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Gap Analysis of Glaucoma Examination Concept Representations within Standard Systemized Nomenclature of Medicine − Clinical Terms

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Objective/Purpose: Standardization of eye care data is important for clinical interoperability and research. We aimed to address gaps in the representations of glaucoma examination concepts within Systemized Nomenclature of Medicine − Clinical Terms (SNOMED-CT), the preferred terminology of the American Academy of Ophthalmology.

Design: Study of data elements.

Methods: Structured eye examination data fields from 2 electronic health records (EHR) systems (Epic Systems and Medisoft) were compared against existing SNOMED-CT codes for concepts representing glaucoma examination findings. Glaucoma specialists from multiple institutions were surveyed to identify high-priority gaps in representation, which were discussed among the SNOMED International Eye Care Clinical Reference Group. Proposals for new codes to address the gaps were formulated and submitted for inclusion in SNOMED-CT.

Main Outcome Measures: Gaps in SNOMED-CT glaucoma examination concept representations.

Results: We identified several gaps in SNOMED-CT regarding glaucoma examination concepts. A survey of glaucoma specialists identified high-priority data elements within the categories of tonometry and gonioscopy. For tonometry, there was consensus that we need to define new codes related to maximum intraocular pressure (IOP) and target IOP and delineate all methods of measuring IOP. These new codes were proposed and successfully added to SNOMED-CT for future use. Regarding gonioscopy, the current terminology did not include the ability to denote the gonioscopic grading system used (e.g., Shaffer or Spaeth), degree of angle pigmentation, iris configuration (except for plateau iris), and iris approach. There was also no ability to specify eye laterality or angle quadrant for gonioscopic findings. We proposed a framework for representing gonioscopic findings as observable entities in SNOMED-CT.

Conclusion: There are existing gaps in the standardized representation of findings related to tonometry and gonioscopy within SNOMED-CT. These are important areas for evaluating clinical outcomes and enabling secondary use of EHR data for glaucoma research. This international multi-institutional collaborative process enabled identification of gaps, prioritization, and development of data standards to address these gaps. Addressing these gaps and augmenting SNOMED-CT coverage of glaucoma examination findings could enhance clinical documentation and future research efforts related to glaucoma.

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The adoption of electronic health records (EHRs) in the United States has undergone a remarkable transformation, increasing from 9% in 2008 to 96% in 2021.[1] Electronic health records are crucial pillars in contemporary health care systems, serving as the foundation for comprehensive patient care and clinical documentation.[2,3] Originating from the imperative to digitize and streamline health-care information, structured EHR data

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fields aim to systematically capture, organize, and store patient-related information, covering medical history, diagnoses, treatments, medications, laboratory results, and more. Electronic health record vendors facilitate this process by supporting and integrating standardized terminologies while also offering customization options for specific medical practices.[4,5]

The shift toward EHRs has not only resulted in improved data accessibility, care coordination, and decision support but has also led to the establishment of databases housing real-world data from numerous clinical encounters. These databases present a unique opportunity for efficient evaluation and enhancement of both clinical care and research.[6,7] However, challenges such as privacy concerns, data security, data quality, adherence to standards, and interoperability have hindered the full realization of the potential of EHR data for research. One key component needed to realize the full potential of EHR data lies in the implementation of standardized medical terminology for health information.[8] The American Academy of Ophthalmology officially adopted Systematized Nomenclature of Medicine − Clinical Terms (SNOMED-CT) as its preferred clinical terminology in September 2007, receiving endorsement from various regional and international authorities. Systematized Nomenclature of Medicine − Clinical Terms is recognized as the most comprehensive and precise multilingual health terminology in the world. It has been developed collaboratively and continues to evolve to meet the diverse needs and expectations of the global medical profession. This extensive resource supports the electronic exchange of clinical health information and can be mapped to other coding systems, such as *International Classification of Diseases, Ninth Edition*, and *International Classification of Diseases, 10th Edition*, which facilitates semantic interoperability. Accepted as a common global language for health terms in over 50 countries, SNOMED-CT is a vital resource with scientifically validated clinical content.[9] This standardization plays a pivotal role in facilitating communication, interoperability, and research. Systematized Nomenclature of Medicine − Clinical Terms is also recognized as an underlying source vocabulary for the Observational Medical Outcomes Partnership common data model, which has been utilized for data harmonization in large efforts such as *All of Us* and National COVID Cohort Collaborative.[10] Leveraging EHR-based real-world data holds promise for accelerating the development of point-of-care clinical decision support tools and precision medicine.

Despite the active involvement of ophthalmologists in shaping these standards, gaps persist in the representation of eye-related examination elements in SNOMED-CT.[11] Recognizing this need for improvement, we established the SNOMED Eye Care Clinical Reference Group (CRG), aiming to identify, prioritize, and propose approaches to fill the existing gaps in SNOMED-CT. As part of our initial pilot study, we concentrated on updating glaucoma examination findings to enhance the accuracy and completeness of SNOMED-CT in capturing critical information related to glaucoma care.

Methods

Source Concept Selection and Gap Identification

We previously extracted data elements consisting of variable names and predefined permissible entry values from 2 EHR systems, Epic (Epic Systems Corporation) and Medisoft (Medisoft Ltd).[11] Here, we focused on glaucoma examination elements, including elements related to intraocular pressure (IOP), tonometry methods, gonioscopy examination findings, bleb grading system, evidence of glaucoma or ocular hypertension, and iris characterization. A comprehensive search of the Observational Health Data Sciences and Informatics (OHDSIs) Automated Terminology Harmonization, Extraction and Normalization for Analytics (Athena) browser,[12] with verification in the SNOMED International SNOMED CT Browser (SNOMED International)[13] was conducted, searching for existing standardized concepts pertaining to the extracted source data elements.

The source EHR concept, target SNOMED-CT term, and identification number were recorded. Each mapping from the source element to the target SNOMED term was categorized based on how well the SNOMED concept represented the EHR source element. The concept map equivalence designation was determined by the Health Level 7 Fast Healthcare Interoperability Resources concept map equivalence.[14] "Equal" is defined as SNOMED mappings directly representing the source EHR element. "Wider" indicates mappings that represent the source element with some information loss, "narrower" indicates mappings that introduce potentially inaccurate representation, and "unmatched" indicates no mapping was possible. The partial match group includes elements with wider and narrower codes. Then, a collated list of potential gaps was created, focusing on the unmatched and partial match groups.

Survey of Glaucoma Specialists

A structured online questionnaire (supplemental file 1, available at www.ophthalmologyglaucoma.org) was administered through the Qualtrics Survey Design website to survey 10 glaucoma specialists from multiple institutions regarding the identified gaps in standardized representation of glaucoma exam-related data elements. Nine (90%) responded to the survey. For unmatched elements, participants were asked to provide their feedback using Likert scale, ranging from 1 (not important) to 3 (very important), to assess their perspectives on the significance of the identified gaps and the proposed solutions. For the elements in the partially matched group, the responses included “the SNOMED term is sufficient,” “the SNOMED term is insufficient,” and “more information needed.”

The glaucoma specialists were members of a glaucoma-focused subgroup of the OHDSI Eye Care and Vision Research Workgroup, a workgroup consisting of ophthalmologists and informaticists focused on advancing the Observational Medical Outcomes Partnership Common Data Model. For data elements without any existing matching representation in standardized terminologies, the specialists were asked to rate each examination finding based on the level of importance for developing new codes. For data elements with partial representation, the specialists were surveyed to find whether the existing codes were sufficient. Survey results were tabulated using counts and proportions to determine the distribution of importance ratings for each data element. The OHDSI group then conducted synchronous reviews of the survey results to identify the highest-priority areas for submission to SNOMED.

Workflow and Terminology Development Process

The survey results, along with the potential modification and addition of the codes, were subsequently discussed within the SNOMED International Eye Care CRG, an international group consisting of terminologists from SNOMED and ophthalmologists engaged in updating SNOMED terminology for eye-related applications. The goal was to reach a consensus on which concepts needed updated terms and to discuss a framework for developing the new terms. The discussions occurred synchronously via teleconferences and asynchronously on the SNOMED Eye Care CRG Confluence space. New terms were developed in close collaboration with a SNOMED terminologist in the team. Proposals for new codes to address the gaps were formulated and submitted for inclusion in SNOMED-CT. Figure 1 summarizes the workflow of the present study.

Ethical Considerations

The University of California, San Diego, (UCSD) Institutional Review Board has approved this study (protocol number 804806). This study involved examining EHR data elements/fields and publicly available standardized terminology browsers but did not involve individual patient data and, therefore, did not require written informed consent. The research was conducted in accordance with the Health Insurance Portability and Accountability Act of 1996 and adhered to the tenets of the Declaration of Helsinki.

Results

We identified gaps in 4 major groups of glaucoma examination findings: gonioscopy, tonometry, bleb characterization, and negative findings. In the context of tonometry, 3 components had partial matches, while 2 lacked matches in SNOMED. Mapping of gonioscopy data elements revealed 6 components with partial matches and 4 without matches in SNOMED. Bleb characterization had 5 concepts with partial matches and 2 with none. Furthermore, 7 negative findings were identified to lack representation in SNOMED (Table 1).

More than half of glaucoma specialists rated the following parameters as "very important" in their evaluations, in descending order: the angle visible to the posterior trabecular meshwork (89%), maximum IOP (78%), angle visible to the anterior trabecular meshwork (67%), angle visible to the ciliary body band (67%), no iris neovascularization (56%), quadrant specification for gonioscopy findings (56%), and target IOP (56%). Glaucoma specialists rated "No iris processes" as not important (78%). Additionally, "No previous fields" and "Visual field not tested" were deemed not important by 67% and 56% of the specialists, respectively. Table 1 and Fig S1 (available at www.ophthalmologyglaucoma.org) provide a detailed review of the survey results. Nevertheless, most partial matches in SNOMED-CT for the extracted fields were deemed insufficient (Table 1).

After discussion within the CRG, the team decided to address the tonometry—and gonioscopy—related concepts as a priority. Bleb characterization was not felt to be a high priority for initial development, given a wide amount of variation in how bleb characterization is represented in different EHRs and by different glaucoma specialists.

Addressing Gaps in Tonometry Findings

Although existing tonometry codes partially represented the examination findings, there was a consensus that we needed to define new codes related to maximum IOP, target IOP, and to delineate all methods of measuring IOP, so that the method of measurement could be represented alongside the measurement value itself.

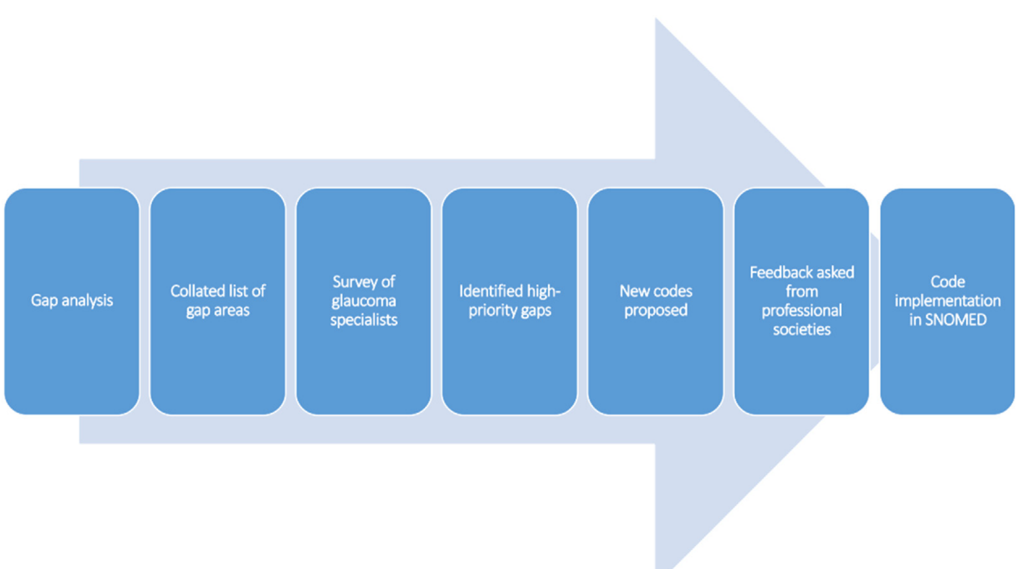

Figure 1. The study workflow and the identification of high-priority gaps in the representation of glaucoma examination concepts within the standard Systemized Nomenclature of Medicine − Clinical Terms. SNOMED = Systemized Nomenclature of Medicine.

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Table 1. Identification of Examination Elements with No or Partial Matches in the Systemized Nomenclature of Medicine — Clinical Terms by Surveying Glaucoma Specialists

	Partial Matches in SNOMED-CT*				
Examination Component	*EHR Data Field*	*Corresponding Concept in SNOMED*	**% Respondents Endorsing Insufficiency in SNOMED Partial Matches**	**No Matches in SNOMED-CT**	**% Respondents Endorsing the Importance of Representation in SNOMED†**
Tonometry	Tonometry method: Tonopen	Applanation tonometry	100	Maximum intraocular pressure	100
	Ocular response analyzer	Noncontact tonometry	87	Target intraocular pressure	100
	Noncontact air puff	Noncontact tonometry	33	Tonometry method: palpation	78
Gonioscopy	Grade 0	Narrow angle of anterior chamber	67	Angle visible to posterior trabecular meshwork	100
	Grade 1	Narrow angle of anterior chamber	67	Gonioscopy quadrant	89
	Grade 2	Narrow angle of anterior chamber	78	Angle visible to ciliary body band	89
	Grade 3	Moderate open angle	44	Angle visible to anterior trabecular meshwork	78
	Grade 4	Wide open angle	44	Gonioscopy grading system	67
	Slit	Narrow angle of anterior chamber	67		
Bleb characterization	Bleb - Seidel negative	Bulbar conjunctival drainage bleb	89	Bleb grading system	78
	Bleb - cystic	Bulbar conjunctival drainage bleb	89		
	Bleb - elevated	Bulbar conjunctival drainage bleb	89		
	Bleb - diffuse	Bulbar conjunctival drainage bleb	89		
	Bleb - thickened	Bulbar conjunctival drainage bleb	78		
Negative findings	-			No angle pigmentation	89
				No evidence of glaucoma or ocular hypertension	78
				No iris neovascularization	78
				No anterior chamber angle rubeosis	78
				No evidence of glaucoma	67
				Visual field not tested	56
				No abnormality on gonioscopy	44
				No previous visual fields	33
				No iris processes	22

SNOMED-CT = Systemized Nomenclature of Medicine — Clinical Terms.
*Elements with partial matches are demonstrated in the following format: *"name of the data element within the electronic health records system"* | *"mapped concept within SNOMED-CT."*
†Calculated by summing up the percentages of respondents ranking it as 'very important' and 'somewhat important, see supplemental figure 1 for details.

Moreover, 2 erroneous synonyms within SNOMED, *digital tonometry* and *portable electronic applanation tonometry* were identified.

Therefore, new terms were proposed and developed for *maximum IOP, maximum untreated IOP,* and *target IOP* (see Table 2). For tonometry methods, a comprehensive list of tonometry methods was codified (Table 2) and could be used in conjunction with SNOMED code 41633001 |IOP (observable entity). Because of SNOMED International regulations, no commercial names (e.g., iCare, Tonopen) could be used in the terms, so generic representations were developed by the CRG. These new terms went live in SNOMED International in July 2023.

Existing Codes and Gaps in Gonioscopy Findings

The current terminology exhibited several gaps, lacking the ability to denote the gonioscopic grading system used (i.e., Scheie, Shaffer, or Spaeth), inability to delineate exact angle features including degree of angle pigmentation, iris configuration (except for plateau iris), and iris approach. There was also no ability to specify eye laterality or angle quadrant for gonioscopic findings. Moreover, we found 6 existing codes within SNOMED-CT explaining gonioscopy examination findings. These codes included: 251728001| angle meshwork pigmentation, 404630001| plateau iris configuration, 247034002| peripheral anterior synechiae, 111512005| posterior synechiae, 70992005| anterior synechiae, and 251732007| neovascularization of angle.

Discussions within the CRG led to the decision to represent examination findings as observable entity concepts in SNOMED-CT, with precoordination of quadrant and laterality. Grading systems were suggested to be included in techniques and placed under the category of 254291000| staging and scales. A consensus was reached to introduce a new code for the examination finding "iridotrabecular contact over 180 degrees," aligning with large-scale angle closure clinical trials. Table 3 summarizes the proposed modifications for representing gonioscopy examination finding within SNOMED-CT. A proposal endorsing these modifications was submitted to and approved by the American Academy of Ophthalmology Preferred Practice Pattern Guidelines for Glaucoma Committee and the American Glaucoma Society.

Discussion

The identification of gaps in the representation of glaucoma examination concepts within the SNOMED-CT is a significant step toward enhancing clinical interoperability and facilitating glaucoma research.[11,15] Comprehensive representation of glaucoma examination findings is pivotal for several reasons. A comprehensive representation of glaucoma examination findings is essential, particularly to improve interoperability, which has a significant potential to ensure continuity of care. For instance, patients might have difficulty recalling specific details such as their maximum IOP or prior target IOP. By leveraging data standards and interoperability, this information can be seamlessly exchanged between different EHR systems, ensuring a smoother continuum of care for patients, enhancing the overall efficiency and effectiveness of glaucoma care across diverse health-care settings.

Moreover, these gaps in SNOMED-CT impact clinical research and secondary use of EHR data for glaucoma studies. There has been a shift in recent years toward using the analysis of real-world patient data collected through EHR systems.[7] Without standardized and comprehensive representations of glaucoma examination findings, research efforts are hampered. Researchers encounter challenges in data extraction, aggregation, and analysis when vital data elements are missing or underrepresented.[8] Even nationwide registries such as the National Institutes of Health *All of Us* database do not include eye-related examination findings, as harmonizing data becomes challenging when there is a lack of representation in standardized terminologies.[16] The identified gaps in SNOMED-CT present an opportunity to enhance the quality and utility of EHR data and large registries in glaucoma research.

Table 2. Added Codes for Representation of Tonometry Terms in the Systemized Nomenclature of Medicine − Clinical Terms

EHR Data Element	SNOMED Concept ID | Fully Specified Name
Maximum IOP	1285559005|maximum intraocular pressure (observable entity)
Maximum untreated IOP	1285557007|maximum untreated intraocular pressure (observable entity)
Target IOP	1284945000|target intraocular pressure (observable entity)
Goldmann applanation tonometry	389152008|Goldmann applanation tonometry (procedure)
Rebound tonometry	1286870002|rebound tonometry (procedure)
Noncontact tonometry	389150000|noncontact tonometry (procedure)
Pneumatic tonometry	252804008|pneumatic tonometry (procedure)
Mackay−Marg tonometry	1286871003|Mackay−Marg tonometry (procedure)
Dynamic contour tonometry	1286902005|dynamic contour tonometry (procedure)
Indentation tonometry	392338001|indentation tonometry (procedure)
Tactile tonometry	1286917009|tonometry by palpation (procedure)
Corneal compensated noncontact tonometry	1286906008|corneal compensated tonometry using ocular response analyzer (procedure)
Goldmann correlated noncontact tonometry	1286913008|Goldmann correlated tonometry using ocular response analyzer (procedure)

IOP = intraocular pressure; SNOMED-CT = Systemized Nomenclature of Medicine − Clinical Terms.

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Table 3. Proposed Modifications for Representation of Gonioscopic Examination Findings in the Systemized Nomenclature of Medicine — Clinical Terms

Data Field/Modification	Relevant Concepts
Grading system	Scheie, Shaffer, Spaeth
Precoordinate laterality and quadrant	Degree of angle openness
	Degree of angle pigmentation
	Presence of neovascularization of the angle
	Presence of synechiae
Precoordinate laterality only (no quadrant specified)	Iris configuration
	Iris approach
Degree of angle openness	Concepts for each grading value (e.g., I to IV, 0 to 4, A to E)
Degree of angle pigmentation	Concepts for each grading value (e.g., I to IV, 0 to 4)
	Generic representation of “light,” “moderate,” “heavy,” “unspecified”
Iris configuration	Spaeth classification (f, b, c, p)
	Generic representation of “flat,” “anteriorly bowed,” “posteriorly bowed,” “plateau iris”
Iris approach	Shaffer grading system
	Generic representation of “steep” or “shallow”
Retired code	Plateau Iris (SNOMED 232080006)
New code	Iridotrabecular contact over 180 degrees

SNOMED = Systemized Nomenclature of Medicine.

Addressing the identified gaps, which hold substantial importance, has significant potential to enable downstream research and discovery. Studies have consistently reported significant variations in IOP readings obtained by different tonometers, making it essential to identify the specific method employed.[17–19] Differentiating the tonometry method is imperative to ensure the comparability of measured IOP values. Additionally, both maximum IOP and maximum untreated IOP serve as critical predictors of disease progression and treatment outcomes in the existing body of literature.[20–22] These parameters play a pivotal role in assessing the effectiveness of therapeutic interventions, especially considering that IOP reduction is currently the only proven approach to slowing down glaucoma progression.

In contemporary glaucoma care, clinicians rely on the concept of target IOP as a threshold for advancing therapy and slowing down progression, although subjectively.[23–27] Without a dedicated code to capture the target IOP, downstream research faces challenges in objectively measuring and optimizing treatment goals. Including a code for target IOP is crucial for enhancing the precision of clinical care and facilitating more objective assessments of treatment success. Another important aspect of interpreting IOP measurements is their measurement time, currently represented using a measurement timestamp, because diurnal changes in IOP might affect the measured number.[28]

In the context of gonioscopy, there were existing gaps in several aspects, ranging from grading systems to the degree of angle pigmentation and iris configuration. Each of the proposed codes holds significance for both clinical practice and research. Without the ability to specify the grading system, the examination findings measured by different grading systems would cause downstream errors in cohort specification and outcome interpretation, leading to inaccurate discoveries. For instance, the degree of openness graded by Shaffer can have grades 1 to 4, superficially mirroring the Scheie system’s I to IV grading.[29] However, a notable discrepancy exists: in the Shaffer system, grade 1 describes a closed angle, while the Scheie system specifies an open angle with grade I. Moreover, the inability to precoordinate laterality and quadrant poses a significant challenge, making it impossible to track changes in angle and iris structures within each subject over time. In addition to the gaps in concept representation, the extent of the utilization of each method remains unclear, and there is a high degree of variability both between and within observers in the gonioscopy data.[30] These additional challenges are beyond the scope of the present work.

Moreover, a detailed understanding of iris anatomy is crucial for determining appropriate treatment strategies. Iris configuration is pivotal in diagnosing and managing conditions such as plateau iris, and the iris approach is particularly significant in assessing narrow-angle glaucoma.[31,32] After assessing and documenting iris approach, clinicians can tailor interventions, such as laser peripheral iridotomy, to address specific anatomical configurations, ensuring targeted and effective treatment. Iridotrabecular contact over 180 degrees is a widely accepted finding as the hallmark of angle closure. Flagship clinical trials such as the Zhongshan Angle Closure Prevention[33] and Effectiveness of early lens extraction for the treatment of primary angle-closure glaucoma[34] have consistently used this specific finding to differentiate between eyes with angle closure and those with open angles. Moreover, multiple studies have examined the degree of angle pigmentation, investigating the nature of the disease as well as the outcomes of different procedures.[35–37] Without standardizing these concepts, similar discoveries would be impossible using existing and emerging data repositories.

The addition of new codes reflects the need to align SNOMED-CT with the criteria and terminologies employed in cutting-edge glaucoma research. These concepts are particularly important as the population ages and the prevalence of glaucoma continuously increases,[38] highlighting the need for accelerated clinical research in these fields. By accommodating different grading systems and providing granularity in the description of angle characteristics, these new codes serve as a valuable resource for clinicians and researchers. In addition, these could be subsequently used for defining relevant cohorts, such as those with narrow/occludable angles or angle-closure glaucoma. This may improve the utility of EHR data for secondary research in glaucoma. The proposed data standards not only improve clinical documentation but also open avenues for more robust glaucoma research, allowing for the comprehensive analysis of real-world patient data.

One of the limitations of this study may be considered the small sample size leading to potential surveillance bias in surveying glaucoma specialists. However, the specialists volunteering in the eye care CRG were from different institutions worldwide and represented their institution in terms of practice variations. Nonetheless, participation in the SNOMED International forum was open to volunteers and discussions were conducted both synchronously and asynchronously to maximize inclusiveness. Another limitation may be the selection bias induced by the limited number of EHRs used to extract the source data elements and the fact that all the survey respondents were academic physicians. However, Epic and Medisoft are the 2 most widely used EHR systems in the US and the UK. The multi-institutional approach was undertaken to account for local customization of these systems across different sites. As the field grows and new concepts develop continuously, there might be a necessity to regularly update these codes in the future.

A novel aspect of this study is the collaborative approach undertaken to address the identified gaps. Multiple institutions and experts in the field of glaucoma actively participated in the process of identifying and prioritizing these gaps. The involvement of glaucoma specialists and the SNOMED International Eye Care CRG ensured that the identified gaps were indeed crucial in real-world clinical practice. Moreover, this international approach will provide the opportunity to harmonize the databases from different countries worldwide to enhance and accelerate scientific discoveries.

In conclusion, the resulting data standards not only bridge existing gaps but also lay a solid foundation for improved clinical interoperability and more extensive glaucoma research.

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Abbreviations and Acronyms:

CRG = clinical reference group; **EHR** = electronic health record; **OHDSI** = Observational Health Data Sciences and Informatics; **SNOMED-CT** = Systematized Nomenclature of Medicine − Clinical Terms.

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