Diagnostic Accuracy of Fundoscopy, Optical Coherence Tomography, and Ocular Ultrasound for Detecting Elevated Intracranial Pressure in Chronic Conditions: A Systematic Review

Cut Hafidzah Usrah[1*], Joandre Fauza[1]

[1] Department of Surgery, Faculty of Medicine, Universitas Malikussaleh, North Aceh, Indonesia
cuthafidzah21@gmail.com

Abstract. Chronic elevated intracranial pressure (ICP) causes progressive optic nerve damage and visual impairment, requiring reliable early detection and long-term monitoring. Non-invasive ocular modalities, including fundoscopy, optical coherence tomography (OCT), and ocular ultrasonography, are increasingly investigated for ICP assessment. This systematic review evaluated the diagnostic accuracy and clinical role of fundoscopy, OCT, and ocular ultrasonography in detecting chronic or non-acute elevated intracranial pressure. Studies published between 2020 and 2026 were screened using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guideline. Diagnostic accuracy studies were assessed using the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool, while studies reporting structural changes, correlations, or longitudinal monitoring were synthesized as supportive evidence. Of 2,048 identified records, 17 studies were included after screening. Seven studies provided diagnostic accuracy evidence, primarily evaluating fundoscopy, fundus imaging, and ocular ultrasonography, while ten provided supportive evidence, predominantly evaluating OCT-based structural and vascular changes. Fundoscopy demonstrated specificity for detecting papilledema but limited sensitivity. Ocular ultrasonography, particularly optic nerve sheath diameter measurement, demonstrated promising performance as a noninvasive screening approach, although differences in cutoff values and reference standards affected comparability. OCT provided a quantitative assessment of the retinal nerve fiber layer, optic nerve head, and retinal microvascular changes, supporting disease characterization and longitudinal monitoring rather than a standalone diagnostic test. Evidence suggests that fundoscopy, OCT, and ocular ultrasonography provide complementary information for assessing chronic elevated ICP. Fundoscopy may confirm papilledema-related manifestations, ONSD ultrasonography screening, and OCT structural monitoring. Further standardized prospective studies using consistent reference standards are required to establish the utility of these modalities.

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1 Introduction

Idiopathic intracranial hypertension (IIH) is a neurological disorder characterized by increased intracranial pressure (ICP) without intracranial mass lesions, hydrocephalus, or other identifiable structural abnormalities [1,2]. The condition predominantly affects young adults and may result in severe visual morbidity due to the development of papilledema and progressive optic nerve injury (1,3). The diagnosis of IIH is established through a combination of clinical manifestations, neuroimaging findings, and measurement of cerebrospinal fluid (CSF) opening pressure using lumbar puncture [1,2]. Although lumbar puncture remains the reference standard for confirming elevated ICP, its invasive nature limits its use for repeated measurements and long-term monitoring [1].

Therefore, the development of accurate and reliable noninvasive approaches for detecting elevated ICP remains an important clinical need [1,2]. Papilledema represents one of the most important clinical manifestations of increased ICP and is commonly evaluated through fundoscopic examination. Fundoscopy remains widely used in clinical practice because it provides direct visualization of optic disc abnormalities associated with increased ICP [4,5]. However, previous studies have demonstrated variability in the diagnostic performance of fundoscopy, particularly in terms of sensitivity, which may limit its ability to exclude elevated ICP when papilledema is absent [4–6].

The limitations of fundoscopy have encouraged the development of alternative noninvasive ocular-based diagnostic modalities for assessing ICP-related changes [6,7]. ONSD measurement using transorbital ultrasonography has gained attention because the expansion of the ONS reflects pressure transmission from the intracranial subarachnoid space [7].

Several diagnostic accuracy studies have demonstrated that ONSD ultrasound provides promising performance for detecting elevated ICP, particularly when combined with advanced ultrasonographic techniques, such as shear wave elastography [7,8]. Retinal vascular assessment has also been investigated as a potential surrogate marker of elevated ICP through analysis of retinal vessel dynamics [9].

Changes in retinal vessel parameters have demonstrated associations with lumbar opening pressure, suggesting that retinal vascular alterations may reflect intracranial pressure changes [9]. Recent advances in ocular imaging have introduced optical coherence tomography (OCT) as a potential supportive tool for evaluating structural changes associated with intracranial hypertension [10]. OCT enables the quantitative assessment of retinal nerve fiber layer thickness, optic nerve head morphology, and other structural parameters related to papilledema [10,11].

Optical coherence tomography angiography (OCTA) provides further information regarding retinal microvascular alterations and vascular complexity associated with increased ICP [12,13. Despite increasing interest in ocular-based assessment of elevated

ICP, the diagnostic accuracy of these modalities remains heterogeneous due to differences in study populations, reference standards, imaging techniques, and outcome measurements [4–13].

Previous studies have evaluated individual diagnostic approaches; however, a comprehensive synthesis comparing fundoscopy, ONSD ultrasonography, retinal vascular analysis, OCT, and OCTA is necessary to clarify their diagnostic and supportive roles [4–13].

Therefore, this systematic review aimed to evaluate the diagnostic accuracy of ocular-based modalities, including fundoscopy, ONSD ultrasonography, retinal vessel analysis, OCT, and OCTA, for detecting elevated intracranial pressure and to summarize their potential clinical applications as non-invasive diagnostic or supportive tools.

2 Methods

2.1 Study Design and Reporting Framework

This study was conducted as a diagnostic accuracy systematic review with narrative synthesis to evaluate the role of fundoscopy, OCT, and ocular ultrasonography in detecting chronic or non-acute elevated ICP. The reporting of this review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparent reporting of the identification, selection, assessment, and synthesis processes [14]. Because this review evaluated diagnostic performance parameters, including sensitivity and specificity, the methodological framework was guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Diagnostic Test Accuracy (PRISMA-DTA) [15].

2.2 Search strategy

A systematic literature search was performed in PubMed, Scopus, and Google Scholar to identify relevant studies evaluating ocular-based modalities for detecting elevated intracranial pressure. The search strategy was developed using Boolean operators to combine condition-related and index-test terms: ("elevated intracranial pressure" OR "intracranial hypertension") AND (funduscopy OR "optical coherence tomography" OR "ocular ultrasound"). The search strategy was adapted according to the characteristics of each database. Studies published between 2020 and 2026 were considered eligible, with inclusion limited to human studies available in full text and published in English or Indonesian. The search and reporting processes followed the PRISMA-S recommendations to improve the transparency and reproducibility of systematic review searches [16].

2.3 Eligibility criteria

Studies were eligible for inclusion if they were original human studies involving patients with suspected or confirmed chronic or non-acute elevated intracranial pressure

and evaluated at least one ocular examination modality, including fundoscopy, fundus imaging, optical coherence tomography, optical coherence tomography angiography, or ocular ultrasonography with optic nerve sheath diameter measurement.

Eligible studies included diagnostic accuracy, cross-sectional, cohort, prospective, retrospective, and case series studies that reported diagnostic performance, correlation, reliability, structural changes, or longitudinal monitoring outcomes. Studies were required to use an appropriate reference standard, including lumbar puncture opening pressure, invasive intracranial pressure monitoring, intraoperative pressure measurement, or established clinical diagnostic criteria.

Studies reporting sensitivity, specificity, cutoff values, area under the curve, or diagnostic data were classified as diagnostic accuracy studies. Studies that evaluated structural changes, correlations between ocular parameters and intracranial pressure, or longitudinal disease monitoring without diagnostic accuracy parameters were classified as supportive evidence and were synthesized separately.

Studies were excluded if they were review articles, systematic reviews, meta-analyses, editorials, commentaries, protocols, conference abstracts without complete manuscripts, animal studies, laboratory studies, studies involving only acute intracranial pressure elevation, studies without the specified ocular modalities, studies without relevant outcomes, duplicate publications, or articles unavailable in eligible full-text and language formats.

2.4 Study Selection and Data Extraction

All retrieved records from the selected databases were collected and screened after duplicate removal. The selection process consisted of title and abstract screening followed by full-text assessment based on predefined eligibility criteria. Reasons for exclusion during the full-text screening stage were documented and categorized as wrong publication year, wrong publication type, wrong index test, wrong outcome, wrong population, and insufficient data. The overall study selection process is summarized using the PRISMA 2020 flow diagram [14].

Data extraction was performed using a standardized extraction form. The extracted information included study characteristics, publication year, study design, patient population, sample size, evaluated ocular modality, examination parameters, reference standard, cutoff values, sensitivity, specificity, area under the curve, confidence intervals, and available diagnostic table data.

The extracted information included relationships between ocular parameters and intracranial pressure, structural changes detected by OCT, longitudinal changes during follow-up, and measurement reliability for studies categorized as supportive evidence.

2.5 Risk of Bias Assessment

The methodological quality of diagnostic accuracy studies was assessed using the Quality Assessment of Diagnostic Accuracy Studies-2 (QUADAS-2) tool, which evaluates four domains consisting of patient selection, index test, reference standard, and flow and timing [17]. Comparative diagnostic accuracy studies involving multiple index

tests were assessed using QUADAS-C when applicable [18]. Supportive evidence studies with case report designs were assessed using the Joanna Briggs Institute critical appraisal approach [19]. The results of the risk-of-bias assessment were used to contextualize the interpretation of diagnostic findings and were not converted into a single numerical quality score.

2.6 Outcomes and Data Synthesis

The primary outcomes of this review included diagnostic accuracy parameters, including sensitivity, specificity, predictive values, likelihood ratios, diagnostic odds ratio, area under the curve, cutoff values, and available true-positive, false-positive, true-negative, and false-negative data.

Supportive outcomes included correlations between ocular parameters and intracranial pressure, structural alterations of the retina and optic nerve detected by OCT, changes during longitudinal follow-up, and the reliability of the examination. Due to expected heterogeneity among studies regarding patient characteristics, disease conditions, reference standards, examination techniques, and cutoff values, the findings were synthesized narratively.

Quantitative pooling was considered only when studies demonstrated sufficient clinical and methodological similarity. When meta-analysis was not appropriate, evidence synthesis was performed according to the principles of Synthesis Without Meta-analysis (SWiM) [20].

3 Results

3.1 Study Selection

A systematic search identified 2,048 records from three databases, including PubMed (n = 534), Scopus (n = 1,000), and Google Scholar (n = 514). After removing duplicate records (n = 277), 1,771 articles underwent title and abstract screening. During this stage, 1,554 records were excluded because they did not meet the predefined eligibility criteria.

Among the included studies, seven were categorized as diagnostic accuracy studies because they reported diagnostic performance parameters, including sensitivity, specificity, cutoff values, or area under the curve (AUC). Ten studies were categorized as supportive evidence because they primarily investigated OCT-based structural changes, retinal vascular alterations, biomarker associations, or longitudinal monitoring outcomes without establishing diagnostic accuracy against a reference standard.

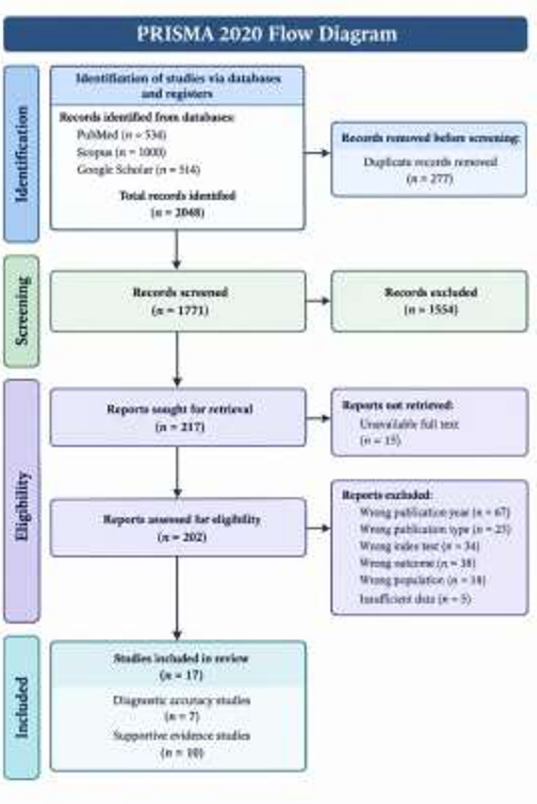


Fig. 1. PRISMA flow diagram

3.2 Characteristics of Included Studies

The included studies were published between 2020 and 2026 and involved diverse populations, including patients with idiopathic intracranial hypertension (IIH), pediatric craniosynostosis, chronic headache, and patients with suspected intracranial pressure elevation. Diagnostic accuracy studies evaluated three major ocular approaches: fundoscopy, fundus-based quantitative assessment, and ocular ultrasonography using ONSD measurement.

Reference standards varied substantially among studies, including invasive ICP monitoring, lumbar puncture opening pressure, and clinical diagnostic criteria for IIH. This heterogeneity is important because differences in reference standards may influence reported diagnostic estimates.

Table 1. Characteristics and Diagnostic Performance of Diagnostic Accuracy Studies.

Study	Population	Sample size	Index test	Reference standard	Cut-off	Sensitivity	Specificity	AUC
Rufai et al.	Pediatric craniosynostosis	35 patients	Fundoscopy/papilledema assessment	48-hour invasive ICP monitoring	Papilledema detection	32.1%	100%	NR
Kerscher et al.	Pediatric suspected ICP elevation	72 patients	ONSD ultrasound and fundoscopy	Clinical treatment indication; invasive ICP subgroup	ONSD 5.73 mm	92% (ONSD)	86.4 % (ONSD)	NR
Rehab et al.	Chronic headache population with suspected IIH	141 patients	Fundoscopy and trans-orbital sonography	Lumbar puncture confirmation	Study-specific criteria	79.5%	98%	NR
Ahmad et al.	IIH vs healthy controls	50 subjects	ONSD ultrasound	IIH diagnosis	5.60 mm	Reported in study	Reported in study	NR
Razek et al.	IIH vs healthy controls	50 subjects	ONSD + shear wave elastography	Clinical diagnosis	Study-derived cutoff	Reported in study	Reported in study	0.98
Hagen et al.	Suspected IIH	Study-specific cohort	Fundus vascular assessment	Clinical IIH diagnosis	Study-derived parameter	78%	92%	0.81

3.3 Diagnostic Accuracy Findings

Fundoscopy and fundus-based assessment

Fundoscopy was primarily evaluated as a method for detecting papilledema, an ocular manifestation associated with elevated ICP. Across included studies, fundoscopy demonstrated high specificity when papilledema was present; however, sensitivity varied considerably depending on disease characteristics and reference standards.

Rufai et al. evaluated fundoscopy in children with craniosynostosis using continuous invasive ICP monitoring as the reference standard. The study reported a specificity of 100% and sensitivity of 32.1%, indicating that visible papilledema strongly supported elevated ICP, while the absence of papilledema could not reliably exclude pressure elevation [4]. Hagen et al. investigated quantitative fundus-based vascular parameters as potential biomarkers of elevated ICP in patients with suspected IIH. The combination of retinal vascular parameters and clinical variables demonstrated a sensitivity of 78%, specificity of 92%, and AUC of 0.81, suggesting that quantitative retinal analysis may provide additional diagnostic information beyond conventional fundoscopy [9].

Rehab et al. evaluated fundoscopy within a chronic headache population undergoing IIH assessment. Using lumbar puncture confirmation as the reference standard, fundoscopy demonstrated sensitivity of 79.5% and specificity of 98%. However, these results require cautious interpretation because partial verification and incorporation bias may occur when ocular findings contribute to clinical diagnostic decisions [5].

Ocular Ultrasonography and ONSD Assessment.

Ocular ultrasonography, particularly ONSD measurement, is the most frequently investigated ultrasound-based diagnostic approach. This method is based on the anatomical relationship between the optic nerve sheath and intracranial subarachnoid space, allowing pressure-related changes to be indirectly assessed through optic nerve sheath expansion [7,8]. Ahmad et al. investigated ONSD ultrasound in patients with IIH and healthy controls using a cutoff value of 5.60 mm.

This study reported favorable diagnostic performance; however, interpretation should consider the two-gate case-control design, as comparison between clearly separated diseased and healthy populations may increase apparent diagnostic accuracy [7]. Razek et al. evaluated ONSD combined with shear wave elastography in patients with IIH and healthy controls. The combined model achieved an AUC of 0.98, demonstrating strong discrimination between groups. Nevertheless, the study design and absence of invasive ICP confirmation in all participants limit direct clinical generalization [8].

Kerscher et al. provided the only direct comparison between ONSD ultrasonography and fundoscopy in the same patient population. ONSD measurement showed a sensitivity of 92% and a specificity of 86.4%, whereas fundoscopy demonstrated a sensitivity of 46% and a specificity of 100%. Because these findings originate from a single comparative study, they should not be interpreted as definitive evidence that one modality universally outperforms another [6].

3.4 Supportive Evidence from OCT-Based Assessment

Ten studies were classified as supportive evidence because they evaluated OCT-related structural changes, retinal biomarkers, and longitudinal monitoring rather than diagnostic accuracy. These studies demonstrated that OCT provides a quantitative assessment of ICP-related ocular changes, particularly involving the retinal nerve fiber layer (RNFL), optic nerve head morphology, ganglion cell complex, and retinal microvascular alterations.

Nogueira et al. reported that OCT parameters were associated with clinical characteristics of IIH, supporting its potential role in evaluating structural consequences of elevated ICP [11]. Wang et al. demonstrated that swept-source OCT and OCT angiography could identify optic nerve head and retinal vascular alterations associated with intracranial hypertension-related changes [12].

Cao et al. reported that retinal vascular complexity assessed using OCT angiography was associated with ICP status and visual impairment in patients with IIH [13]. Although these findings support OCT as an objective structural assessment tool, available evidence remains insufficient to establish OCT as an independent diagnostic test because validated universal diagnostic thresholds have not yet been established [10–13].

3.5 Risk of Bias Assessment

Risk of bias assessment was performed using QUADAS-2 for diagnostic accuracy studies. Several methodological concerns were identified, particularly regarding patient selection, reference standards, and cutoff values. The methodological quality of the diagnostic accuracy studies was assessed using QUADAS-2, which evaluates the patient selection, index test, reference standard, and flow and timing domains [17].

Studies using case-control designs, including Ahmad et al. and Razek et al., were considered to have potential concerns because comparison with healthy controls may inflate diagnostic performance estimates [7,8,17]. Differences in reference standards, including invasive ICP monitoring, lumbar puncture opening pressure, and clinical diagnostic criteria, also limited comparability between studies.

Overall, diagnostic accuracy estimates should be interpreted within the methodological context of each study rather than as direct evidence of superiority between ocular modalities.

4 Discussion

This systematic review evaluated the diagnostic performance and clinical role of fundoscopy, optical coherence tomography (OCT), and ocular ultrasonography in detecting chronic or non-acute elevated ICP. The main finding of this review is that these ocular modalities provide complementary information rather than competing diagnostic alternatives. Fundoscopy, ocular ultrasonography, and OCT serve different clinical purposes, including the identification of papilledema, screening for pressure-related changes, structural characterization, and longitudinal monitoring.

Diagnostic accuracy evidence demonstrates that fundoscopy remains clinically valuable for detecting papilledema, particularly because papilledema provides strong evidence of pressure-related optic nerve involvement. However, the sensitivity of fundoscopy varies considerably between studies, indicating that the absence of visible papilledema does not reliably exclude elevated ICP. Rufai et al. demonstrated high specificity but limited sensitivity when comparing fundoscopy with invasive ICP monitoring in children with craniosynostosis [4]. These findings emphasize that fundoscopy should be interpreted as a confirmatory examination for visible optic nerve manifestations rather than a standalone exclusion test for elevated ICP.

Ocular ultrasonography, particularly ONSD measurement, showed potential as a non-invasive screening approach. The physiological basis of ONSD measurement is derived from the anatomical continuity between the optic nerve sheath and intracranial subarachnoid space, allowing changes in cerebrospinal fluid pressure to influence optic nerve sheath expansion. Several studies have reported favorable diagnostic performances; however, their interpretation requires consideration of methodological differences, including cutoff selection, patient population, and reference standards [7,8].

The comparison between ONSD ultrasonography and funduscopy requires particular caution. Although Kerscher et al. reported higher sensitivity for ONSD and higher specificity for fundoscopy in the same patient population, this evidence originates from a single comparative study and cannot be interpreted as the definitive superiority of one modality over another [6]. Differences in disease characteristics, clinical settings, and reference standards among studies prevented the direct ranking of modalities based solely on pooled sensitivity and specificity values.

A major finding of this review was the distinct role of OCT compared with other ocular examinations. Unlike fundoscopy and ONSD ultrasonography, which have been investigated mainly for diagnostic assessment, OCT provides quantitative structural information regarding retinal nerve fiber layer thickness, optic nerve head morphology, ganglion cell complex changes, and retinal microvascular alterations. The included OCT studies mainly evaluated correlations, biomarkers, and longitudinal changes rather than diagnostic accuracy. Therefore, OCT should currently be considered primarily as a tool for structural characterization and disease monitoring, rather than an independent diagnostic replacement for ICP measurement [10–13].

The interpretation of diagnostic accuracy estimates should also consider the differences in reference standards among studies. Some studies used invasive ICP monitoring, whereas others relied on lumbar puncture opening pressure or clinical diagnostic criteria [4–8]. These differences may affect the reported sensitivity and specificity because the reference standards do not provide identical levels of diagnostic certainty. Furthermore, when papilledema contributes to the clinical diagnosis of IIH, incorporation bias may occur because the index test and reference standard are not completely independent. This issue may lead to overestimation of diagnostic performance, particularly for fundoscopy-based assessments [4,5].

Another important methodological consideration is the study design. Several diagnostic accuracy studies have used case-control designs involving patients with IIH and healthy controls [7,8]. Although these designs may demonstrate the ability of a test to distinguish clear disease states, they may overestimate clinical performance compared

with prospective clinical populations with diagnostic uncertainty [7,8]. Therefore, future studies should prioritize prospective cohort designs with standardized reference standards and predefined cutoff values.

The findings of this review have several clinical implications. Currently, no single ocular modality can replace invasive ICP assessment. Instead, a multimodal approach may provide greater clinical utility. Fundoscopy may assist in identifying papilledema-related manifestations, ONSD ultrasonography may provide rapid non-invasive screening information, and OCT may support objective assessment of structural changes during disease progression and follow-up [4,7,10–13]. The integration of these modalities may improve clinical decision-making while reducing dependence on repeated invasive procedures.

This review has several limitations. First, substantial heterogeneity existed among the included studies regarding patient populations, reference standards, examination protocols, and cutoff thresholds, preventing the quantitative pooling of diagnostic estimates [4–13]. Second, several diagnostic accuracy studies had methodological concerns related to case-control designs and reference standard selection [7,8,17]. Third, OCT evidence was predominantly supportive rather than diagnostic, limiting conclusions regarding its ability to independently detect elevated ICP [10–13]. Finally, the limited number of direct comparative studies prevents definitive conclusions regarding the relative diagnostic performance of individual modalities.

5 Conclusion

This systematic review demonstrates that fundoscopy, optical coherence tomography (OCT), and ocular ultrasonography provide complementary information for the assessment of chronic or non-acute elevated ICP. Current evidence does not support replacing invasive ICP measurement with a single ocular modality. Fundoscopy remains valuable for identifying papilledema-related manifestations, although its limited sensitivity restricts its use as an exclusion test. Ocular ultrasonography, particularly optic nerve sheath diameter measurement, shows potential as a rapid and non-invasive screening approach; however, differences in cutoff values and reference standards limit direct comparison between studies. OCT provides quantitative structural and vascular information that may support disease characterization and longitudinal monitoring; however, current evidence is insufficient to establish OCT as a standalone diagnostic tool. Future prospective studies using standardized protocols, consistent reference standards, and validated diagnostic thresholds are required to define the clinical utility of these modalities more accurately.

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