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Readability and Comprehension in Radiology Reports and Patient Education: A Comprehensive Review

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Keywords: readability, radiology documentation, patient education materials (PEMs), structured reporting, health literacy, plain language, visual aids, artificial intelligence (AI), natural language processing (NLP), patient-centered care.

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Readability and Comprehension in Radiology Reports and Patient Education: A Comprehensive Review

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Abstract- Readability in radiology documentation is critical for effective communication between healthcare professionals and patients. Radiology reports and Patient Education Materials (PEMs) often contain complex technical language that can hinder patient understanding, leading to potential miscommunication and reduced patient satisfaction. This article explores the significance of readability in radiology, emphasizing the importance of making these documents accessible to non-specialist audiences.

The objective of this article is to review the current challenges in radiology documentation readability and explore strategies for improvement. Recent studies have identified significant issues with the complexity of radiology reports and PEMs, noting that many exceed the recommended reading levels for the general population[Carmody et al., 2019]. Additionally, the transition from narrative to structured reporting has had mixed effects on readability, highlighting the need for further research and innovation [Friedman et al., 2006].

Key findings suggest that plain language, visual aids, and interactive content can enhance the clarity of radiology documentation [Hani et al., 2018]. Moreover, AI and natural language processing (NLP) tools have shown promise in simplifying complex medical information, tailoring radiology reports to different audiences, and improving patient comprehension [Doak et al., 1996]. For instance, AI-generated summaries have improved readability without compromising the accuracy of medical information [Wang et al., 2013].

In conclusion, this article emphasizes the need for ongoing efforts to enhance the readability of radiology reports and PEMs. Collaboration between radiologists, educators, and patient advocates, along with the integration of advanced technologies, will be crucial in ensuring that radiology documentation meets the diverse needs of patients, ultimately improving patient-centered care and outcomes[Gunning, 1952].

Keywords: readability, radiology documentation, patient education materials (PEMs), structured reporting, health literacy, plain language, visual aids, artificial intelligence (AI), natural language processing (NLP), patient-centered care.

I. Introduction

a) Importance of Readability in Radiology

Readability in radiology is a critical element that influences the clarity and effectiveness of communication between healthcare professionals and patients, thereby playing a crucial role in ensuring optimal patient care. Radiology reports are often filled with technical language and complex terminology, serving as the primary tool for radiologists to convey their findings to referring physicians and, increasingly, to patients themselves. However, when these reports are not written in a manner that is easily understood, it can lead to miscommunication, confusion, and potentially detrimental outcomes for patients. Readability directly impacts the ability of healthcare providers to make informed decisions and patients' ability to comprehend their medical conditions, which is essential for shared decision-making and patient-centered care (Friedman et al., 2006)).

Clear communication in radiology is particularly important because radiology serves as the diagnostic cornerstone for many medical conditions. The interpretation of radiology reports by other healthcare professionals, including surgeons, oncologists, and primary care physicians, guides treatment plans and interventions [Mamlouk et al., 2020]. When these reports are difficult to read or understand, there is a risk of misinterpretation, which can negatively affect patient outcomes [Ziemer et al., 2017]. Moreover, as healthcare becomes more patient-centered, the direct communication of radiology results to patients has become more common. Patients, who are often not medically trained, need accessible and understandable information to engage in their care. This need for readability is even more significant in radiology, where diagnostic language can be highly specialized and technical (Carmody JB et. al).

b) Historical Context

Concerns about readability in radiology have a long history, with early studies highlighting the difficulty many patients and even healthcare professionals experience in understanding radiology reports [Blease et al., 2020]. In the mid-20th century, readability formulas such as the Flesch-Kincaid Grade Level, originally developed for educational materials, began to be applied to medical documents, including radiology reports[Flesch, 1948]. These early assessments demonstrated that many medical texts were written at a level far too advanced for the general population,

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leading to concerns about the accessibility of medical information [McLaughlin, 1969].

Over time, the concept of structured reporting emerged as a means to standardize radiology documentation and improve its clarity. Structured reporting involves the use of templates and predefined formats to ensure that all relevant information is included consistently. This approach was designed to improve communication between radiologists and other healthcare providers by making reports more organized and easier to navigate[Johnson, 2014]. While structured reporting has undoubtedly enhanced the consistency of radiology documentation, it has not always addressed the broader issue of readability, particularly for non-specialists and patients[Knight et al., 2019]. The balance between technical accuracy and readability remains a challenge.

c) Current Challenges

Despite advancements in structured reporting and the growing awareness of the importance of readability, significant challenges persist in making radiology reports and patient education materials (PEMs) accessible to non-specialists. One of the major obstacles is the continued use of medical jargon and complex terminology, which can be difficult for patients and even some healthcare providers to understand [Szabó et al., 2021]. Medical language is often precise and necessary for clinical accuracy, but it can also obscure meaning when not clearly explained. This is particularly problematic in radiology, where reports are often written at a high reading level, far exceeding the average literacy level of many patients [Bange et al., 2019].

Moreover, patient education materials, which are designed to help patients understand their medical conditions and treatment options, often suffer from similar readability issues [Weiss, 2003]. Studies have shown that many PEMs are written at a level that is too advanced for the general population, making it difficult for patients to fully grasp the information being presented to them. This is especially concerning given the growing emphasis on patient autonomy and shared decision-making in healthcare. To address these challenges, healthcare organizations have increasingly turned to readability formulas as tools to assess and improve the accessibility of written materials[Ganeshan et al., 2019].

However, readability formulas are not without their limitations. While formulas such as the Flesch-Kincaid Grade Level, SMOG Index, and Gunning Fog Index can provide useful metrics for assessing the complexity of a text, they do not always account for the specific challenges of medical language, such as the prevalence of jargon and specialized terminology [McLaughlin, 1969]. Moreover, these formulas primarily focus on surface-level features such as sentence length and word complexity, without considering the broader context of the text or the reader's background knowledge. Therefore, while readability formulas can be valuable tools in the effort to make radiology reports and PEMs more accessible, they must be used in conjunction with other strategies, such as simplifying language and providing clear explanations of medical terms, to truly enhance communication in radiology [Doak et al., 1996].

II. Readability of Radiology Reports

The readability of radiology reports is a significant factor in the effective communication of diagnostic information to healthcare professionals and patients alike. As the demand for patient-centered care grows, the readability of medical documents has become a focal point of discussion in radiology. Radiology reports are complex documents that contain a wealth of technical information, often presented in specialized medical language. The challenge lies in balancing the need for clinical accuracy with the requirement for clear, accessible communication that non-specialist audiences can understand.

a) Complexity of Radiology Language

i. *Technical Jargon*

Radiology is a highly technical field, and the language used in radiology reports reflects this complexity. Radiologists must convey precise diagnostic information using specific terminology, which is often unfamiliar to non-specialists, including many referring physicians and patients. The technical jargon inherent in radiology serves an important purpose: it provides clarity and precision in describing medical findings. Terms like "hyperintense," "lytic lesion," or "effusion" are used to ensure that diagnoses are communicated accurately within the medical community. However, this level of specificity can present a barrier to readability, particularly for those without a background in medicine.

One of the central challenges in radiology is striking a balance between accuracy and clarity. While technical language is necessary for conveying specific information, overreliance on jargon can obscure meaning and reduce the readability of radiology reports. For healthcare providers who may not be familiar with radiology-specific terminology, this can lead to misinterpretations and delays in patient care. Moreover, as patients increasingly have access to their medical records, including radiology reports, there is a growing need to make these documents more understandable to laypersons. Studies have shown that the average reading level of the general population is around the 7th to 8th grade, while many radiology reports are written at a much higher reading level, often above the 12th grade. This disparity highlights the need for a greater focus on readability in radiology.

ii. *The Need for Accuracy vs. Clarity*

The tension between accuracy and clarity is an ongoing concern in medical communication. Radiologists are trained to use precise language to avoid ambiguity in their diagnoses. However, this technical language can hinder comprehension for those not familiar with the field. A study by Friedman et al. (2006) highlighted the importance of simplifying medical language without sacrificing accuracy. The challenge is to find ways to present complex information in a manner that is both clinically accurate and accessible to non-specialists. This is particularly important in the context of patient-centered care, where clear communication is essential for ensuring that patients understand their diagnoses and treatment options.

b) Structured Reporting

i. *Historical Shift*

The shift from narrative to structured reporting in radiology represents a significant evolution in how radiology reports are produced and communicated. Traditionally, radiology reports were written in a narrative format, where radiologists would describe their findings in free-text form. While this approach allowed for flexibility and detailed descriptions, it also introduced variability in report quality and structure, leading to inconsistencies that could impact the clarity and interpretability of the information conveyed (Johnson et al., 2009).

Structured reporting was introduced as a solution to these issues, aiming to standardize the content and format of radiology reports. By using predefined templates and checklists, structured reporting helps ensure that all relevant information is included in a consistent manner. This approach not only improves the clarity and completeness of reports but also enhances communication between radiologists and referring physicians. Structured reporting has been shown to reduce errors and improve the quality of radiology reports by providing a clear framework for documentation (Hani et al., 2018).

The transition to structured reporting was driven by the need for improved clarity and consistency in radiology documentation. By organizing reports into standardized sections—such as clinical history, findings, and conclusions—structured reporting makes it easier for healthcare providers to locate and interpret the information they need. This format is particularly beneficial in busy clinical environments, where time is of the essence, and quick access to critical information is paramount (Johnson et al., 2014).

ii. *Impact on Readability*

While structured reporting has improved the organization and consistency of radiology reports, its impact on readability is more nuanced. Studies have shown that structured reports are often more concise and focused, making them easier to navigate than narrative reports. However, the use of standardized templates can also lead to reports that are overly rigid or formulaic, potentially limiting the ability of radiologists to provide detailed explanations when needed (Hani et al., 2018).

Research comparing the readability of structured and narrative reports has produced mixed results. Some studies have found that structured reports are more readable for healthcare providers because they are easier to scan for key information. However, other studies have noted that structured reports can be less flexible and may not always capture the nuances of complex cases as effectively as narrative reports (Bosmans et al., 2011). For non-specialist audiences, including patients, structured reports may still present challenges in terms of readability, particularly if they contain technical jargon that is not clearly explained.

Bosmans et al. (2011) conducted a study comparing the readability and user satisfaction of structured versus narrative reporting in radiology. They found that while structured reporting improved the overall organization and ease of use, there were still significant readability challenges, particularly related to the technical language used in the reports. The study highlighted the need for ongoing efforts to simplify language and enhance the accessibility of radiology documentation.

c) AI-Large Language Models (AI-LLMs) in Radiology

i. *Butler et al. (2024) Study*

The introduction of artificial intelligence (AI) and large language models (LLMs) in radiology has opened new possibilities for enhancing the readability of radiology reports. A notable study by Butler et al. (2024) explored the use of AI to improve the readability of foot and ankle radiology reports. In this study, AI algorithms were applied to structured radiology reports to assess and enhance their readability for non-specialist audiences, including patients.

Butler et al. (2024) demonstrated that AI-LLMs could be used to automatically simplify complex medical language, reduce the use of jargon, and improve sentence structure without compromising the accuracy of the diagnostic information. The study involved a comparison between traditional structured reports and AI-enhanced reports, with participants—including healthcare providers and patients—evaluating the readability and clarity of each version. The AI-enhanced reports were consistently rated as more readable and easier to understand, particularly by patients who had no medical background.

One of the key findings of the Butler et al. (2024) study was the potential of AI to bridge the gap between clinical accuracy and readability. By using natural language processing (NLP) techniques, the AI was able to identify and rephrase complex sentences,

substitute medical jargon with more accessible language, and reorganize information to improve the overall flow of the report. This represents a significant advancement in the effort to make radiology reports more accessible to non-specialists, particularly in the context of patient-centered care.

ii. *Future Applications*

The success of AI in enhancing readability in foot and ankle radiology reports, as demonstrated by Butler et al. (2024), points to a broader potential for AI to improve readability across other areas of radiology. As AI-LLMs continue to evolve, their application in radiology reporting could expand to include a wide range of subspecialties, from oncology to neurology, where the complexity of medical language presents ongoing challenges to readability.

One potential future application of AI-LLMs in radiology is the development of personalized reporting. AI could be used to tailor radiology reports to the specific needs of different audiences, automatically adjusting the level of detail and complexity based on whether the report is intended for a specialist, a referring physician, or a patient. This could help ensure that all recipients of the report receive information that is both accurate and accessible to them, improving overall communication and patient outcomes.

Moreover, AI could be used to create real-time language assistance tools for radiologists as they dictate or type their reports. These tools could provide suggestions for simplifying language, flagging potential readability issues, and offering alternative phrasing that balances clinical accuracy with clarity. Such innovations could significantly enhance the readability of radiology reports, making them more user-friendly for both healthcare providers and patients.

In conclusion, the introduction of AI and large language models in radiology holds great promise for improving the readability of radiology reports. The study by Butler et al. (2024) provides a glimpse into the future of radiology reporting, where AI could play a central role in ensuring that diagnostic information is communicated clearly and effectively to all stakeholders, regardless of their level of medical expertise

III. Patient Education Materials in Radiology

Patient education materials (PEMs) in radiology are essential tools for helping patients understand their diagnostic imaging procedures, results, and associated risks. These materials, which include brochures, online resources, and written guides, aim to demystify complex radiology procedures and provide patients with the knowledge they need to make informed decisions about their healthcare. However, achieving this goal requires that PEMs are not only accurate but also accessible and easy to comprehend. The readability of these materials is a key factor in ensuring that they are effective in educating patients. Unfortunately, many PEMs in radiology are written at reading levels that exceed the average patient's comprehension ability, which can lead to confusion, anxiety, and a lack of informed consent.

a) Readability Challenges in PEMs

i. *Szabó et al. (2021)*

A study conducted by Szabó et al. (2021) focused on the readability challenges of radiology-specific patient education materials in Hungary. The study found that many of these PEMs were written at a level that was too complex for the average patient to understand. Specifically, the study revealed that most radiology PEMs were written at a Flesch-Kincaid grade level of 12, which is well above the recommended reading level of 6th to 8th grade for patient education materials (Szabó et al., 2021). This discrepancy between the reading level of the materials and the reading ability of the target audience presents a significant barrier to effective patient education.

The study by Szabó et al. (2021) highlighted several key challenges in the development of radiology PEMs. One of the primary issues identified was the use of technical language and medical jargon, which can be difficult for patients to understand. Additionally, the materials often included long, complex sentences that further hindered readability. These challenges are not unique to Hungary; similar issues have been identified in PEMs across different countries and healthcare systems.

The findings of Szabó et al. (2021) underscore the importance of simplifying language and reducing the complexity of sentences in PEMs to make them more accessible to patients. The study recommended that healthcare providers work with communication specialists and use readability assessment tools to ensure that PEMs are written at an appropriate reading level. By addressing these readability challenges, healthcare providers can improve patient comprehension, reduce anxiety, and promote better health outcomes.

ii. *Health Literacy Implications*

The challenges identified in the study by Szabó et al. (2021) have broader implications for health literacy, particularly for populations with lower educational levels. Health literacy, which refers to an individual's ability to obtain, process, and understand basic health information, is a critical determinant of health outcomes (Berkman et al., 2011). Patients with low health literacy are more likely to experience difficulties in understanding medical information, adhering to treatment plans, and navigating the healthcare system.

For populations with lower educational levels, the readability of PEMs is a significant barrier to accessing healthcare information. When PEMs are

written at a level that is too complex, patients with low health literacy may struggle to understand key concepts related to their health. This can lead to misunderstandings, poor health outcomes, and increased healthcare costs. Improving the readability of radiology PEMs is essential for addressing health disparities and ensuring that all patients, regardless of their educational background, have access to clear and comprehensible health information.

b) Radiation Safety Information

i. *Delaney et al. (2021)*

Radiation safety is a critical topic in radiology, and patients often have concerns about the potential risks associated with diagnostic imaging procedures that involve radiation exposure. Patient education materials on radiation safety are intended to inform patients about the benefits and risks of these procedures, helping them make informed decisions about their care. However, a study by Delaney et al. (2021) found that the readability of radiation safety guides is often too complex for patients to fully comprehend.

The study by Delaney et al. (2021) assessed the readability of radiation safety guides using the SMOG (Simple Measure of Gobbledygook) index, which is a commonly used readability formula for health materials. The study found that the average SMOG grade level of radiation safety guides was 14, which is equivalent to a reading level of a college sophomore (Delaney et al., 2021). This is significantly higher than the recommended reading level of 8th to 10th grade for radiation safety materials. The study also noted that the high complexity of the materials, particularly the use of technical language related to radiation exposure and risk, deterred patients from fully understanding the information.

The findings of Delaney et al. (2021) suggest that there is a need for significant improvements in the readability of radiation safety guides. Simplifying language, using visual aids, and providing clear explanations of technical terms are potential strategies for improving the accessibility of these materials. By making radiation safety information more understandable, healthcare providers can help alleviate patient concerns, promote informed decision-making, and enhance overall patient safety.

c) Online Patient Education

i. *Bange et al. (2019)*

The internet has become a primary source of health information for many patients, and online patient education materials play a crucial role in providing accessible and up-to-date information about radiology procedures and safety. RadiologyInfo.org, a popular online resource for radiology education, has made significant progress in improving the readability of its content. However, a study by Bange et al. (2019) found that there are still ongoing challenges in ensuring that online radiology PEMs are accessible to a wide audience.

The study by Bange et al. (2019) evaluated the readability of online radiology PEMs using the Gunning Fog Index, a readability formula that measures the complexity of text based on sentence length and the use of complex words. The study found that the average Gunning Fog Index for online radiology PEMs was 15, indicating that the materials were written at a reading level higher than that of the general population (Bange et al., 2019). Although improvements had been made in simplifying the language and structure of the materials, the study noted that challenges remained in making the content fully accessible to all patients.

One of the key findings of the study was the need for ongoing efforts to improve the readability of online radiology PEMs. The study recommended that content creators continue to use readability assessment tools and collaborate with health communication experts to ensure that the materials are written at an appropriate reading level. Additionally, the study emphasized the importance of testing the materials with target audiences to identify areas for further improvement.

ii. *Digital Health Literacy*

In the context of online radiology education materials, digital health literacy is an increasingly important consideration. Digital health literacy refers to the ability to seek, find, understand, and use health information from electronic sources (Norman & Skinner, 2006). As more patients turn to the internet for health information, it is essential that online PEMs are not only readable but also easy to navigate and understand in a digital format.

For patients with low digital health literacy, navigating online radiology education materials can be challenging. Issues such as poor website design, complex navigation, and a lack of clear instructions can hinder patients' ability to find and understand the information they need. To address these challenges, content creators must consider both the readability of the text and the usability of the digital platform. Providing clear navigation, using visual aids, and offering interactive features can help enhance the digital health literacy of patients and improve their overall experience with online radiology education materials.

IV. Radiology Reports and Patient Comprehension

The increasing availability of radiology reports to patients through online health portals has led to a shift in how patients engage with their medical information. Access to these reports offers transparency and empowers patients to take a more active role in their healthcare. However, this access also highlights a

significant challenge: many patients struggle to understand the technical language and complex structure of radiology reports. This section will explore the gap between patient expectations and reality, the impact of report readability on patient satisfaction, and the role of clinicians in bridging this gap.

a) Patient Expectations vs. Reality

i. *Patient Access to Reports*

The advent of patient portals has made it easier for patients to access their radiology reports directly, without waiting for a clinician to interpret them. While this increased access aligns with the broader goals of patient empowerment and shared decision-making, it also presents new challenges. Many patients expect that accessing their radiology reports will provide them with clear, actionable information about their health. However, the reality is often far more complex. Radiology reports are typically written in highly technical language, intended for interpretation by clinicians rather than patients.

A study by Mervak et al. (2021) found that although 80% of patients appreciated having direct access to their radiology reports, a significant portion of them reported difficulty understanding the content. This gap between expectations and reality can lead to confusion and anxiety for patients. They may misinterpret the findings, potentially assuming the worst if they cannot fully grasp the report's meaning. The study suggested that while access to reports is a step forward, the readability and accessibility of these reports need to be addressed to truly benefit patients.

ii. *Study Comparisons*

Several studies have compared how patients interpret radiology reports. Mervak et al. (2021) highlighted that a majority of patients experienced difficulties with medical jargon and the complex structure of the reports. In another study, Blease et al. (2020) examined the impact of direct access to radiology reports on patient comprehension. They found that while some patients valued the ability to read their reports, many struggled to extract meaningful information from them. The study emphasized that patients often misunderstood key terms or misinterpreted the severity of findings due to the technical nature of the language used.

Comparatively, studies like those by Mamlouk et al. (2020) have shown that patients who receive simplified reports or additional explanatory materials alongside their radiology results tend to have a better understanding and feel more reassured about their health. This suggests that the inclusion of patient-friendly summaries or annotations in radiology reports could bridge the gap between patient expectations and reality.

b) Impact on Patient Satisfaction

i. *Understanding and Satisfaction*

There is a clear link between a patient's ability to understand their radiology reports and their overall satisfaction with their care. Patients who are able to comprehend their reports are more likely to feel involved in their healthcare decisions, which enhances their sense of autonomy and satisfaction. Conversely, when patients struggle to understand their reports, it can lead to frustration, dissatisfaction, and even mistrust of the healthcare system.

A study by Ziemer et al. (2017) examined the relationship between report readability and patient satisfaction. The study found that patients who reported a better understanding of their radiology reports were significantly more satisfied with their care. Conversely, patients who had difficulty interpreting their reports were more likely to express dissatisfaction. The study concluded that improving the readability of radiology reports could have a direct impact on patient satisfaction, particularly in the context of direct patient access.

Another study by Knight et al. (2019) explored the impact of providing patient-friendly summaries along with traditional radiology reports. They found that patients who received these summaries reported higher levels of satisfaction and a greater sense of involvement in their care. The study suggested that including a brief, layperson-friendly summary of the key findings in radiology reports could be a simple yet effective way to improve patient satisfaction.

c) Role of Clinicians

i. *Clinician-Patient Communication*

Despite the increasing availability of radiology reports to patients, clinicians still play a crucial role in helping patients understand their medical information. The complexity of radiology reports means that many patients will still need guidance from their healthcare providers to interpret the findings accurately. Effective clinician-patient communication is therefore essential in ensuring that patients fully understand their radiology reports and can make informed decisions about their health.

Several strategies have been proposed to improve communication between clinicians and patients regarding radiology reports. One approach is for clinicians to take a more active role in reviewing the reports with patients, either during in-person consultations or through follow-up calls. This provides an opportunity for clinicians to explain the findings in simpler terms and address any concerns or questions the patient may have. Another strategy is the use of visual aids or annotated images to help patients better understand their diagnosis.

A study by Brook et al. (2018) highlighted the importance of personalized explanations. Patients who received a detailed verbal explanation of their radiology report from their clinician reported higher levels of understanding and satisfaction. The study emphasized that while patient access to reports is important, the clinician's role in contextualizing and clarifying the findings remains critical.

The role of clinicians in educating patients about their radiology reports is also supported by the work of Ganeshan et al. (2019), who argued that structured communication training for radiologists could enhance their ability to explain complex findings to patients. The study advocated for a collaborative approach, where radiologists work alongside referring physicians to ensure that patients receive clear, consistent information about their radiology results.

V. Strategies for Improvement and Future Directions

The field of radiology is crucial for patient care, yet its documentation is often perceived as complex and difficult for patients to understand. Simplifying these documents can significantly improve patient outcomes by enhancing understanding and compliance. This section explores various strategies for improvement, focusing on simplification techniques, education and training, and the role of technology.

a) Simplification Techniques

Plain Language and Visual Aids: One of the most effective strategies for enhancing the readability of radiology documentation is the use of plain language. Plain language involves writing in a straightforward and clear manner, avoiding medical jargon, and using terms that are easy for patients to understand. This approach not only makes the information accessible but also reduces anxiety and confusion, allowing patients to make informed decisions about their health.

In addition to plain language, the incorporation of visual aids can further simplify complex medical information. Visual summaries, such as diagrams, charts, and images, can help convey intricate data in a more digestible format. For instance, a visual representation of a radiological finding, like a tumor or fracture, can be easier for a patient to comprehend than a textual description alone. These visuals can illustrate the location, size, and nature of the finding, providing patients with a clearer understanding of their condition.

Interactive content, such as videos or interactive online tools, also holds promise for simplifying radiology reports. By engaging patients through interactive platforms, they can explore their radiological findings at their own pace, with options to click on specific terms for definitions or view animations that explain procedures or conditions. Such interactivity caters to various learning styles and can significantly enhance patient comprehension.

b) Education and Training

Radiologist Training: To create patient-centered radiology documents, specialized training for radiologists is essential. Traditionally, radiologists have been trained primarily to communicate with other healthcare professionals, often using technical language and complex terminology. However, to improve patient understanding, radiologists need training that emphasizes the principles of plain language and patient-centered communication. This training can be incorporated into radiology education programs, with modules focused on effective communication strategies, empathy, and cultural competence. By equipping radiologists with these skills, the quality of radiology reports can be significantly improved, making them more accessible and understandable to patients.

Interdisciplinary Collaboration: Improving the readability of radiology documentation requires a collaborative effort involving radiologists, educators, and patient advocates. Collaboration between these stakeholders can lead to the development of standardized guidelines for creating patient-friendly reports. Educators can provide insights into effective teaching methods and communication strategies, while patient advocates can offer perspectives on what patients need and expect from radiology reports. By working together, these professionals can create documents that are not only informative but also empathetic and tailored to patient needs. This interdisciplinary approach ensures that the information conveyed is accurate, understandable, and meaningful, ultimately leading to better patient engagement and health outcomes.

c) The Role of Technology

AI and NLP Tools: The advancement of technology, particularly in artificial intelligence (AI) and natural language processing (NLP), presents new opportunities for tailoring radiology reports to different audiences. AI-powered tools can analyze radiology reports and automatically simplify complex terms, generate plain-language summaries, and highlight key information relevant to patients. NLP algorithms can be designed to identify medical jargon and replace it with simpler terms or provide definitions and explanations within the text. This automated simplification process can make radiology reports more patient-friendly without compromising the accuracy or completeness of the information.

Moreover, AI and NLP tools can be customized to cater to different audiences, including both patients and healthcare providers. For instance, while patients may need simplified explanations, healthcare providers may require detailed technical information. AI can

dynamically generate different versions of the same report, tailored to the needs of each audience. This customization ensures that all stakeholders receive the appropriate level of detail, improving communication and understanding across the board.

In the future, AI-driven platforms could offer real-time assistance to radiologists as they prepare reports, suggesting simplifications and enhancements based on best practices and patient feedback. Such tools could also track patient understanding and outcomes, providing valuable data to further refine and optimize the readability of radiology documentation.

VI. Discussion

Improving the readability of radiology reports is critical for patient understanding and effective healthcare delivery. This discussion provides a summary of the major findings from the review, explores the broader implications for radiology practice, and suggests future research directions to further enhance the field.

a) Summary of Findings

The review highlights several persistent challenges in making radiology reports more readable, even as technological advancements continue to evolve. Despite the increasing availability of digital tools and resources, many radiology reports remain difficult for patients to understand due to the use of complex medical jargon, technical language, and dense formatting. Patients often struggle to grasp the meaning of their diagnoses, prognoses, and treatment options, which can lead to confusion, anxiety, and non-compliance with recommended care.

Several key findings emerged from the review:

1. *Persistent use of Complex Language:* Radiology reports frequently use specialized medical terminology that is not easily understood by the general public. This complexity hinders patient comprehension and can create barriers to effective communication between patients and healthcare providers.
2. *Limited use of Plain Language and Visual Aids:* While there is growing recognition of the importance of plain language and visual aids, their use in radiology reports is still limited. Many reports fail to incorporate these simplification techniques, which could help patients better understand their health information.
3. *Challenges in Adapting to Patient-Centered Communication:* Radiologists have traditionally been trained to communicate with other healthcare professionals rather than with patients. This focus on professional communication has led to reports that prioritize clinical precision over patient accessibility, making it challenging for patients to fully engage with their health information.
4. *Emerging Role of Technology:* Although AI and NLP tools offer significant potential for improving the readability of radiology reports, their application is still in the early stages. The review found that these technologies have not yet been widely adopted in clinical practice, and there is a need for further development and integration to maximize their benefits.

b) Implications for Radiology Practice

Improving the readability of radiology reports has far-reaching implications for radiology practice, patient care, ethical considerations, and the role of technology.

1. *Enhancing Patient Care:* Readable radiology reports can improve patient outcomes by fostering better understanding and communication. When patients can easily comprehend their health information, they are more likely to engage in shared decision-making, adhere to treatment plans, and take proactive steps in managing their health. This engagement can lead to improved health outcomes and a higher quality of care.
2. *Ethical Considerations:* The ethical imperative to provide patients with understandable health information is gaining recognition in the medical community. Clear and transparent communication is essential for informed consent, which is a fundamental ethical principle in healthcare. Radiologists have a responsibility to ensure that their reports are not only accurate but also comprehensible, allowing patients to make informed decisions about their care.
3. *Role of Technology:* Technology has the potential to transform the way radiology reports are created and communicated. AI and NLP tools can automate the process of simplifying complex language, generating plain-language summaries, and customizing reports for different audiences. By leveraging these technologies, radiologists can produce reports that are tailored to the needs of both patients and healthcare providers, improving the overall effectiveness of communication.
4. *Interdisciplinary Collaboration:* To achieve meaningful improvements in report readability, collaboration between radiologists, educators, patient advocates, and technology developers is essential. By working together, these stakeholders can develop standardized guidelines and best practices for creating patient-centered radiology reports. This collaborative approach ensures that the information conveyed is not only accurate and precise but also accessible and meaningful to patients.

c) *Future Research Directions*

While the review provides valuable insights into the current state of radiology report readability, several areas warrant further research to continue advancing the field:

1. *Long-Term Impact of Readability Improvements on Patient Outcomes:* Future research should investigate the long-term effects of improving radiology report readability on patient outcomes. Studies could explore how readable reports influence patient understanding, compliance with treatment plans, health behaviours, and overall health outcomes. This research would provide evidence of the benefits of readable reports and reinforce the importance of patient-centered communication.
2. *Development of More Effective AI Tools:* As AI and NLP technologies continue to evolve, there is a need for research focused on developing more sophisticated and effective tools for enhancing radiology report readability. Future studies could explore how AI can be used to automatically generate multiple versions of reports tailored to different audiences, detect and replace complex medical jargon, and provide real-time feedback to radiologists during the report-writing process.
3. *Integration of Visual Aids and Interactive Content:* Further research is needed to assess the impact of visual aids and interactive content on patient comprehension and engagement. Studies could examine how different types of visuals, such as diagrams, images, and animations, affect patient understanding of radiological findings. Additionally, research could explore the potential of interactive tools that allow patients to engage with their reports, access additional information, and seek clarification on specific terms or concepts.
4. *Training and Education for Radiologists:* Investigating the effectiveness of training programs that teach radiologists how to create patient-centered reports is another important area of research. Future studies could evaluate the impact of such training on the quality of radiology reports, patient satisfaction, and communication between radiologists and patients. Research could also explore how training can be integrated into radiology education and continuing professional development programs.

VII. Conclusion

Improving the readability of radiology documentation is crucial for enhancing patient understanding, satisfaction, and overall healthcare outcomes. Clear, accessible radiology reports and Patient Education Materials (PEMs) play a vital role in fostering better communication between healthcare providers and patients. By simplifying medical language, incorporating visual aids, and utilizing emerging technologies such as AI and natural language processing, we can make radiology information more comprehensible to non-specialist audiences.

Ongoing research and interdisciplinary collaboration are essential to refining these strategies and ensuring that radiology documentation meets the needs of all patients, regardless of their health literacy levels. Radiologists, educators, and patient advocates must work together to develop standardized approaches that balance medical accuracy with readability. As efforts continue in this direction, the future of radiology documentation looks promising, with the potential to significantly improve patient-centered care and healthcare outcomes across the board.

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Table 1: Readability Formulas Commonly Used in Radiology Documentation

Formula	Description	Strengths	Limitations	References
Flesch-Kincaid Grade Level	Measures readability based on sentence length and syllable count. Originally developed for educational texts.	Widely used, simple to calculate, provides a readability grade level.	Does not consider medical jargon, context, or sentence complexity.	Flesch R. A new readability yardstick. *J Appl Psychol*. 1948;32(3):221-233. doi:10.1037/h0057532. Friedman DB, Hoffman-Goetz L. *J Cancer Educ*. 2006;21(1):2-3. doi:10.1207/s15430154jce2101_1.
SMOG Index	Focuses on the number of polysyllabic words (three or more syllables) in a text. Accurate for health materials.	Effective for health-related documents, good predictor of reading difficulty.	Complex to calculate manually, can overestimate difficulty in shorter texts.	McLaughlin GH. SMOG grading: a new readability formula. *J Read*. 1969;12(8):639-646. Doak LG, Doak CC, Meade CD. *Patient Educ Couns*. 1996;27(2):140-146. doi:10.1016/07 38-3991(95)00713-3.
Gunning Fog Index	Considers both word complexity (based on the number of complex words) and sentence length.	Useful for general readability assessment, simple calculation.	Less effective for technical and specialized texts like radiology reports.	Gunning R. *The Technique of Clear Writing*. New York: McGraw-Hill; 1952. Wang LW, Miller MJ, Schmitt MR, Wen FK. *Patient Educ Couns*. 2013;90(2):225-230. doi:10.1016/j.pec.2012.10.019.
Fry Readability Formula	Based on sentence length and the number of syllables per 100 words. Used for health literacy materials.	Simple to use, effective for shorter texts, visually represented in graphs.	Less accurate for longer, more complex documents like radiology reports.	Fry E. *J Reading*. 1977;21(3):242-252. Wang LW, Miller MJ, Schmitt MR, Wen FK. *Patient Educ Couns*. 2013;90(2):225-230. doi:10.1016/j.pec.2012.10.019.
Automated Readability Index (ARI)	Uses characters per word and words per sentence to determine readability, typically used for technical documents.	Quick to calculate, works well for technical materials.	May not accurately assess readability for all age groups, limited in health contexts.	Senter RJ, Smith EA. Automated Readability Index. Cincinnati, OH: U.S. Air Force, 1967. Kim H, Mazor KM. *J Health Commun*. 2016;21(Suppl):2-9. doi:10.1080/10810730.2016.1193910.

Coleman-Liau Index	Evaluates readability using characters per word and sentence length, emphasizing the importance of word length.	Easy to automate, effective for digital documents.	Does not consider syllable count, can misjudge medical texts.	Coleman M, Liau TL. *J Appl Psychol*. 1975;60(2):283-284. doi:10.1037/h0076540. Berland GK, Elliott MN, Morales LS, et al. *JAMA*. 2001;285(20):2612-2621. doi:10.10 01/jama.285.20.2612.

Table 2: Common Readability Scores for Radiology PEMs

Study	Type of PEM	Readability Score	Recommended Reading Level	Key Findings
Szabó et al. (2021)	General Radiology PEMs	Flesch-Kincaid Grade 12	Grade 6-8	Szabó et al. found that most radiology PEMs in Hungary are written at a high reading level, making them difficult for the average patient to comprehend. The study emphasized the need for simplified language and shorter sentences to make materials more accessible to patients with varying literacy levels.
Delaney et al. (2021)	Radiation Safety Guides	SMOG Grade 14	Grade 8-10	Delaney et al. highlighted that radiation safety materials often contain complex terminology and polysyllabic words, which significantly reduce readability. The study recommended revising these guides to include clearer language and visual aids to improve patient understanding of radiation risks.
Bange et al. (2019)	Online Radiology PEMs	Gunning Fog Index 15	Grade 6-8	Bange et al. examined online radiology PEMs and found improvements in readability over time, but challenges persist. Despite efforts to simplify content, many PEMs are still written at a high level, which limits their effectiveness for patients with lower health literacy. The study recommended ongoing revisions to online content to align with best practices for readability.
Friedman et al. (2006)	Cancer Information Materials	Flesch Reading Ease 40	Grade 6-8	Friedman et al. conducted a systematic review of cancer-related PEMs and found that many were written at a reading level too high for the average patient. The study suggested that PEMs should be routinely evaluated using readability formulas and revised to ensure they are accessible to all patients, regardless of their literacy level.
Weiss et al. (2003)	General Health Literacy Materials	Flesch-Kincaid Grade 11	Grade 6-8	Weiss et al. focused on the broader context of health literacy and patient safety, noting that many PEMs do not meet recommended reading levels. The study emphasized that improving readability is crucial for ensuring that patients understand medical information, which in turn enhances safety and health outcomes.

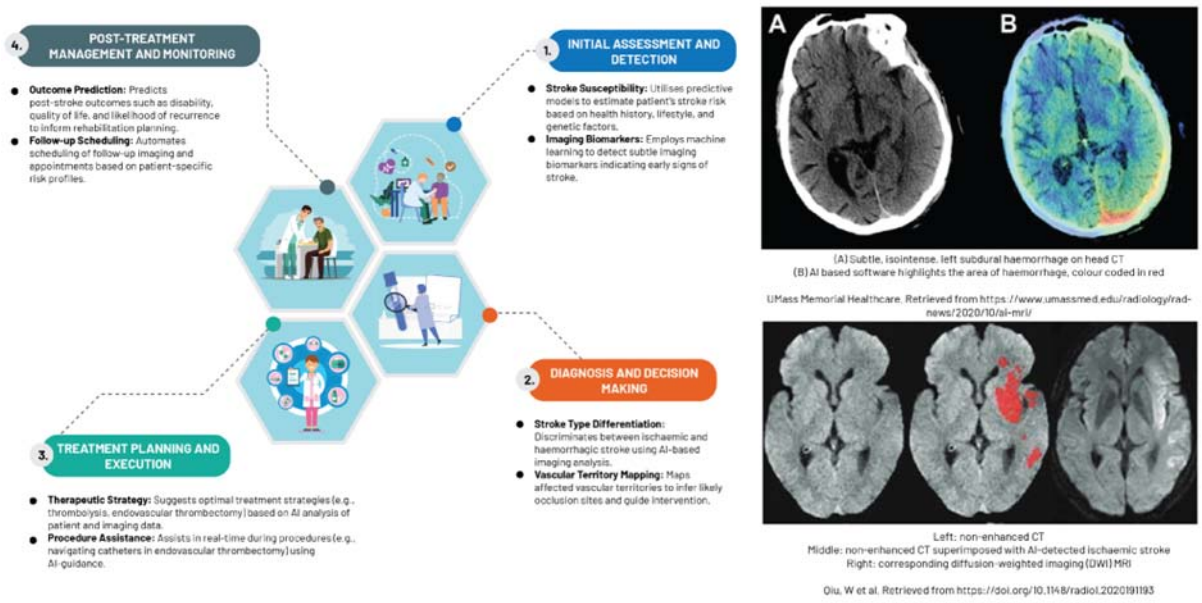

Image 1: Example of a Structured Radiology Report Before and After AI Enhancement

Caption: "Comparison of a traditional structured radiology report with an AI-enhanced version, showing improved readability for non-specialist audiences."