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Quality of Reporting Electronic Health Record Data in Glaucoma

A Systematic Literature Review

Bethany E. Higgins, PhD,[1,2] *Benedict Leonard-Hawkhead, BSc Hons, MPH,*[1] *Augusto Azuara-Blanco, PhD, MD*[1]

Topic: Assessing reporting standards in glaucoma studies utilizing electronic health records (EHR).

Clinical Relevance: Glaucoma's significance, underscored by its status as a leading cause of irreversible blindness worldwide, necessitates reliable research findings. This study evaluates adherence to the CODE-EHR best-practice framework in glaucoma studies using EHR, aiming to improve clinical care and patient outcomes.

Methods: A systematic review, following Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (PROSPERO CRD42023430025), identified relevant studies (January 2022−May 2023) in MEDLINE, EMBASE, CINAHL, and Web of Science. Eligible studies, using EHR data from clinical institutions for glaucoma research, were assessed for study design, participant characteristics, EHR data, and sources. Quality appraisal used the CODE-EHR best-practice framework, focusing on data construction, linkage, fitness for purpose, disease and outcome definitions, analysis, and ethics and governance.

Results: Of 31 identified studies, predominant EHR sources were hospitals and clinical warehouses. Commonly reported elements included age, gender, glaucoma diagnosis, and intraocular pressure. Only 16% fully adhered to CODE-EHR best-practice framework's minimum standards, with none meeting preferred standards. While statistical analysis and ethical considerations were relatively well-addressed, areas such as EHR data management and study design showed room for improvement. Patient and public involvement, and acknowledgment of data linkage processes, data security, and storage reporting were often missed.

Conclusion: Adherence to CODE-EHR best-practice framework's standards in EHR-based studies of glaucoma can be improved upon. Standardized reporting of EHR data are essential to ensure the reliability of research, facilitating its translation into clinical practice and improving healthcare decision-making for better patient outcomes.

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Supplemental material available at www.ophthalmologyglaucoma.org.

Electronic health records (EHRs) have revolutionized the way eye-related data is collected, analyzed, and translated into meaningful outcomes. The EHR systems offer numerous advantages not only to clinicians but also to researchers, including enabling access to large amounts of patient data and removing the requirement for recruitment and labor-intensive data collection processes.[1] As a result, research has become more efficient and time-effective, enabling investigators to focus on the core analysis of existing data rather than diverting resources toward setting up new studies to acquire information. The EHRs allow researchers to delve into the intricacies of ophthalmic history, disease progression, and treatment outcomes, thereby yielding meaningful insights of clinical significance. As a result, large repositories of EHR data have been created, such as the National Institutes of Health All of US research program in the United States,[2] the IRIS® Registry (Intelligent Research in Sight) by the American Academy of Ophthalmology,[3] and the Eye & Vision data in UKBiobank in the United Kingdom.[4]

Among the domains of vision research where the impact of EHR-driven research is notably pronounced, glaucoma research has emerged with particular prominence. The intricate nature of glaucoma's pathophysiology and the diverse range of factors that influence its progression make it an ideal candidate for investigation through EHR data. For example, Craig et al[5] analyzed the optic nerve head in 67 040 UK Biobank participants and generated a polygenic risk score that can categorize glaucoma risk, forecast disease progression, and surgical needs. This

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polygenic risk score facilitates early treatment for high-risk individuals and could only be achieved by utilizing a large amount of EHR data.[5]

However, despite the evident potential to research, the heterogeneity of EHR data sourced directly from clinical institutions makes comparing these studies difficult. The rich diversity of data sources, coupled with inconsistent reporting practices makes the translation of EHR-driven research findings difficult. In light of these challenges, the need for a standardized framework to ensure the quality and reliability of EHR-based reports has become increasingly apparent. Hence, the CODE-EHR best-practice framework, published in 2022 was welcome and timely.[6] The aim was to create standardized reporting guidelines in the context of structured health care data that adhere to Findable, Accessible, Interoperable, and Reusable (FAIR) principles.[7] The European Society of Cardiology and the BigData@Heart consortium brought together a diverse collaboration of international stakeholders, encompassing patients, clinicians, scientists, regulators, journal editors, and industry members, underscoring the pivotal role of patient and public involvement (PPI) in shaping the development of the CODE-EHR best-practice framework. This framework, tailored specifically for the use of EHR data, serves as a touchstone to ensure that research endeavors meet stringent standards of reproducibility.

As the momentum of EHR-driven glaucoma research continues to surge, it is imperative to address the challenges that impede its progress. Therefore, through this systematic literature review, a comprehensive exploration of the current landscape of glaucoma research utilizing EHR data is undertaken. The primary objective of this systematic review is to critically assess the quality of these studies reporting EHR data through the lens of the CODE-EHR best-practice framework.[6] By applying the framework, this review endeavors to bridge the gap between raw patient data and meaningful insights into glaucoma medical history, symptom progression, and treatment outcomes while ensuring that research adhere to rigorous standards of robustness and replicability.

Methods

Eligibility Criteria for Considering Studies for this Systematic Review

Initially, to be eligible for inclusion, studies had to be: (i) published in the English language; (ii) dated from January 2019 to current; (iii) include adult participants with glaucoma (of any form); and (iv) include use of EHR data sourced from a hospital or clinical setting. Furthermore, studies were required to be focussed on the condition glaucoma and not just reporting presence of glaucoma as an outcome measure. The protocol for this review has been registered in the online database PROSPERO (CRD42023430025). This review follows PRISMA guidelines, see Supplemental Material 1 (available at www.ophthalmologyglaucoma.org) for PRISMA checklist. IRB review was not required for this review article. All research adhered to the tenets of the Declaration of Helsinki. The requirement for informed consent was waived because of the retrospective nature of the study.

Studies were excluded if they were review articles, letters to the editor, published protocols, conference abstracts, or animal-based studies. Studies were also excluded if they did not explicitly state that the health record was electronic or digital.

After the first stage of screening was completed and a large number of papers were selected for full-text screening, the authors decided to reduce the inclusion window in terms of dates of publication, to papers published from January 2022. All other inclusion and exclusion criteria remained the same.

Search Methods for Identifying Studies

The following databases were searched: MEDLINE, EMBASE, CINAHL, Web of Science for publications published between 01/01/2019 and present. We also searched for studies using the IRIS Registry. A list of search terms and the search query used is provided in Supplemental Materials 2 (available at www.ophthalmologyglaucoma.org). Key terms regarding EHR were used. The reference lists of the included literature were examined as a further source of relevant studies. Covidence software[8] (Veritas Health Innovation) was used for extraction, organization, and screening of the literature.

Study Selection

Duplicates were automatically removed by Covidence software.[8] Two authors (B.E.H. and B.L.H.) independently assessed for eligibility for inclusion through screening titles and abstracts. The same 2 authors then independently read the full texts of potential eligible studies with any disagreements about inclusion resolved through discussion and then arbitration by a third author (A.A.B.).

Data Collection and Risk of Bias Assessment

Study characteristics were extracted (by author B.H.), including study authors, aims, location, the study population, the EHR data collected, and the source of the data. To assess the included studies (and to analyze for any bias), the CODE-EHR best-practice framework was used.

The CODE-EHR Best-Practice Framework

The CODE-EHR best-practice framework contains 5 minimum standards encouraged to be used by researchers and clinicians to improve study design and enhance transparency of methods.[6] These 5 items are: (i) Data Construction and Linkage (how EHR data were identified and used in study), (ii) Data Fit for Purpose (transparency regarding the method taken to code EHR data for study), (iii) Disease and Outcome Definitions (how conditions and outcomes were defined in order to allow replicability), (iv) Analysis (how EHR data were statistically analyzed), and (v) Ethics and Governance (how good clinical practice was adhered to).[6] See Table 1 for details, adapted from Kotecha et al.[6] Further details to enable full understanding of the framework and minimum information required has been provided by Kotecha et al[6] in Appendix 2: Using the CODE-EHR reporting checklist.[6] A checklist has been produced by Kotecha et al[6] to enable a research team to easily consider all points of the framework while designing their study methodology. To meet the preferred standards of the framework, it is encouraged that a protocol is published, outlining the study's intended methodology. Furthermore, a statistical analysis plan is advised, locked prior to the start of the study. For full details of the framework, see the original paper by Kotecha et al.[6]

Despite the emergence of various frameworks over the past decade, with some specifically targeting the enhancement of EHR

Table 1. Items of the CODE-EHR Best-Practice Framework and the Minimum Information Required

Item	Framework Standards	Minimum Information Required
1. Data Construction and Linkage	*Minimum Standard*: Flow diagram of datasets used in the study, and description of the processes and directionality of any linkage performed, published within the research report or supplementary documents. *Preferred Standard*: Provided within a prepublished protocol or open-access document	(a) State the source of any datasets used. (b) Comment on how the observed and any missing data were identified and addressed, and the proportion observed for each variable. (c) Provide data on completeness of follow-up. (d) For linked datasets, specify how linkage was performed and the quality of linkage method
2. Data Fit for Purpose	*Minimum Standard*: Clear unambiguous statements on the process of coding in the methods section of the research report. *Preferred Standard*: Provided within a prepublished protocol or open-access document.	(a) Confirm origin, clinical processes, and the purpose of data. (b) Specify coding systems, clinical terminologies or classification used and their versions, and any manipulation of the coded data. (c) Provide detail on quality assessment for data capture. (d) Outline potential sources of bias.
3. Disease and Outcome Definitions	*Minimum Standard*: State what codes were used to define diseases, treatments, conditions, and outcomes prior to statistical analysis, including those relating to patient identification, therapy, procedures, comorbidities, and components of any composite endpoints. *Preferred Standard*: Provided within a prepublished protocol or open-access document prior to statistical analysis.	(a) Detailed lists of codes used for each aspect of the study. (b) Date of publication and access details for the coding manual (please add to box below). (c) Provide definitions, implementation logic and validation of any phenotyping algorithms used. (d) Specify any processes used to validate the coding scheme or reference to prior work.
4. Analysis	*Minimum Standard*: Describe the process used to analyze study outcomes, including statistical methods and use of any machine learning or algorithmic approaches. *Preferred Standard*: Provide a statistical analysis plan as a supplementary file, locked prior to analyses commencing.	(a) Provide details on all statistical methods used. (b) Provide links to any machine code or algorithms used in the analysis, preferably as open-source. (c) Specify the processes of testing assumptions, assessing model fit and any internal validation. (d) Specify how generalizability of results was assessed, the replication of findings in other datasets, or any external validation.
5. Ethics and Governance	*Minimum Standard*: Clear unambiguous statements on how the principles of Good Clinical Practice and Data Protection will be/were met, provided in the methods section of the research report. *Preferred Standard*: Provided within a prepublished protocol or open-access document with evidence of patient and public engagement.	(a) State how informed consent was acquired, or governance if no patient consent. (b) Specify how data privacy was protected in the collection and storage of data. (c) Detail what steps were taken for patient and public involvement in the research study. (d) Provide information on where anonymized source data or code can be obtained for verification and further research.

Further details to enable full understanding of the framework and minimum information required can be found in Appendix 2: Using the CODE-EHR reporting checklist.[6]

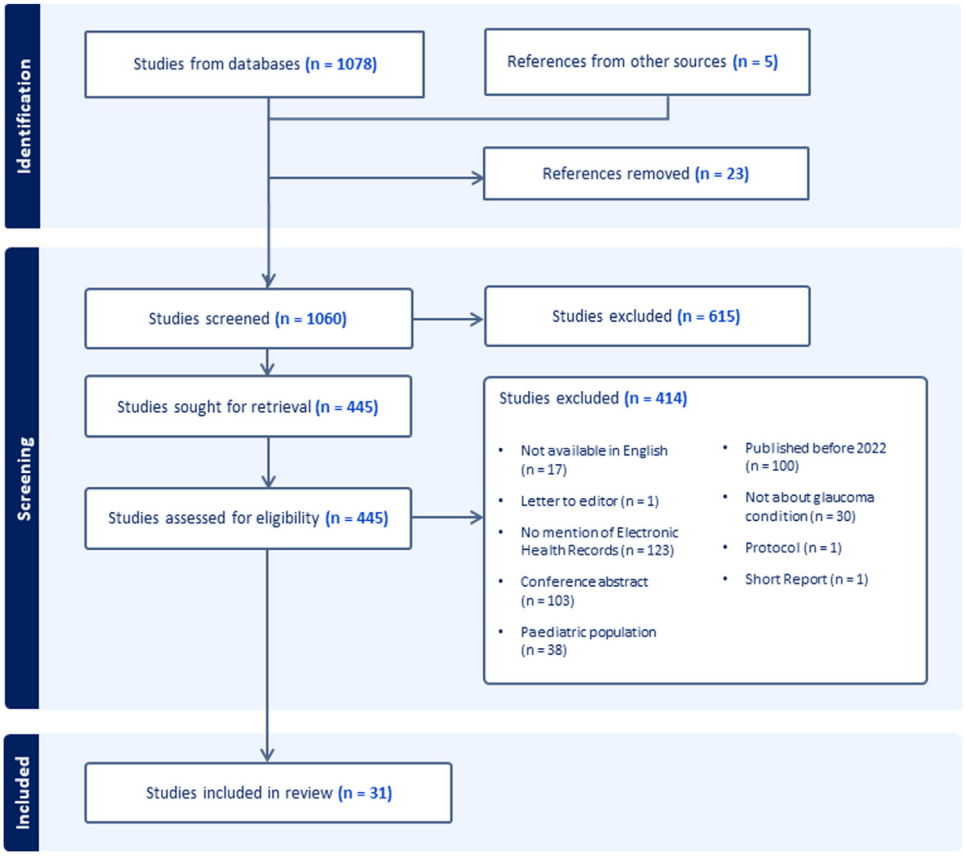

Figure 1. PRISMA flowchart illustrating the systematic review process for the inclusion of studies.

phenotyping algorithms,[9–13] we opted for the CODE-EHR best-practice framework. While not developed in ophthalmology, it was chosen for its inclusivity, applicability, endorsement by key regulatory bodies, and simplicity via a user-friendly checklist. These factors make it particularly suitable for our analysis, ensuring transparency and adherence to FAIR principles.

Data Synthesis and Analysis

The data extracted (by author B.H.) were put into a data synthesis (Table S2 and Supplemental Materials, available at www.ophthalmologyglaucoma.org), A meta-analysis was not appropriate given the range of study topics and outcome measures. Data were analyzed based on adherence to the CODE-EHR best-practice framework standards (by author B.H.). Studies were judged if they met the 5 minimum framework items, the 5 preferred framework items and if they adhered to the minimum information required (see Table 1 for reference). The outcome of this assessment can be found in Table S3 (see Supplemental Materials, available at www.ophthalmologyglaucoma.org).

Results

The search of bibliographic databases performed on May 24, 2023 identified 1536 publications. Due to the unprecedented number of papers published in this field, it was decided to add an additional screening criterion of papers published in January 2022 onwards. During the abstract screening procedure, most studies (n = 615) were excluded. There were 445 studies screened during the full text screening process and 414 studies were deemed ineligible, primarily for not mentioning electronic health records (n = 123), or because they were conference abstracts (n = 103). Thirty-one papers were deemed appropriate for the final review process (Figure 1).

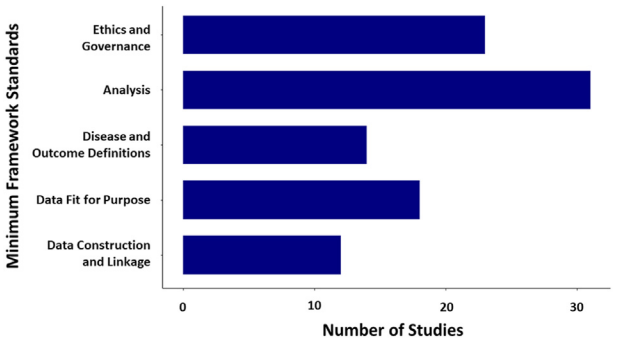

Figure 2. The proportion of 31 included studies that met the 5 minimum standards of the CODE-EHR best-practice framework. Note: No studies met the Preferred Standards of the Framework.

Study Characteristics

Data from the 31 included studies were sourced from the United States[14–31] (18 studies, 58%), India[32–34] (3 studies, 9%), China,[35] Faroe Islands,[36] Finland,[37] Japan,[38] South Korea,[39] Spain,[40] Taiwan,[41] and the United Kingdom.[42] Two studies did not report

their location.[17,43] Most studies sourced EHR data from hospitals[17,19,21,24,32–42,44] (16 studies, 64%), 5 studies utilized data from Stanford Clinical Warehouse,[18,20,22,23,25] 4 studies sourced data from the IRIS Registry,[26–29] and 2 studies used data from the Duke Ophthalmic Registry.[14,30] Chen et al[16] used data from Oregon Health and Science University EHR Clinical Warehouse,[16] Lee et al[31] used data from the All of Us Research Program database[31] and one study did not explicitly report where data was sourced from Hindi et al.[43] In the 31 studies, the most frequently reported EHR data extracted were glaucoma diagnosis (all 31 studies) and age, gender, ethnicity and/or race (30 studies). Additional frequently reported data included intraocular pressure (IOP), reported by 26 studies (83%); visual acuity (VA), reported by 19 studies (61%); OCT, reported in 13 studies (41%); and visual field data, was reported by 11 studies (35%). For full details, see Table S3 (available at www.ophthalmologyglaucoma.org).

CODE-EHR Best-Practice Framework Adherence: Overall

Only 5 studies (16%) met all 5 of the CODE-EHR best-practice framework minimum standards.[22,25,28,31,37] Eight studies met 4 of the minimum standards,[14,15,18,21,23,26,27,38] 7 studies met 3,[16,17,20,24,29,30,42] 9 studies met 2[19,32,35,36,39–41,43,44] and 2 studies met one of minimum the standards.[33,34] None of the 31 included studies met the CODE-EHR best-practice framework preferred standards. Furthermore, no study included in this review reported that the CODE-EHR best-practice framework had been followed.

It was found that while most of the included studies met the minimum framework standards for items on statistical analysis and ethical considerations, a substantially smaller number of studies met the minimum framework standards for items pertaining to EHR data management and study design. For example, the minimum framework standard for Data Construction and Linkage was the least frequently observed, met only by 12 studies of the included 31[15,17,21–28,31,37] (Figure 2). What follows is a narrative synthesis of the included studies, how they adhered to each of the 5 minimum framework standards and where they did not. For full details, see Table S3 (available at www.ophthalmologyglaucoma.org).

CODE-EHR Best-Practice Framework Adherence: Data Construction and Linkage

The minimum standard framework for Data Construction and Linkage advises the use of a flow diagram to illustrate the datasets used in the study and where necessary, a description of the processes and any dataset linkage performed. Twelve studies featured flow diagrams (meeting the minimum framework standard)[15,17,21–28,31,37] (39% of 31 studies), while 19 studies (61%) did not. No studies explicitly provided a prepublished protocol or open-access document pertaining to dataset construction. While all studies bar one reported where data was sourced from, 15 studies reported or considered missing EHR data in their reports,[14–18,20,22,26–28,31–33,37,39] whereas 16 studies did not. Six studies explicitly sourced data from multiple datasets,[15,16,34,36,39,42] while this was unclear or not the case for the remaining 25 studies.

CODE-EHR Best-Practice Framework Adherence: Data Fit for Purpose

Eighteen studies (58% of 31 studies) were assessed to have met the minimum framework standard for Data Fit for Purpose,[14–16,18,20–23,25–31,37,38,42] which consisted of clear, unambiguous statements regarding how coding was completed. Yet, no papers featured a prepublished protocol, meaning the preferred framework standard was not met. Only 2 studies stated who completed the coding for the EHR data,[15,16] which enables understanding of the coding workflow used. Notably, only half the studies explicitly reported the coding type used in the Methods section of the research reports.[14,15,18,20–23,25–31,37,38] Of these studies, all reported using International Classification of Diseases (ICD) 9 or 10 codes, while 11 of these studies also reported using Current Procedural Terminology (CPT) codes[14,15,18,20,23,25–30] and Lee et al[31] reported using Systematized Nomenclature of Medicine Clinical Terms (SNOMED CT).[31] Twelve studies considered quality assessment of the EHR data extracted (for example, any amendments to data or replacements for missing data).[14–18,22,26–28,31,32,42] None of the included studies explicitly commented on bias of merging EHR datasets nor methods to address this.

CODE-EHR Best-Practice Framework Adherence: Disease and Outcome Definitions

To meet the minimum framework standard for Disease and Outcome Definitions, studies had to report which codes were used to define disease, treatment, and conditions. Fourteen of 31 included studies (45%) met this condition.[14,15,18,20–23,25–29,31,37,38] None of the included studies provided details of disease and outcome definitions within a prepublished protocol or open-access document before statistical analysis, hence the preferred framework standard was not met. Less than half of the 31 studies explicitly specified the list of codes used in their methodology,[15,18,20,23,25–29,31,37] yet it should be noted that this criterion was considered followed if a list of codes was featured within Methods text, opposed to a standalone list as a Supplemental File. Notably, only 2 studies reported the date the EHR data were extracted.[27,29] However, all 31 included studies featured how glaucoma-related phenotypes and outcome events were defined, and 7 studies validated these defined phenotypes by referencing previously published disease and outcome definitions.[14,15,33,35,40,42,43]

CODE-EHR Best-Practice Framework Adherence: Analysis

All the 31 studies met the minimum framework standard for analysis, which was to describe the statistical processes used to analyze outcomes and use of any machine learning or algorithms. However, none of the studies reported a prepublished statistical plan, locked prior to starting analysis so the preferred framework standard was not met. All included studies set out what statistical methods were used, while only 2 studies utilized machine learning code/algorithms and made them open access.[18,39] Seven studies explicitly assessed testing the featured models fit, tested assumptions or conducted some form of internal validation.[14–16,18,22,25,39] Both Nealon et al[15] and Wang et al[18] also included an assessment of external validation.

CODE-EHR Best-Practice Framework Adherence: Ethics and Governance

Most of the included studies were explicit in statements on good clinical practice and data protection, thus meeting the minimum framework standard for Ethics and Governance (23 studies, 75%). As before, no prepublished protocols were included so the preferred framework standard was not met. Twenty studies (65% of 31 studies) made clear statements about participant consent and if it was not required, what governance was sought. However, only 5 studies reported on the EHR data security and storage.[14,16,21,40,42] Furthermore, no studies reported any form of PPI in their study design, and only 4 studies provided anonymized open-source data to allow verification and further research.[15,16,18,39]

Discussion

In this systematic literature review, we have conducted a comprehensive assessment of the quality of reporting of current glaucoma studies that utilize EHR data. Using the CODE-EHR best-practice framework,[6] this review highlights opportunities for enhancement in the current standards, emphasizing the importance of standardizing reporting practices. For example, while 16% of studies included in this review met all the of the CODE-EHR best-practice framework minimum standards, none met preferred standards. Most studies notably exhibited noticeable adherence to the minimum standards related to statistical analysis and research ethics, but did not meet the criteria for EHR data management and study design. There was no evidence of PPI and few studies acknowledged data linkage processes, data security, and storage. These are our main findings. We conclude that observing a standardized framework for designing studies using EHR data and consistently reporting results can significantly enhance transparency, replicability, and data quality in glaucoma research based on structured health care data.

Challenges in EHR Data Management and Study Design

Most studies included in this review did not explicitly provide information on how the featured EHR data were identified and used. A clear and informative flow diagram of EHR data collection and any data linkage strategies ensures readers understand how data is gathered and processed, thus enhancing transparency, promoting data consistency, and supporting replicability. For examples, refer to the 12 studies featured in this review that utilized flow diagrams.[15,17,21–28,31,37] Flow diagrams are a key feature of other reporting guidelines such as Strengthening the Reporting of Observational Studies in Epidemiology (STROBE).[45] By proactively incorporating data linkage strategies and adhering to a structured EHR data framework during the design of studies, researchers can effectively identify and mitigate biases associated with dataset integration, ultimately resulting in more robust and reliable research outcomes.[46]

Glaucoma studies featuring EHR data would benefit from clear and unambiguous statements regarding EHR coding methods. The implications of studies not consistently reporting the codes used for defining diseases and outcomes include hindering inter-study comparability and reducing clarity of results.[47] In addition, clear reporting of codes is essential for ensuring that the definitions align with clinical standards. Inconsistencies can lead to discrepancies between research findings and clinical practice. As a result, this could impact the clinical relevance of results. Lack of publishing clinical codes is widespread in research and is rarely a requirement by journals or funding bodies for obtaining grants or publishing research.[47] In glaucoma research, where accurate disease and outcome definitions are paramount, the significance of standardized coding practices becomes even more pronounced. Inaccurate or inconsistent coding could lead to misinterpretations of glaucoma-related data, potentially impacting the development of effective treatments and interventions for this sight-threatening condition.

None of the studies included in this review used prepublished protocols, which if adopted, could have offered the advantage of documenting the study's design and methodology before data analysis, thus enhancing research integrity, reducing the risk of bias, and facilitating replication for future studies.[48] Such practices are crucial in glaucoma research, where precision and transparency in data collection and analysis are vital for developing effective treatments and ultimately improving patient outcomes.

Statistical Analysis, Ethical IRB Not Required for Review Article and Governance Considerations

Although all of the studies included in this review adhered to the minimum framework standard for Analysis from the CODE-EHR best-practice framework, there were no prepublished statistical plans and few examples of open-source datasets and code. This may have implications for the credibility of research. Published statistical plans prevent data-driven choices that could unintentionally (or intentionally) bias results, and it encourages thoughtful planning over random data analysis and makes this distinction clear to reviewers and readers.[49] To ensure that glaucoma research contributes meaningfully to clinical practice, it encourages studies to adopt rigorous statistical planning and reporting practices. Furthermore, publishing anonymized open-source datasets and code contributes to the advancement of glaucoma research while also ensuring that research EHR resources are accessible and useful to a wide range of stakeholders.

Most studies included in this review adhered to good ethical research practice and participant consent was either collected or governance was sought when consent was not required. As a result, 75% of studies met the minimum framework standard for Ethics and Governance. Yet, discussion regarding data security could be improved upon. EHR data security and storage is essential for safeguarding patient privacy, complying with regulations, preventing data breaches, maintaining data integrity, and ensuring ethical and responsible research conduct.[50] It is a foundational aspect of conducting research that involves sensitive health care data and should be routinely reported in EHR studies.

There was no discussion of PPI in the included studies. As the very nature of this research involves utilizing

glaucoma patient's medical data in order to ultimately improve patient outcomes, it is essential to acknowledge the valuable insights that patients and the general public can provide. Incorporating PPI into clinical research aligns with "Nothing About Us Without Us" principles, which advocates the involvement of patients in health care research and decision making.[51] The PPI can be easily implemented into study design by having discussions with patients and stakeholders and giving space for opinions and views to be shared.[52] Integrating PPI in future studies would enhance the relevance of research questions, improve study design, and ensure that the findings directly benefit the individuals affected by glaucoma, thus fostering a more patient-centred approach to research in this field.

Recommendations for Future Studies

In order to aid researchers conducting glaucoma studies using EHR data, the authors put forward the following 5 recommendations: (i) Utilize published guidelines designed for studies utilizing structured health data such as the CODE-EHR best-practice framework. These guidelines should be consulted during EHR-study design, not simply for guidance on reporting EHR study results. This would improve the design of studies and enhance transparency of study methods. (ii) Ensure EHR codes used are reported unambiguously in the Methods of research reports, to allow result replicability and clinical translation of results. (iii) Incorporate PPI into study design, in order to benefit from valuable insights from glaucoma patients' experiences. For example, establishing a PPI group or collaborating with patient advocacy organizations during the study design phase ensures that research questions, outcomes, and methodologies align with their needs. Furthermore, regular updates and ongoing involvement with the PPI group fosters patient-centered research. (iv) Report on EHR-data security and storage methods used in studies to prioritize safeguarding patient privacy. Clearly describing encryption methods, access controls, and de-identification processes in the Methods section builds trust among patients, clinicians, and the research community. (v) Consider prepublishing research protocols in reputable registries like ClinicalTrials.gov or Open Science Framework. This proactive step enhances the transparency of study objectives, methods, and analysis plan, contributing to the credibility and reproducibility of EHR-based glaucoma studies. See Table S4 (available at www.ophthalmologyglaucoma.org) for these guidelines in checklist format.

Review Strengths and Limitations

Our systematic review is not only timely, but it also addresses a need within the field of glaucoma research. With the increasing use of EHR data in recent years and the noticeable variability in reporting quality, there is a demand for a comprehensive evaluation. To the best of our knowledge, this review represents the first application of the CODE-EHR best-practice framework to glaucoma research studies. By assessing the quality of these studies, our review not only fills a crucial gap in the literature but also lays the foundation for future research in the domain. Our findings offer recommendations to enhance the standardization and reporting quality of EHR-based studies in glaucoma research, ultimately increasing impact of this vital area of vision science. While this review focuses on EHR data, it is worth noting research using any observational health data (e.g., medical claims data) should be required to follow transparent reporting guidelines, utilize robust data security, and feature PPI.

This study assessed a small window of studies published between January 2022 and May 2023, and this may raise concerns about the comprehensiveness of the analysis, potentially omitting earlier research that could have contributed valuable insights. Yet, the decision to narrow the scope to this specific timeframe was intentional as the number of EHR-based glaucoma studies was unreasonable to allow a considered and comprehensive analysis. Our aim was to capture the most recent developments and trends in the field of interest and this timeline allowed for this.

It is important to acknowledge that the CODE-EHR best-practice framework includes items that may not be applicable to all glaucoma studies. For instance, in cases where a study is assessing free-text clinical note data, reporting ICD or CPT codes may not be relevant. It is essential to recognize that the absence of these elements does not inherently imply poor data reporting quality in such studies. The CODE-EHR best-practice framework is designed to be adaptable, allowing researchers to specify when certain items from the minimum standards are not applicable in their Methods section. However, it is also worth emphasizing that critical elements such as transparent data linkage and robust data storage practices are pertinent to all EHR studies, regardless of their specific focus. As a result, the adoption of a framework ensures that EHR data is consistently reported in a secure and interpretable manner. While the CODE-EHR best-practice framework primarily emphasizes phenotype definition through codes, its structured approach provides a standardized foundation for reporting. However, it's essential to acknowledge that in certain cases, the complexity of glaucoma, including nuanced factors like IOP thresholds or prescribed medications, might extend beyond the framework's checklist. Adherence to the CODE-EHR best-practice framework was assessed by a single author, which may pose as a limitation to the assessment strategy. Yet, the study's approach aimed to maintain a standardized evaluation process. We would also highlight that CODE-EHR best-practice framework is a recent initiative, published in August 2022, and thus some authors of the reports would not have been aware of this checklist.

Conclusion

This systematic review underscores the need for standardization and transparency in glaucoma research utilizing EHR data. Although most studies adhered to minimum standards in statistical analysis and research ethics of the CODE-EHR best-practice framework, there remains room for improvement in EHR data management and study design. Embracing the CODE-EHR best-practice framework, transparent coding practices, robust data security, and PPI will heighten the credibility and impact of EHR-based glaucoma research.

Footnotes and Disclosures

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[1] Centre for Public Health, Institute of Clinical Science Block A, Royal Victoria Hospital, Belfast, United Kingdom.

[2] Optometry and Visual Sciences, School of Health & Psychological Sciences, City, University of London, London, United Kingdom.

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HUMAN SUBJECTS:

No human subjects were included in this study. IRB review was not required for this review article. All research adhered to the tenets of the Declaration of Helsinki. The requirement for informed consent was waived because of the retrospective nature of the study.

No animal subjects were included in this study.

Author Contributions:

Conception and design: Higgins, Leonard-Hawkhead

Analysis and interpretation: Higgins, Leonard-Hawkhead

Data collection: Higgins

Obtained funding: N/A

Overall responsibility: Higgins, Leonard-Hawkhead, Azuara-Blanco

Abbreviations and Acronyms:
CPT = Current Procedural Terminology; **EHR** = Electronic Health Records; **FAIR** = Findable, Accessible, Interoperable, and Reusable; **ICD** = International Classification of Diseases; **IOP** = intraocular pressure; **IRIS® Registry** = Intelligent Research in Sight; **PPI** = patient and public involvement; **SNOMED CT** = Systematized Nomenclature of Medicine Clinical Terms; **STROBE** = Strengthening the Reporting of Observational Studies in Epidemiology; **VA** = visual acuity.

Keywords:
CODE-EHR, Electronic health data, Glaucoma, Systematic review.

Correspondence:
Augusto Azuara-Blanco, PhD, MD, Centre for Public Health, Institute of Clinical Science Block A, Royal Victoria Hospital, Belfast BT12 6BA, United Kingdom. E-mail: a.azuara-blanco@qub.ac.uk.

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