and all authors are accountable for the accuracy and integrity of this manuscript.

DATA AVAILABILITY STATEMENT

The data used in this study can be found in the referenced literature.

ETHICS APPROVAL

This systematic review summarizes previously published articles, rather than collecting or creating new data from humans who would require that they get ethics approval, authority under any law or obtain consent to use that person's tissues or other materials. The authors assume that all studies have obtained ethics approval prior to conducting the studies and obtained the necessary consent, in accordance with the Declaration of Helsinki.

CONSENT FOR PUBLICATION

This manuscript does not contain any person's data. All information reported is reported as found in the literature as cited in the text.

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