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Designing a Health Consumer-Friendly Radiology Report Using a Patient-Centered Approach

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DESIGNING A HEALTH CONSUMER-FRIENDLY RADIOLOGY REPORT USING A
PATIENT-CENTERED APPROACH

by

Mohammad Abdullah Alarifi

A Dissertation Submitted in
Partial Fulfillment of the
Requirements for the Degree of
Doctor of Philosophy
in Health Sciences

at

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December 2020

ABSTRACT

DESIGNING A HEALTH CONSUMER-FRIENDLY RADIOLOGY REPORT USING A PATIENT-CENTERED APPROACH

by

Mohammad Abdullah Alarifi

The University of Wisconsin-Milwaukee
Under the Supervision of Dr. Jake Luo

In this dissertation, we needed to do four studies to reach the main objective of this dissertation. The fifth goal, which is the main one, is to reach a patient-friendly radiology report that can be easily understood.

Study one: *Full Radiology Report through Patient Web Portal: A Literature Review*
Alarifi, M., Patrick, T., Jabour, A., Wu, M., & Luo, J. (2020). *Full Radiology Report through Patient Web Portal: A Literature Review. International Journal of Environmental Research and Public Health*, 17(10), 3673.

The aim of this study discusses the gap between the patient web portal and providing a full radiology report. A literature review was conducted to examine radiologists, physicians, and patients' opinions and preferences of providing patients with online access radiology reports. The databases searched were Pubmed and Google Scholar and the initial search included 927 studies. After review, 47 studies were included in the study. We identified several themes, including patients' understanding of radiology reports and radiological images, as well as the need for decreasing the turnaround time for reports availability. The existing radiology reports written for physicians are not suited for patients. Further studies are needed to guide and inform the design of patient friendly radiology reports. One of the ways that can be used to fill the gap between patients and radiology reports is using social media sites.

Study two: *Understanding patient needs and gaps in radiology reports through online discussion forum analysis*
Alarifi, M., Patrick, T., Jabour, A., Wu, M., & Luo, J. (2020). *Understanding patient needs and gaps in radiology reports through online discussion forum analysis. Insights into imaging*.

Our objective is to investigate patient needs and understand information gaps in radiology reports using patient questions that were posted on online discussion forums. We leveraged online question and answer platforms to collect questions posted by patients to understand current gaps and patient needs. We retrieved six hundred fifty-nine (659) questions using the following sites: Yahoo Answers, Reddit.com, Quora, and Wiki Answers. The questions retrieved were analyzed and the major themes and topics were identified. The questions retrieved were classified into eight major themes. The themes were related to the following topics: radiology report, safety, price, preparation, procedure, meaning, medical staff, and patient portal. Among the 659 questions, 35.50% were concerned with the radiology

report. The most common question topics in the radiology report focused on patient understanding of the radiology report (62 of 234 [26.49%]), image visualization (53 of 234 [22.64%]), and report representation (46 of 234 [19.65%]). We also found that most patients were concerned about understanding the MRI report (32%; n=143) compared with the other imaging modalities (n=434). Using online discussion forums, we discussed major unmet patient needs and information gaps in radiology reports. These issues could be improved to enhance radiology design in the future.

Study three: *The Development of Radiology Report Literacy Assessment Tool*

Diagnostic imaging and radiotherapy have become an important part of medical care. Patient understanding of radiology reports can improve their level of engagement and communication. There is little known about measuring a patient's literacy level of a radiology report. The aim of this study is to design a tool to measure the radiology literacy of patients. We have designed and tested a radiology literacy tool. Participants were split into two groups and each group was given a radiology report sample to assess their understanding of the report. Participants also answered the radiology report literacy questions and the correlation between the understanding of the radiology report and radiology report literacy questions was calculated. The correlation between the report understanding and the radiology report literacy questions for the intervention and control groups was 0.537, $P = .00$, and 0.517, $P = .00$, respectively. Our radiology literacy tool had a good ability to measure the awareness of radiology (area under the receiver operator curve (95% CI: 0.72 (0.62-0.82)). We successfully designed a tool that can measure the radiology literacy of patients. This tool is considered one of the first tools that measures the level of patient knowledge in the radiology field.

Study four: *Health consumer social economic factors and health conditions as predictor for health literacy in radiology domain*

Patient literacy of radiology is imperative for patient engagement in care and management of their own health. Little is known about the factors that could predict patient literacy of radiology reports, testing, or treatment. This study aims to identify the most important factors of health consumer social economic and health conditions as a predictor of health literacy in the radiology domain. The study recruited 616 participants using Amazon.com's Mechanical Turk (MTURK) and presented these participants with our questionnaire. We measured the level of participants' radiology awareness, social factors, and health status. Descriptive statistics including Chi-Square and multiple linear regression models were used to test if the factors could predict radiology literacy. The area under the receiver-operator curve was calculated to determine the prediction accuracy of the regression models. Multiple linear regression indicated that 15 of the 19 social-economic factors and health conditions were significantly associated with radiology literacy ($P < .05$). On the other hand, only 12 of the 19 factors were significant by using Pearson Chi-Square ($P < .05$). Stepwise linear regression analysis demonstrated the r^2 linear of 9 out of 12 common factors. These factors are the level of education, smoking, radiology experience, insurance status, white race, employment status, disability status, gender, and income at 0.201. These nine factors had a good ability to predict radiology literacy (area under the receiver operator curve of 0.677 [95%CI 0.549; 0.804, $P = 0.013$]). Social economic factors and health conditions can be used to successfully predict radiology literacy. We were able to successfully identify the predictive factors that have a high association with the radiology literacy tool by comparing social factors and health status versus radiology awareness.

Study five: *Designing a consumer-friendly radiology report using a patient-centered approach*

Patient portals have helped accelerate patient engagement in treatment. Patient understanding of radiology reports has become a necessity and we are working to design a patient-friendly radiology report that can be easily understood. We have based the design of this new radiology report on the results of a previous study that examined patient desires and needs by exploring their questions posted on online discussion forums. The current design was tested by presenting it in two groups, a control group, and an intervention group. In our evaluation, we relied on the following five concepts: understanding (quiz), cosmetics appearance, perceived ease of use, acceptance, and preference. The results showed that the new design outperformed the current design in all five concepts with an overall of ($P < .00$). Based on these results, we have determined that the radiology report should include both an image and notes section and the design can be applied to all types of radiological examinations using various imaging devices. We believe this design will be an important building block in facilitating patient understanding of radiology reports.

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I. INTRODUCTION

Published research shows an interest in the field of radiology. Some of the research has focused on the development of new or improved radiographic imaging devices while other studies have worked to develop the output of radiology modalities including reports and images. The importance of this type of imaging involves the diagnosis of many diseases and conditions including tumors and bone fractures. Surgeries often require radiology machines in the operating room and radiology reports help patients understand their health. The current radiology reports discussed in Chapter 2 showed that patients are not satisfied with the current radiology report structure. The reports face many challenges including the fact that the reports are intended for use by doctors, not patients. This dissertation aims to develop a radiology report that is easy for patients to understand.

We believe that this dissertation is unique for the following reasons:

1. Our new design for the radiology report is more understandable to patients than the current design
2. We used patient understanding of radiology as the main pillar in designing the new radiology report
3. We designed the new report based on an analysis of questions asked on social media to discover major unmet patient needs and information gaps
4. The report design is applicable to all radiology modalities
5. This is the first radiology report design that incorporates Atlas images into the report to facilitate patient understanding
6. We created the first tool to measure the radiology literacy level of patients

Prior to starting, we conducted a literature review to determine the extent to which patients' electronic portals provide radiology reports. In the literature review, we tried to determine the obstacles in the submission of a full radiology report, including images and notes. Healthcare providers were concerned that giving patients full access to the report could have a negative impact. In our initial study, we determined that there was dissatisfaction with the current design of radiology reports. This finding prompted us to conduct another study to identify patient needs and concerns and address these items in the current design. We collected patients' questions and inquiries posted on social media. The results of the social media study helped us to design a radiology report that better met patient needs. To test the new design, we conducted an interventional study on two groups, the control and intervention groups (Figure VI. 3, 4, 5). We also ensured that the questionnaire could be used to test the radiology awareness tool we designed (Appendix A). We worked to identify the predictive factors that have a high association with the radiology literacy tool by comparing social factors and health conditions with radiology literacy levels. Our goals are shown in the following list:

1. To discover and discuss the gap between the patient web portal and providing a full radiology report.
2. To investigate patient needs and understand information gaps in radiology reports using patient questions that were posted on online discussion forums.
3. To design a tool to measure the radiology literacy of patients.
4. To identify the most important factors of health consumers' social, economic, and health conditions to determine if these factors are a predictor of radiology literacy.
5. To design a patient-friendly radiology report that can be easily understood.

II. FULL RADIOLOGY REPORT THROUGH PATIENT WEB PORTAL: A LITERATURE REVIEW

This is a pre-copyedited, author-produced version of an article accepted for publication in the International Journal of Environmental Research and Public Health following peer review. The version of record [Alarifi, M., Patrick, T., Jabour, A., Wu, M., & Luo, J. (2020). Full Radiology Report through Patient Web Portal: A Literature Review. International Journal of Environmental Research and Public Health, 17(10), 3673.]

1. Introduction

The patient portal is an online instrument that provides patients with secure and direct access to their medical records [1, 2]. There is a need to improve communication between patients and their doctors [3]. A better communication tool is also needed to help patients understand their treatment procedures that could lead to better outcomes. In addition, improved communication not only can help patients better understand treatment procedures and result in more favorable outcomes, but also can reduce potential medical errors. There are many ways for patients to communicate with doctors that may or may not be time-consuming or costly. One of these methods involves scheduling face-to-face appointments with physicians to discuss issues and receive advice. A patient could also call the clinic or hospital and ask to speak directly to a physician or nurse to have questions answered. These methods can be time-consuming and could impact the quality of treatment. Therefore, new technologies are developed to improve the health care communication and information delivery, such as electronic health records (EHRs), personal health records (PHRs), and health information exchanges (HIE). These systems provide information and mechanisms to facilitate patients to understand their health conditions. The systems also improve communication between the patient and their medical provider(s). Patient portals offer a convenient way for patients to

access their PHR online. Some patient portals also provide a rich amount of information imported from medical records, such as clinical notes, laboratory results, radiology images, scheduled appointments, and medical bills [4-7]. A study of 129,419 patients who had access to a patient portal found that patients were more likely to view their laboratory results (59.8%) than clinical notes (34.4%) and radiology results (51.2%) [2]. A previous study on this topic found that patients prefer to view their medical information using patient portals and that there was a strong need to improve the current portal system [2]. This project focuses on full radiology reports in the patient web portal. The goal of the paper is to identify why information about radiology is limited in the online portal. The paper also provides suggestions to address this issue [2]. By evaluating the gap between patient preferences and current access to full radiology reports, researchers and developers can design and create a better solution to improve the communication of radiology reports to patients. Over the years, medical centers have always struggled to improve quality and operational efficiency and cut down costs. Despite efforts and using a variety of strategies, many problems arise while delivering quality health care.

2. Materials and Methods

The goal of this study was to understand patients' needs and preferences related to access to their radiology images and reports. Prior to the literature review, we also called 110 hospitals to inquire about existing practice when it comes to providing patients with radiology images and reports. Later, a literature review was conducted to examine patients' preferences and needs related to radiology reports.

2.1. Context and Existing Status

To enhance our understanding of existing practice prior to the literature review, we contacted 110 US hospitals over the phone to inquire if they provide patients with radiology reports, radiological images, or both. Of the hospitals surveyed, 98 responded that they only

provided patients with access to the reports, but not the images themselves. Twelve hospitals stated that the information made available to patients depended on the case. For example, in cases involving breast cancer, brain cancer, or renal cell carcinoma (RCC), a hospital could offer all available information to the patient. Some health care providers, such as Mayo Clinical Health, require patients to receive doctor permission before obtaining access to certain medical images, such as an electrocardiogram (ECG). This health care system generally offers full radiology reports.

2.2. Search Strategy and Criteria

Google Scholar and PubMed were used to find studies that discuss the gap between the patient web portal and the full radiology report. The keywords used were patient portal OR patient web portal AND radiology report. We searched for journal articles published within the last five years (after 2015). In addition, the reference lists of the relevant results were also checked.

The initial search resulted in 927 articles that were screened by reviewing the title for its relevance to the topic. After title screening, 618 articles were removed and 307 remained. We reviewed the abstracts of the 309 abstracts and removed 123 for not being relevant to the topic. The full texts of the remaining 184 articles were retrieved for further screening. Of these 184 articles, 47 met our criteria for being relevant to the topic and were further reviewed in detail (Table II. 1). Our inclusion criteria were: it should be an original study, published within the last five years, relevant to the topic, discuss patients' needs and preferences of radiology reports, and published in English (Figure II. 1).

Citation	Goal / Purpose	Based on Specific Patient Portal y/n	Study Design	Number of Participants	Types of Participants (Patients / Doctors/ Others)	Finding
Cook TS, et al. 2017 [8]	Impacts the annotations in the radiology reports that included patient-oriented definitions,	No	Survey	185	Patients	Increased the understanding.

	anatomic illustrations, and hyperlinks to improve patient understanding.					
Miles RC, et al. 2016 [2]	To evaluate the frequency with which patients viewed their online radiology reports in relation to in a clinic or laboratory.	Yes	Survey	129,419	Patients	More than half of patients with access to online radiology reports viewed them, with higher viewing rates associated with viewing other types of reports.
Garry K, et al. 2020 [9]	Comparative study of patient satisfaction and understanding of radiology results when received through an electronic patient portal versus direct communication from providers.	No	Survey	1005	Patients	Patients' understanding of their radiology reports were more through direct provider communication than those who first received their results through the patient portal (26.7% versus 47.8%; $P < .001$).
Cho JK, et al. 2020 [10]	To explore patient understanding of the radiology report by using five radiology reporting templates and radiology colloquialisms.	No	Survey	1369	Patients	Adding patient summaries in the report can help increase their comprehension of radiology reports.
Mervak BM, et al. 2016 [11]	To understand patient preferences in the radiology reports by analysis of patient-initiated messages submitted through a web-based electronic patient portal.	Yes	Survey	1489	Patients	Analysis of patient-initiated messages submitted through a patient portal helped to understand the patients' concerns.
Broman KK, et al. 2015 [12]	To evaluate surgeon and patient acceptance of online postoperative care after general surgical operations.	yes	Survey	50	Patients, Doctors	In general, online postoperative visits were accepted by surgeons and patients.
Rosenkrantz AB, et al. 2017 [13]	Comparing the radiologists, referring physician, and patient interpretations of radiology reports to describe findings of likely low clinical significance.	Yes	Survey	123	Patients, Doctors	Ambiguity in radiologists' language for incidental low-risk findings may contribute to increased patient anxiety and follow-up testing, warranting greater radiologist attention, and potentially new practice or reporting strategies.
Gunn AJ, et al. 2017 [14]	Providing actual radiology reports to the patients to evaluate their understanding	Yes	Survey	104	Patients	Medical terminologies and longer reports tend to be less well understood.
Martin-Carreras T, et al. 2019 [15]	This study looks to assess the readability of radiology reports.	Yes	Data analysis	108,228	Reports	Only 4% of all reports were readable at the 8th-grade level, which is the reading level of the average US adult.
Vitzthum von Eckstaedt, et al. 2020 [16]	Using the feedback of the patient advisory groups to design a new radiology report for lung cancer.	No	Survey	n/a	Patients	The new report has the potential to serve as a bridge between radiologists and patients, allowing for better patient understanding.
Henshaw D, et al. 2015 [1]	The feasibility of releasing reports to patients before the doctor's appointment.	No	Survey	508	Patients	Releasing reports to patients was useful before the doctor's appointment.
Oh SC, et al. 2016 [17]	Will the Prototype System for Patient-Oriented Radiology	No	Survey	300	Reports	PORTER improves patients' understanding

	Reporting (PORTER) improve patients' understanding of and satisfaction with radiology reports?						of and satisfaction with radiology reports.
Reicher JJ, et al. 2016 [18]	The impact of the usage of Meaningful Use-compliant electronic health record (EHR) technology and direct messaging in radiology practice.	Yes	Data analysis	752,496	Messages		It improved radiologist-patient communication.
Short RG, et al. 2017 [19]	Comparing the results of using online crowdsourcing to assess the effectiveness of a Web-Based Interactive radiology report.	No	Survey	193	Patients		Report understanding scores were significantly higher for the interactive web-based than the standard report group ($P < .05$)
Martin-Carreras T, et al. 2018 [20]	Comparing MedlinePlus, RadLex, and the PORTER (Patient-Oriented Radiology Reporter) lay-language radiology glossary for the readability of their definitions and coverage of radiology reports.	Yes	Data analysis	10,000	Reports		The readability in PORTER's glossary definitions was higher than the others.
Qenam B, et al. 2017 [21]	Text Simplification by using Consumer Health Vocabulary can help to increase the readability of the radiology report.	No	Data analysis	792	Reports		The CHV covered a high number of concepts found in the reports but unmapped concepts are associated with locations that are commonly found in radiology reporting
McNamara M, et al. 2015 [7]	To know if the patients prefer to have access to their radiology images or notes.	Yes	Survey	41	Patients		The study found that patients prefer to have access to both their radiology images and notes.
Sadigh G, et al. 2015 [22]	Doctor's opinion regarding Traditional Text-Only Versus Multimedia-Enhanced Radiology Reporting.	Yes	Survey	402	Doctors		Doctors were satisfied with the format of their current text-only radiology reports and believed that MERR would represent an improvement.
Dy GW, et al. 2018 [23]	To evaluate a patient-centered radiology report (PCRR) for renal ultrasounds in children with hydronephrosis.	Yes	Survey	44	Patients		The patients showed high confidence in the PCRR.
Lye CT, et al. 2019 [24]	To evaluate U.S. hospital compliance with government guidelines and patient straightforward entry to imaging studies.	No	Survey	81	Hospitals		All 80 hospitals provided imaging studies on CDs. Only 8% of hospitals by email and three (4%) via an online patient portal.
Pahade JK, et al. 2018 [25]	To know what information patients or caregivers found useful before an imaging examination.	No	Survey	1542	Patients		Delivery of pre-examination information for imaging examinations is suboptimal, with half of the patients and caregivers seeking information on their own.
Short RG, et al. 2018 [26]	To determine the readability of language used in chest	Yes	Data analysis	11,357	Chest CT (reports)		The language used by radiologists to explain a normal thyroid gland in

	Computer Tomography reports to explain a “normal” thyroid gland.					chest Computer Tomography reports is complex and variable.
Yi PH, et al. 2019 [27]	To evaluate the readability of the lumbar spine in the MRI reports.	Yes	Data analysis	110	Lumbar spine (reports)	The study found that the lumbar spine in the MRI reports are written at a level too high for the average person to comprehend.
Kemp JL, et al. 2017 [28]	The opinion of radiologists regarding direct communication with their patients.	No	Survey	694	Doctors	89% agreed that they should have direct communication with their patients.
Alpert JM, et al. 2018 [29]	To evaluate the current content of oncology in the patient portal.	No	Semi-structured interviews	60	Patients, Doctors	Most of the participants were relatively comfortable with this manner of disclosure but still preferred direct communication.
Mityul MI, et al. 2018 [30]	To know how patients and radiologists understand the commonly used phrases within the radiology report.	No	Survey	113	Patients, Doctors	There is a huge difference between patients and doctors in terms of understanding the medical terms in the radiologic report.
Choudhry A, et al. 2015 [31]	To evaluate the current content of the Biopsy Result in the patient portal.	Yes	Survey	301	Patients	Most of the patients preferred to have direct communication with their doctors by telephone.
Brook OR, et al. 2015 [32]	To compare structured radiology reports versus nanostructured reporting and the effects of both reports on subjective assessment of resectability.	No	Survey	120	Reports	Surgeons were more confident in regards to the structured radiology reports.
Hoang JK, et al. 2018 [33]	The affective of applying American College of Radiology Thyroid Imaging Reporting and Data System (ACR TI-RADS) criteria in the number of thyroid nodules recommended for biopsy.	Yes	Survey	100	Thyroid nodules (reports)	ACR TI-RADS criteria decreased the number of thyroid nodules recommended for biopsy.
Balthazar P, et al. 2017 [34]	To study the impact of trainee involvement and any factors on addendum rates in radiologic reports.	Yes	Data analysis	129,033	Reports	Trainees helped to decrease the addendum rates in radiology report.
Rosenkrantz AB, et al. 2016 [35]	To evaluate information about radiology practices on public transparency Web sites.	Yes	Data analysis	8	Web sites	Transparency Web sites had a lesser extent of service quality and information.
Patmon FL, et al. 2016 [36]	To evaluate using interactive patient engagement technologies (iPET) by nurses.	Yes	Survey	38	Nurses	Nurses who received sufficient training on the iPET system were more comfortable with iPET.
Giardina TD, et al. 2015 [37]	Opinions of patients who have chronic diseases regarding their results in the patient portal.	Yes	Interview	13	Patients	They have several concerns that affected their experience.
Cabarrus M, et al. 2015 [38]	To know patients’ preferences for receiving their radiologic report results.	Yes	Survey	617	Patients	64% of patients want to have copy of their results or online access.

Fang J, et al. 2018 [39]	To know doctor's experiences with patient interactions in the era of open access of patients to imaging reports.	Yes	Survey	128	Staff and trainee doctors	Most of the respondents found interactions with patients to be a satisfying experience.
Sorondo B, et al. 2016 [40]	To evaluate the patient self-reported screening tool in a patient portal and user experience in primary care.	Yes	Survey	72	Patients	Patients can effectively use their portals to complete the patient report.
Laccetti AL, et al. 2016 [41]	To examine patterns of use of patient portals by clinic employees at a National Cancer Institute-designated comprehensive cancer center.	Yes	Data analysis	289	Nurses, Ancillary staff, Clerical/managerial staff, Doctors, Advanced practice providers	All the staff efforts that related to a patient portal has improved markedly over time, especially among nursing staff.
Woollen J, et al. 2016 [42]	To investigate patient experience with browsing their laboratory test results and radiology reports on a tablet or computer from the patient portal.	Yes	Semi-structured interviews	14	Patients	Providing a tablet computer may enhance satisfaction, lower anxiety, and increase understanding of their health conditions.
Edwards EA, et al. 2019 [43]	To know parent preferences for pediatric radiology patients.	Yes	Survey	n/a	Parents	The majority of parents prefer to receive the radiology report from a radiologist in-person.
Jung HY, et al. 2017 [44]	This article examined differences in access to text-only reports compared with radiology images through a health information exchange system by health care professionals.	Yes	Data analysis	1670	Doctors and non-doctors	Radiologists, orthopedists, pulmonary disease specialists, and surgeons accessed imaging more often than text-based reports only.
Zide M, et al. 2016 [45]	The effect of patient health literacy in radiology on perceived portal usability.	No	Survey	500	Patients	Those who have more medical conditions have a greater preference for patient portals.
Johnson EJ, et al. 2017 [46]	To evaluate the content of the private practice radiology facilities in the USA.	Yes	Survey	50	Private practice radiology facility	The quality of the content was low.
Kelly MM, et al. 2017 [47]	To know the parent's opinion of using the inpatient portal application on a tablet computer that presents information about a child's hospital stay.	Yes	Survey	296	Parents	In general, parents were satisfied with the inpatient portal.
Wildenbos GA, et al. 2018 [48]	To know the opinion of the older adult patients using a patient portal.	No	Survey	10,679	Older adult patients	The majority indicated that they prefer to review their medical information and appointments by the portal.
Alper DP, et al. 2020 [49]	To assess the impact of a reports template quality improvement (QI) initiative on the use of preferred phrases for connecting normal findings in structured abdominal CT and MRI reports.	Yes	Data analysis	44,680	Radiology reports	A QI intervention decreased the use of equivocal terms and increased the use of preferred phrases when connecting normal findings in abdominal MRI and CT reports.
Mishra VK, et al. 2019 [50]	To analyze the patient's perceptions after being given access to specialist's	No	Survey	6439	Patients	The study confirms that the patients who have access to their specialists' online medical records and

	notes and primary care via the patient portal.					primary care perceived benefits of OpenNotes.
O'Leary KJ, et al. 2016 [51]	To evaluate health care provider and patient perceptions of a patient portal and identify opportunities to enhance the current design.	Yes	Semi-structured interviews	18	Patients	Optimizing the patient portal will require attention to the format of information provided, including type and timing.

Table II. 1. Detailed references of the patient portals and the radiology report in the reviewed studies.

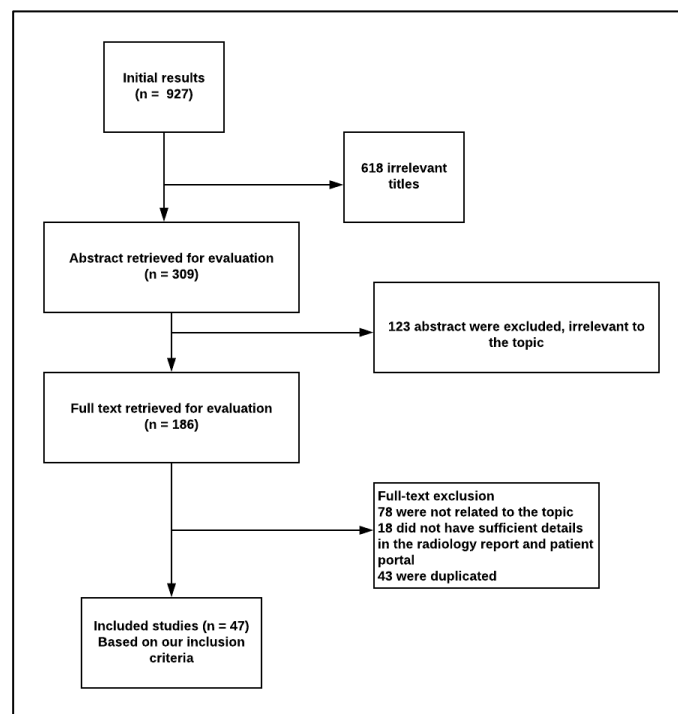


Figure II. 1. The criteria for inclusion and exclusion.

3. Results

3.1. Current Radiological Reports and Patient Portal

Dr. David Naeger, the co-director of the Henry I. Goldberg Center for Advanced Imaging Education at the University of California, stated that at this time, most patients prefer to have full access to their medical information and a full radiology report [38]. In the same survey, two-thirds of the participants stated that they preferred having a copy of their full radiology reports and that they wanted to meet with or engage in some form of communication with their physicians to discuss the reports [38]. The author noted that half the participants did not know that radiologists are doctors, but 79% of patients understood that radiologists were specialists at explaining certain medical images [38]. Another study found that 86,400 patients per month

out of 234,679 total patients accessed their portal online [18][18]. This statistic showed that there was an increase in awareness of the portal among the patient population. The current output of the system showed that radiology reports are not generally available through the web portal [38]. Information about radiology reports is generally limited when viewed through the portals [2, 9, 17, 22, 39, 42, 47]. The information currently provided is not easily understood by patients, which is an issue for many radiologists and referencing physicians (RPs). These medical professionals are concerned that patients who can access these reports may experience greater anxiety and engage in a time-consuming follow-up process with their RPs to answer their questions and obtain a greater understanding of the report content [13, 28-30, 38, 41, 44, 52]. To evaluate these issues, many points must be taken into account.

3.2. Social Media and Patient Understanding

The patient questions and comments in social media have been used to understand the patient's concerns and needs in many fields. As an example, a study conducted to know cancer patients' needs and preferences for accessing different formats of platforms. They found that 22% of patients wanted a wide range of platforms that were easier to understand, and 25% wanted the platforms to be more accurate [53]. Unfortunately, there is no study at this moment that leverages social media to understand unmet patients' needs related to reading and interpreting radiology reports. There are many platforms that can be used to collect patients' questions such as Yahoo!Answers, WebMD community, PatientsLikeMe, Quora and Tumblr.

4. Discussion

4.1. Benefits of a Patient Portal for Patient Engagement

Patient engagement is a process that puts a patient at the center of his or her health care [36, 47, 54]. Patients can be informed about their health conditions in a variety of ways, including receiving calls and messages from doctors, seeing doctors during appointments, or by accessing a patient web portal. Studies have found that many patients who used the health portal at some point in the previous year had a more positive feeling about their health care

experiences [37, 50]. By accessing personal health records (PHRs), patients can see their health records and will be able to gain a better understanding of their health [37]. When patients have an electronic copy of their medical records, they can share these records with other health care providers to acquire second opinions and advice. A PHR will lead to an increase in the interaction between patients and their health care providers and allow patients to play an important role as a member of their health care team [55]. In a survey, patients with greater engagement with their medical portal reported fewer errors and received higher quality treatment [56].

Patient portals also lead to decreased health care costs by reducing medical errors and improving the patient's cooperation [56]. An increased understanding of the treatment process could lead to patients making fewer mistakes in their care that could lead to a repeat condition or illness and require the same type of medical treatment [8, 11, 14, 16, 19, 20, 57]. Through increased patient engagement, a health care provider can save time and money. These resources could be spent on the treatment of patients for other issues [56]. Patient engagement is one of the critical requirements for meaningful use. Health information and patient engagement exchange are required in stage 2 of meaningful use [2]. The most significant factor in enhancing communication between physicians and patients involves supporting patient engagement with tools such as a patient web portal. These tools can deliver specific and generic medical information to patient users [36]. For example, when a patient sees images and reads the interpretations for the images of an indication, such as a lung cancer tumor, the patient can then gain a better understanding of what the cancer condition looks like. This information of imaging reports will form a foundation of information that a health care provider can build on in future visits. The goal of achieving full patient engagement using medical record access is important but remains something that is far from becoming a universal reality [54].

4.2. Impacts of the Health Communications Objectives

Health communication objectives have varied benefits within the process of giving health care services. Some of the benefits of the scientific providing contribution towards developing a shared decision making process between the providers and patients include the following [9, 18, 21, 28, 31]. The objective contributes to improving the quality of health care as well as health care safety. During shared decision making, clinicians and patients work in unison in coming up with agreements regarding the care plans, tests, and treatments to be employed that are based on clinical evidence [58]. This factor makes it possible to balance or reduce risks and then anticipated health outcomes, which are by the patient's values and preferences [38, 59]. When the health outcome expectations of the patients are met, health care safety and quality are believed to have been prevalent [60].

The benefits of developing social support networks include enhancing care at home and within the community. The majority of the moves that are aimed at improving social support are mostly directed at the mothers, as they are seen as a group at risk, which starts with carrying the burden of pregnancy. Elements used in building social support networks include health information and health education which tend to give more attention to enhancing parenting skills, which makes it possible to attain better health outcomes for children [43, 61].

The objective of providing accessible, actionable and accurate health information that is patient tailored and targeted is essential as it raises the efficiency of public health service and health care delivery [57]. Health information resources are critical to producing health information that helps improve the efficiency of public health services and health delivery, as it enhances care outcomes for families and individuals. Consumer health informatics have been able to assist practitioners with resources that aid towards achieving tailored health care services, which improves efficiency within the public health service [47]. As the public is increasingly getting involved in health care, consumer health informatics are playing a vital

role in linking up the digital divide as well as backing up the ability of the consumers to author and understand health information [6].

A proper understanding of tailored health information enables caregivers to know what they need to provide quality health care services. Tailored data improve the quality of care delivery, as patient satisfaction is likely to be high [62]. In the event that there is knowledge of the health care information, all the necessary resources can be gathered. This aspect helps create an environment where there is efficiency in care delivery as all the resources regarding a particular health issue have been collected [63].

4.3. Addressing the Objectives

The objectives selected include contributing to developing a shared decision making process between the providers and patients, improving social support networks, and providing accessible, actionable and accurate health information, which is tailored and targeted. On the objective relating to shared decision making, the critical consideration would be to create a platform within the health care environment [64]; a situation where both the patient and the caregivers can come together and be able to analyze different aspect that related to treatment and tests among other health care practices that, at the end of the day, ensure that there are quality health care outcomes. This approach can be implemented within a care setting through coming up with advance care planning talks, decision support counseling, and ensuring patient decision aids. When this strategy is in place, the objective of attaining share decision between caregivers as well as patients [64].

The objective of developing social support networks can be attained by coming up with opportunities that enhance social connectedness, which targets improving health care outcomes [65]. Some of the initiatives that can be used to promote this objective include coming up with education sessions, which tend to provide more knowledge on issues like parental skills to enhance the health of children. These meetings can be held in a health care facility or within

community centers to help the communities at risk of disadvantaged social support to achieve quality health.

On the objective of providing accessible, actionable and accurate health information, which is tailored and targeted, the primary focus is on the deliverance of reliable health information that can be used to achieve quality care [57]. For health information to be honest, it has to be accurate, actionable, and accessible. This objective can be achieved through ensuring that there are reliable health information resources such as tools and standards like routine community and facility reporting systems, health statistics and data like the Global Health Observatory (GHO), and national evaluation and monitoring guidance, like in [66].

4.4. Quality Initiatives and Patient Satisfaction

One incentive geared towards quality is the use of computerized information technology [67]. Together with electronic health care records (EHRs), this system will make it easier for health care providers to assess correct data and in turn, patients will receive better treatment [68]. The EHRs will help to reduce or prevent any medical errors while improving patient care while inducing an illness diagnosis to a patient [35, 46, 49, 69]. In addition, the EHRs can determine potential health issues and can aid the medical center to prevent any occurrence of entering a wrong diagnosis, hence, creating better results for the patients [70].

Secondly, taking measures that reduce medical errors, readmission, and implementation of ways to minimize errors is a quality initiative for patient satisfaction [71]. The programs that address care practices to reduce readmission and good quality health care implementation have registered health care improvement and have shown improved patients' outcome. A misunderstanding or poor patient care given on the first visits may be a reason for readmission [72]. These readmissions cause high annual costs [73]. Reduction in readmissions can save costs concerning the patient and the hospitals, which can result in fewer errors, hence improving the patient outcome [73]. At this condition, the patient's education is of necessity so that patients can follow up on their appointments to avoid readmission [70].

Improving communication by using applications, such as mYhealth in mobile technology, can be another step. There exists a difficulty in communication between the providers and the patients. Current metrics show that hospitals waste billions of dollars because they lack proper communication with providers [73]. Medical centers are evaluating how going mobile can help improve communication. With applications in mobile technology being a priority, it will serve to improve patient safety and increase clinician efficiency [74]. These new ways of technology and treatment will improve the quality of patient outcomes.

4.5. Patient Portal Platforms

There are many examples of patient portals on the web, such as Intelichart, the Kaiser patient portal, MyChart, and others [54]. Some of the portals are used by many hospitals, such as MyChart, which covers 99 hospital systems. The need for this type of system is high because patients need tools that can remind them to follow up with their medication schedule, to add personal notes about doctor instructions, and to engage in a convenient dialogue with health providers for issues that may be of concern. Some example applications that address these needs include Dosecast, Mango Health, MedCoach, MediPrompt, MediSafe, MedMory, MyMedSchedule, MyMeds, Pillboxie, PillMonitor, and RxmindMe. They provide different degrees of services to the patients [54]. One application, RxmindMe, allows users to create nine types of reminders including hourly, daily, weekly, and monthly reminders. The application also allows users to download their prescription history and send it via email. Users can download these applications onto their smartphones or tablets to track their health record. This portal allows patients to improve their health by ensuring that the patients correctly follow clinicians' medication instructions. Patients can also input additional signs that their health is negatively changing including new injuries, weight gain, or skin conditions that occur with no apparent cause. When the portal is updated, the patients can share the portal contents with external parties to obtain a more accurate treatment.

4.6. Limitations in the Patients' Portal

Patient web portals generally need a lot of work to improve the limitations of these platforms [52]. This paper focuses on access to full radiology reports in web portals and, therefore, will concentrate on the limitations of the portal regarding this issue. Many studies mention that there are issues and limitations in the radiology section of patient web portals [2, 24, 52]. There are many physicians, radiologists, and patients who are dissatisfied with the radiology portion of the web portal [52]. There are also limitations in the ability to access all radiology reports in the online portal [2]. In addition, the information available is not understandable for many patients because of the complex medical terminology used in the reports [26, 52]. A survey of 617 patients was conducted to investigate how many of these patients would prefer to have full access to their radiology reports using the patient portal [38]. The survey found that 65% of patients preferred to have access to their medical images and the radiology interpretation [38]. This contrast between patient performance and the available information in patient portals reveals that there is a gap between them.

4.7. Observed Issues

The information provided by the radiologist department is currently not understandable by all patients and is an issue which concerns referencing physicians (RPs) [52]. The RPs are concerned that patients could misunderstand the images and that these misunderstandings could cause unnecessary anxiety or worry [52]. Radiological images are not easy to understand for those without proper training. Most radiology modalities provide images in white, black, and gray [75]. These colors make the anatomy present in the images difficult to identify and the lack of contrast between the organs in the images is not high. As a result, there could be confusion when differentiating between organs. The reader must also know what to look for when viewing the image, such as knowing that blood would appear as white in the image. If an image of the brain shows a white spot within the brain tissue, this would be an indication of hemorrhage or tumor. The location of the camera concerning the body also provides issues when viewing the radiology images. The sections of the image could be sagittal, coronal, and

axial (as shown in Figure II. 2) [76]. When patients look at the image without the help of a medical professional, they could be confused because of the various views of the same area of the body (Figure II. 3) [77]. The third barrier that patients may face is that they could not understand the image due to the image's brightness. Many variables impact the brightness of the image, including contrast, modality type, and electronic window. For example, a patient who has a semi fracture in the foot would have an image with very low brightness to allow the fracture to be seen. Patients could feel that the image is useless or unimportant because the image is very dark. These examples show challenges that decrease the readability of radiology reports and these barriers should be considered and improved as part of the overall improvement in patient access to radiology reports in the patient portal [15].

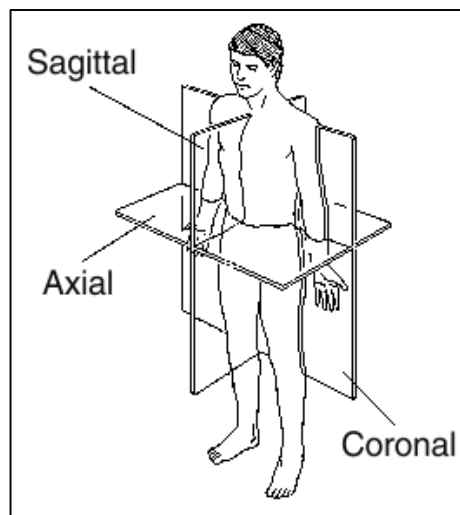


Figure II. 2. 3D Axis set of the human body.

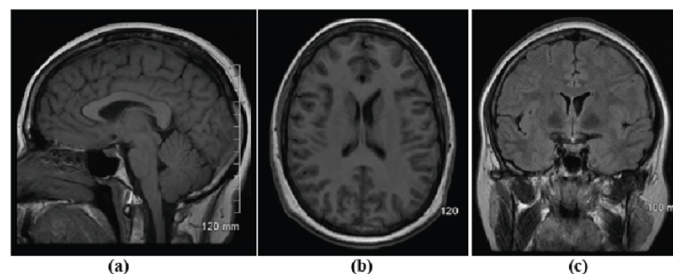


Figure II. 3. Brain MRI obtained from (a) Sagittal Plane, (b) Axial plane, and (c) Coronal plane.

Most people are not familiar with medical terminology. Radiologists have suggested being given more time to work on the report before uploading the reports to the portal in a form that is more readable and understandable for patients [52]. However, radiologists are concerned about the turnaround time (TAT) for reports [78]. The TAT refers to the time that it takes for radiologists to receive images from PACS, write their interpretation of the images, and then, upload these interpretations into the PACS system. The speed and productivity of radiologists vary based on the individual and the level of the individual. A locum radiologist is a physician who temporarily works in the radiology department while a resident radiologist is a physician who has a contract with the hospital for some time. In the USA, a radiologist must complete 5 years as a resident and a 1- to 2-year fellowship to become a consultant. A consultant radiologist is a physician who can provide final approval for a radiology report written by the locum and resident radiologist. Based on this system, radiology departments have delays in the time it takes to finish all reports [79]. For these reasons, radiology departments do not have additional time or flexibility to work to make the radiology reports easier and more readable for patients [27, 32, 79]. Some health care providers have a radiology staff shortage that could impact the workflow and TAT. A computerized physician order entry (CPOE) may help to write readable radiology reports for patients in a short amount of time.

5. Conclusions

This study shows that there is a gap between information provided in the radiology section of the patient web portal and other sections of the portal. After reviewing the opinions of radiologists, RPs, and patients, we have found that the radiology section needs improvement. The primary concern for radiologists is the time needed to write a simplified report. Before providing images to patients, physicians would like to be able to provide a readable draft to help patients understand the report. The critical factor in making these improvements is to find a way to decrease the TAT by creating ways for radiologists to increase their report writing

output while decreasing the time. In addition, it is necessary to investigate the patient's needs and concerns regarding the radiology report, and questions in social media could be beneficial. These changes would allow patients to receive an understandable radiology report. Additionally, they encourage health providers to provide a radiology section in the patient portal with the same general amount of information as other parts of the portal.

III. UNDERSTANDING PATIENT NEEDS AND GAPS IN RADIOLOGY REPORTS THROUGH ONLINE DISCUSSION FORUM ANALYSIS

1. Introduction

A radiology report is the official record of medical images that contains the interpretations and images [80]. The main goal of the radiology report is to present the outcomes of the imaging procedure (e.g. X-ray, MRI) of the patients to physicians [81]. Recent studies show that patients want to read their own report or the reports of family members. Oftentimes, they have difficulty understanding the content presented in the reports [20, 27, 82, 83]. Many patients are now able to access their radiology reports online [1, 2, 84]. This encourages patients to communicate with doctors about their radiology imaging results [1]. A study conducted involving 61,131 patients found that there was a high percentage of patients (51.2%) who reported that they were interested in browsing and reading radiology reports online [2]. This study confirmed patient interest in reading radiology reports. A study of two outpatient groups who had recently undergone MRIs found that most patients were not satisfied with current radiology reports because the reported results were not easy to understand. The same study showed that there is a lack of detail and cited delays in report release as the most important problem with radiology reports. Patients generally preferred to have the option to access more detail in the reports [85].

The involvement of patients in the therapeutic and diagnostic stage has positive benefits [86-89]. Good patient understanding of health reduces the time a doctor must spend explaining treatment steps [90]. In the field of radiology, radiologists and the doctors radiologists refer patients to complain about the lack of time to write reports as well as the time they must use to explain procedures to patients [91]. Giving patients access to their radiology reports provides them with the opportunity to understand the reports prior to meeting with the doctor [20, 92]. Patients can also share the reports with family or other specialists to obtain further explanations

[93]. The patient's understanding of the treatment steps helps raise the efficiency of treatment and a better understanding of the health condition can reduce the level of anxiety [94, 95]. Some studies have shown that radiologists fear that patients' current lack of understanding of the radiology reports could increase anxiety [13, 52]. This concern raises the important issue of the extent of the gap between patient understanding and the current radiology report design. This study will aim to identify the extent of this gap.

The next aim will be to design a more user-friendly radiology report by considering the patient as the primary target of the design. To achieve this objective, we first studied the obstacles involved with submitting the current version of the radiology report to the patient. The results of this study were published in May 2020 [92]. Our current aim is to identify patient desires and priorities for their radiology report by exploring patient questions in online discussion forums (Figure III. 1). This study will be the final step before the process of designing a more patient-friendly radiology report begins. Patient comments and questions in online discussion forums were used for a variety of purposes in previous studies [96] [97]. One research study looked at patient concerns about the nature of the healthcare environment based on social media questions. This study collected data from social media sites, including online discussion forums, to find ideas that would help to create a kinder, more reliable healthcare environment [98]. Online discussion forums can be used in the pharmaceutical field to evaluate drugs based on patient questions. For instance, a study used online discussion forums to identify potential candidates for a drug repurposing study and created five potential drug repurposing candidates [99]. This strategy can also be used to understand the medical terminology challenges that patients face. Popular data sources such as Yahoo!Answers, WebMD community, PatientsLikeMe, and Tumblr were studied to understand the language gap between consumers and health practitioners [100].

2. Methods

2.1 Data sources & collection

To understand patient needs and gaps in radiology reports, we conducted a scan of four online discussion forums to evaluate the publicly available content addressing patient concerns about their radiology reports. The four sites examined were Yahoo Answers, Reddit.com, Quora, and Wiki Answer. All questions were in English (Figure III. 4). The analysis occurred in the following four steps: determine what websites should be used, collect questions, filter the data, and categorize the questions. To reach more people, the most frequent and recommended platforms from previous studies were used [4-6]. Yahoo Answers is the largest consumer Q&A site and is available in 12 languages, one of which is English. Wiki Answers is another large platform that allows people to ask and answer any question. Quora and Reddit.com are online platforms where patients can ask about and share their own experiences. They are all public websites that allow people from all parts of the world to answer the same question. The platforms allow patients to share their own experiences and improve outcomes.

The search keywords used were selected by the author, a specialist in the radiology field who is familiar with the terms used. The goal was to determine patient needs and gaps in radiology reports. The researchers collected all radiology-related questions as they worked toward their goal. Some procedures that were tracked included radiology modalities such as Magnetic Resonance Radiology (MRI), Nuclear Imaging, Ultrasound, X-Ray, Computer Tomography (CT), Fluoroscopy, and Angiography. Other procedures included radiology services for specific indications like breast cancer or lymphoma. The questions were manually collected using search terms that included the following: radiology reports, radiology modalities, and radiology interpretations.

2.2 Thematic analysis

A total of 987 questions were collected. Of these, 328 questions were discarded because they did not meet the quality criteria which included the following: unrelated to radiology, no clear topic, not in English, and/or contained confidential information. Questions that were added by medical students to answer homework or exam questions were excluded along with any questions that had a patient's identifying information or full name. We extracted 659 questions from the collected data (Figure III. 2).

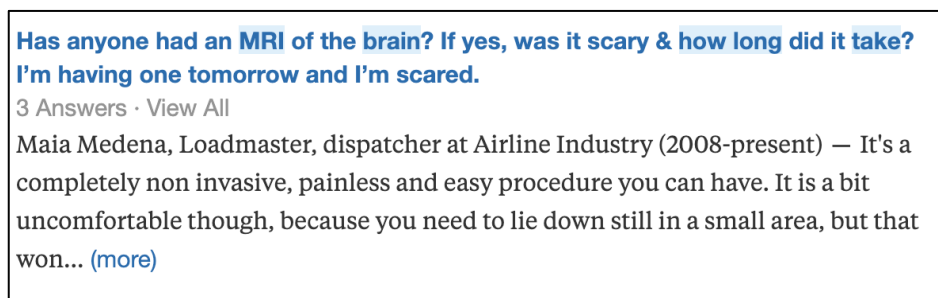


Figure III. 1. An example of a question from quora.com

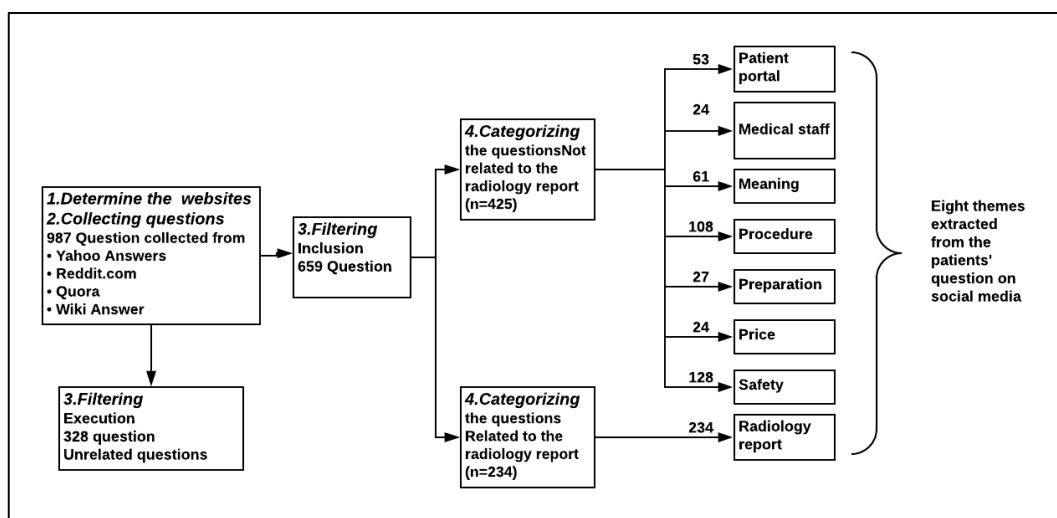


Figure III. 2. Filtering the questions and creating the eight themes

Patients are the focus of our research and we searched for the most important themes to understand the radiology report (Figure III. 3). The first phase focused on gathering as many questions about radiology as possible from online discussion forums. Based on the review of these forums, we created the eight themes that involved patient concerns regarding the radiology report. The eight themes complement one another to some degree. We also found that patients asked many questions about radiology scan pricing. They wanted to learn about how to access their medical files through the portal. Additionally, some questions showed patient concerns about problems with the portal and the deficiencies of the portal. The questions also inquired about the best doctors based on procedures and test as well as the intricacies of the test itself including those who were responsible for giving instructions and explanations of the scan. The majority of the questions were about safety. The second phase focuses on analysis of the eight themes based on percentage. This allowed us to discover unmet patient needs and information gaps in the radiology reports. We started by categorizing the questions into two main themes, questions related to the radiology report (n=234) and questions not related to the radiology report (n=425). Some questions were not directly related to the radiology report but were generally related to the radiology scan. For thematic analysis, we adopted a grounded theory approach in which themes emerged from the data [101]. We reviewed the questions extracted for topics and themes, then we grouped similar topics and developed a hierarchical code of themes. Extracting topics and themes from questions was conducted independently by two researchers (MA and JL). The topics were merged if they agreed with one another. If disagreements between the reviewers were identified, they were discussed until a consensus was reached. If no consensus reached, both topics were kept. Eight themes and 19 sub themes were developed (Table III. 1). The main eight themes are as follows: the radiology report, patient portal, medical staff, meaning of terms, procedure, preparation,

price, safety (Figure III. 2). There were six themes that concerned patients: radiology report, safety, price, preparation, procedure, and meaning. The themes and sub themes were later reviewed and altered by the author, committee reviewers, and the radiologist involved in this study.

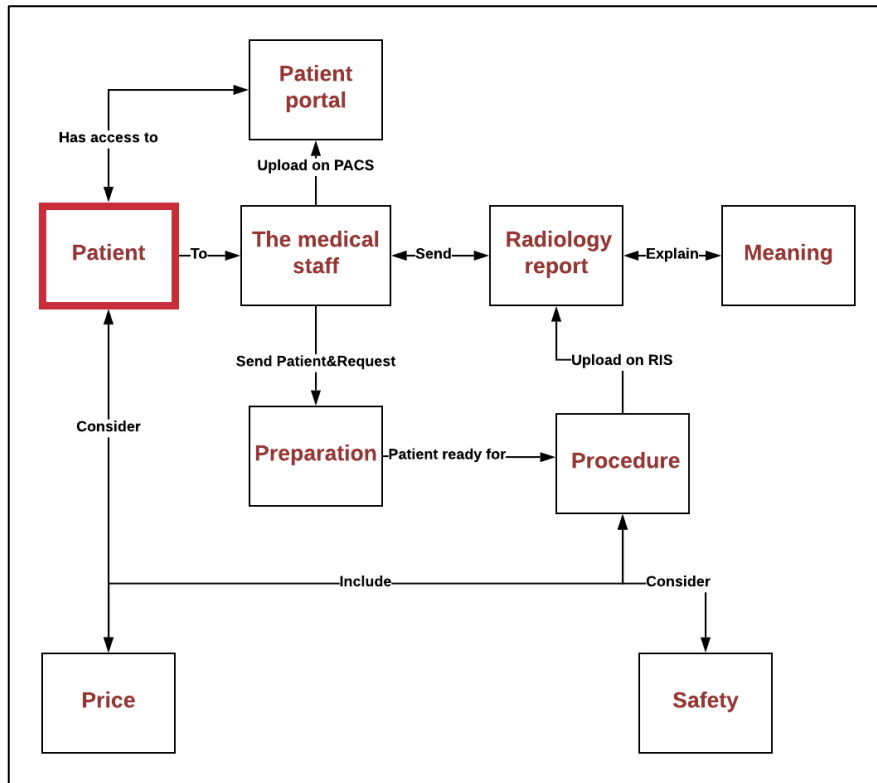


Figure III. 3. Diagram of the relationship between the 8 themes

3. Results

3.1 Summary of the four data sources

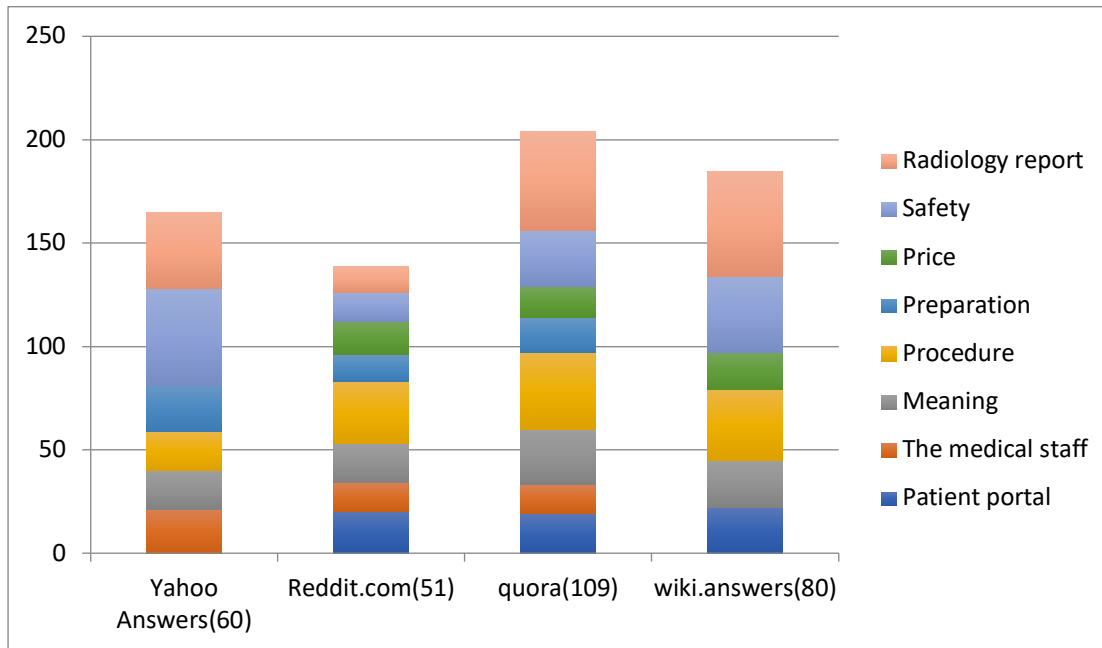


Figure III. 4. Number of questions for each theme among the four online discussion forums

A total of 659 questions were identified from four online discussion forums and categorized into eight themes.

Main themes	Sub-themes	% per of theme	% out of 659
Patient portal (n=53) (8.04%)	Technical Issues	45.28%	3.64%
	Features	54.71%	4.40%
The medical staff (n=24) (3.64%)	Responsibility	100%	3.64%
Meaning (n=61) (9.25%)	Modality types	45.90%	4.24%
	Test types	54.09%	5%
Procedure (n=108)	Length of procedure	23.15%	3.79%
	Cognitive questions	45.37%	7.43%

(16.38%)	Feeling comfortable	31.48%	5.15%
Preparation (n=27) (4.09%)	Preparation	100%	4.09%
Price (n=23) (3.64%)	Price	100%	3.64%
Safety (n=128) (19.42%)	Pregnancy	23.43%	4.55%
	Radiation	29.68%	5.76%
	Anxiety	32.03%	6.22%
	Contrast media	14.84%	2.88%
Radiology report (n=234) (35.50%)	Report Representation	19.65%	6.98%
	Image visualization	22.64%	8.04%
	Resources	8.54%	3.03%
	Preference	22.64%	8.04%
	Understanding	26.49%	9.40%

Table III. 1. The main themes that concern patients in radiology

3.2 Analysis of patient question themes

3.2.1 Patient portal

The patient portal is a secure website that allows patients to access their own medical records. Our findings showed that 8.04% (n= 53) were concerned with the patient portal. The concerns were divided into two sub themes, technical issues (54.28%) and features (54.71%) (Table III. 1). Technical issues referred to any issue that patients could face such as finding or

downloading the report. An example of a technical issue is “I have set up my account, but it isn’t activated” and “My portal has limited options.”

3.2.2 The medical staff

Medical staff is a term that refers to the individuals responsible for preparing the full radiology report, including the image generation process. The term can include radiologists, physicians, and radiology technicians. Our findings show that this theme is asked about with a percentage of 3.64% (n=24) (Table III. 1). Additionally, 77.77% of questions were about radiologists. As an example of question in this theme is "What is the difference between the physician and the radiologist?"

3.2.3 Meaning

We included any question that evidences a lack of basic patient knowledge of the radiology field (9.25%). The questions could involve radiology modality types (45.90%) and test types (54.09%) (Table III. 1). Modality types and test types are shown as some of the sub themes in Figure III. 5. An example of a question regarding modality and test type is "What is the difference between an open MRI and a closed MRI?" or "What is angiography?".

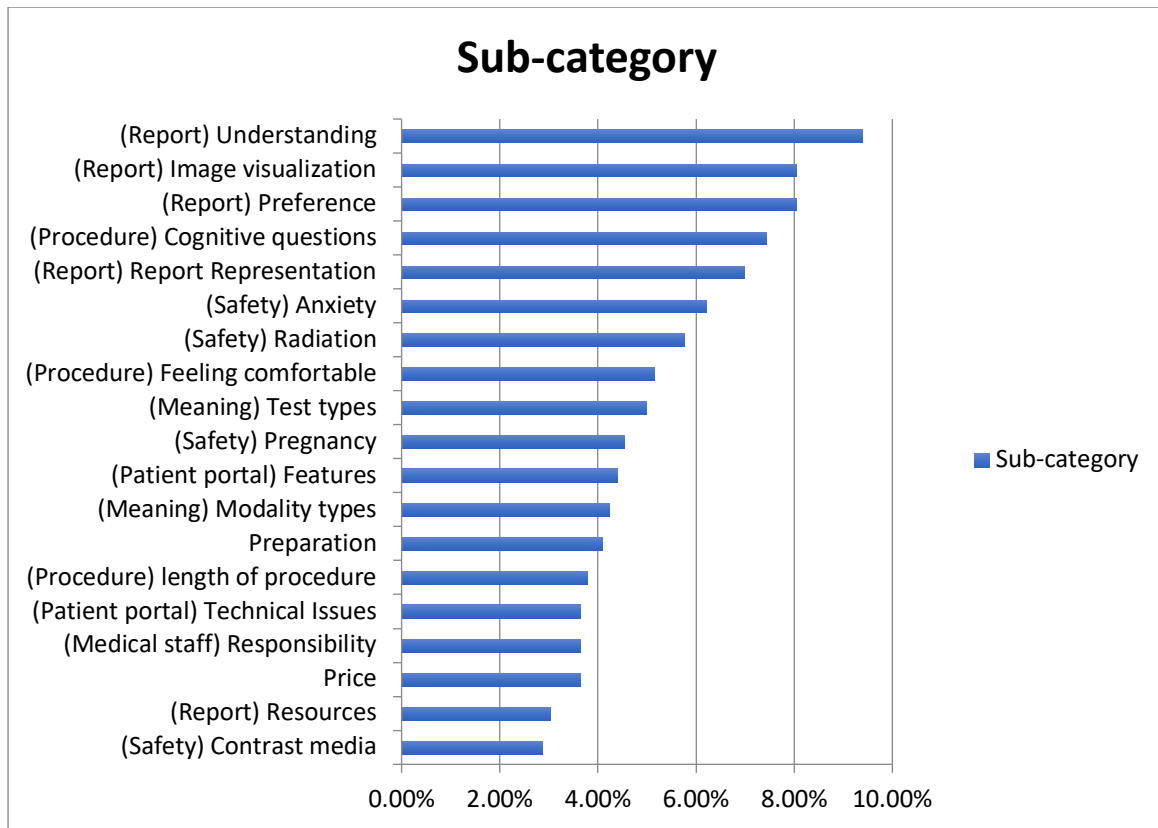


Figure III. 5. Percentage of questions per sub themes among online discussion forums

3.2.4 Procedure processing

This theme involves performing a series of operations during the procedure. We found that 108 of 659 (16.38%) patients were concerned with the steps in the test. Additionally, 45.37% of patients posed cognitive questions. Many questions were about differences in various radiology procedures. Additionally, 23.15% of question involved the length of time that a procedure would take. Patients were less concerned about the length of the procedure than they were about feeling comfortable during the procedure (Table III. 1).

3.2.5 Preparation

Preparation includes concerns regarding test preparation including clothing, fasting, and drinking of liquids. The concerns include all radiology types at a percentage of 4.09%

(n=27) (Table III. 1). Many questions were about MRI test preparation. Patients are given MRI instructions for their own safety and these instructions are critical to help patients avoid danger. An example of this is how patients must be free of certain minerals during the examination, especially if the minerals are in the heart valve. It is important to ensure that the patient is free of metal prior to entering the imaging room. This particular requirement has raised issues about the particular examination such as the question of "Why are the instructions of the MRI scan so complicated?".

3.2.6 Price

Questions about the price of radiological imaging represented 3.64% (n= 24) of questions (Table III. 1). Many questions were about MRI costs along with questions about what insurance would or would not cover. Despite our findings, patients want to get the best diagnostic imaging even if the cost is high. Many patients have insurance that will cover these costs. There are many potential variables that could increase imaging cost such as the radiology modality and facility capacity. An example of a question that patients asked is "How much does an MRI or CT scan of the head cost?"

3.2.7 Safety

These questions refer to concerns involving safety including radiation exposure, medical errors, contraindications, and other negative consequences that could be experienced as a result of the procedures. These issues made up 19.42% (n= 128) of questions (Table III. 1). Questions about the anxiety that can lead patients to cancel their imaging appointments comprised 32.03% of questions. One of the patients asked about travelling by airplane after a

nuclear imaging scan. A second major patient concern was about radiation which comprised 29.68% of questions. The other sub themes were pregnancy and contrast media injections which comprised 23.43% and 14.84% of questions, respectively. An example of a question with this theme is "Should all female trauma patients be given a pregnancy test to prevent accidental exposure to radiation?".

3.2.8 Radiology report results

This theme involves the step after the test and includes radiology images and interpretations. The report results were the major concern for patients with a percentage of 35.50% (n= 234) (Table III. 1). A total of 234 questions were sorted into five sub themes based on question times. The sub themes were *report representation* (19.65%), *resources* (8.54%), *understanding* (26.49%), *image visualization* (22.64%), and *preference* (22.64%) (Figure III. 6). **Report representation** includes any question about the format of the radiology interpretations, such as font size, font color, unstructured information, information abundance, and confusion about what documents pertain to what information. **Resources** include any external resources such as links and brochures that provide further information to patients about a variety of topics. **Understanding** refers to any question related to issues such as explanations, unclear medical terms, and general confusion about results. **Image visualization** refers to any issues about images, resolution, enhancement, contrast, and color. **Preference** refers to the way that results can be given. These five issues all work to allow patients to contribute to their radiology procedure experience to increase the quality of their diagnostic reports.

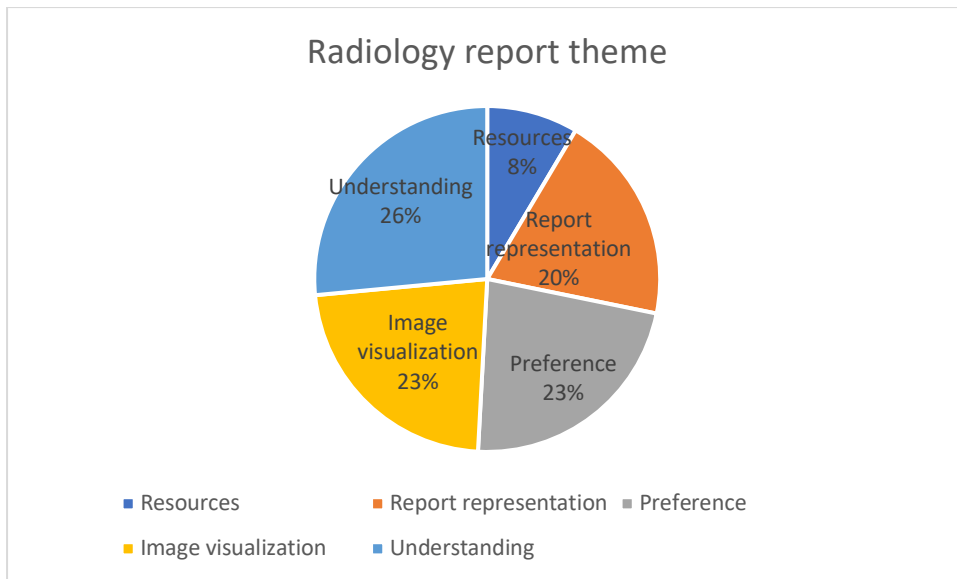


Figure III. 6. Percentage of questions of sub themes among in radiology report theme

4. Discussion

Previous studies focused on patient and physician opinions, challenges, and preferences in fully enabling patients to obtain their radiology reports [20, 92]. For example, there was a study that showed 51% of patients had a strong desire to obtain radiology reports without obstacles [2]. Likewise, we found studies that showed that doctors do not mind giving patients their radiology reports, but that the doctors feared that patients would not understand the reports properly [13, 52]. Some studies have gone further and determined the level of patient satisfaction with current radiology reports [2, 19]. One of the studies showed patients' dissatisfaction with the current reports due to the difficulty of understanding the reports [102]. These studies did not address patient concerns and their specific concerns about the radiology reports. One study used patient evaluations at yip.com to determine the most important factors for positive and negative patient perceptions of radiology centers across the United States [103]. This study focused on evaluating the performance of medical radiology centers [103], but did not address general patient concerns about the overall radiology field.

Our study used patient postings on four social media websites and collected the questions that patients posted on these sites about the radiology fields. The questions were divided into the following eight themes: the patient portal, medical staff, meaning, procedure, preparation, price, safety, and radiology report. We then worked to determine the most interesting and concerning topics for patients regarding the radiology report. We found that patients are most concerned with the understanding, image visualization, and report representation of the radiology report. A total of 26.49% of the radiology report's results focused on patient understanding. From our data, patients want to improve their understanding of the report by enhancing image visualization, report representation, resources, and preference. In addition, we found that there is difficulty understanding medical terms, instructions, and the main report issue(s). Also, 20% of the questions suggested that there is a need to improve report representation. The report representation issues include the report being unstructured, containing too much information, or containing font or color issues. In image visualization, 23% of patients asked many questions to eliminate ambiguity from the images they were given and obtain a better understanding. To our knowledge, our study is the first to explore patient needs and gaps in radiology reports using patient questions posted on online discussion forums. The findings of the study have significant implications for developing a friendly radiology report which aims to improve patient understanding. A major finding is that patients do not understand their radiology reports and that the reports are negatively impacted by the lack of image visualization and report representation.

5. Conclusion

Patients believe that considering their needs to fill gaps in report representation and image visualization can provide a better understanding of the full radiology report. The new design of the report must consider the following three sub themes:

1. **Report representation** – this refers to the issues involving font size, colors, unstructured information, too much information, and confusing content
2. **Image visualization** – this refers to issues related to the image itself such as resolution, contrast, enhancement, annotation, and color issue
3. **Understanding** – this refers to questions related to patient understanding including what items require more explanation, unclear medical terms, and general confusion about content

By using online discussion forums, we were able to successfully discover major patient needs and gaps in the current radiology report format. This result shows that it is important to design a consumer-friendly radiology report that focuses on major patient concerns. The design of the report must be universally adopted and applicable to all modality types. Another topic that has been discovered is why patients are more concerned with the MRI report than they are with other radiology reports.

IV. THE DEVELOPMENT OF RADIOLOGY REPORT LITERACY ASSESSMENT TOOL

1. Introduction

The extent to which patients are able to read and understand radiology reports reflects the extent of their radiology literacy [104]. In the field of health, studies have shown that there is a close relationship between identifying public health awareness and developing research [105]. There has been great interest in developing health literacy tools for conditions such as diabetes and high blood pressure [106-108]. A study designed a 10-question tool to measure awareness of blood pressure [106]. Another study used this same tool to measure hypertension awareness in individuals living in rural areas of China [109]. This study produced important results that would guide the government in developing health care approaches for those who have hypertension in these geographic areas. The study discussed the relationship between income level, age, and education with the health awareness of blood pressure [109].

We conducted research to determine if there was a tool in the radiology field that measured the extent of radiology awareness. Radiology involves the diagnosis and treatment of many diseases including cancer and arterial diseases. It is generally known that radiation can be used to diagnose and treat certain diseases and that this type of treatment will take some time to complete. Numerous studies have showed that patient participation in the diagnosis and treatment process can help to improve treatment efficiency [56, 110-112]. Studies have found that one of the most important obstacles in patient involvement is the extent of their awareness of the target field [112]. As patients' access to reports increases, low radiology awareness can cause discomfort and anxiety. These reasons could be why there have been an increasing

number of studies designed to explore the extent to which radiologists want their patients to participate in the treatment process.

The reason why the topic of literacy does not appear in many radiology research studies could be because radiology involves diagnosis, therapeutic, and various modalities. Many studies have looked into developing the technical fields of radiology including radiology protocols and signals from magnetic resonance imaging [112, 113]. Other studies have also worked to develop the performance of radiologists to accelerate the report generation process [114-118].

Studies that focused on patients in this field only focused on patient desires and needs without measuring patients' knowledge of radiology [14, 16, 19, 119]. A radiology literacy tool can study patients' awareness of the field. In this study, we will work to design a viable tool to determine radiology knowledge levels. This study is unique because it studies the level of radiology knowledge in individuals. The tool has been designed to cover important radiology pillars such as basic medical terminology, image content, instructions, and radiation protection. The tool was examined by comparing each question with the quiz results. Patients were given a radiology report and then were administered a short quiz to determine what they were able to retain from the report.

2. Methods

2.1 Study design & data collection

This study was part of a study in which we sought to evaluate a new design by comparing it to the current radiology report design [120]. We used Amazon's MTurk platform to distribute the survey and obtained 616 participants. Each participant received the amount of \$0.40

pledged by the author. The participants were divided into two groups, the intervention and control groups. The intervention group was presented with a new design for the radiology report. The control group was shown the current radiology report. The assignments occurred using a random computer distribution. The questionnaire was uploaded onto the Qualtrics platform and linked to the Amazon MTurk platform for distribution. The sample size for each group had to be at least 257 individuals for the alpha to be 0.05 and the desired power to be 0.80. The control group had 320 participants and the intervention group had 296 participants. The study included participants from all 50 states in the United States. The participants must have been fluent in English to complete the survey. Table IV. 1 shows the participant demographics. The study was approved by the University of Wisconsin-Milwaukee (#IRB 20.230).

2.2 Study setting & statistical analysis

The questionnaire contained a group of questions designed to measure the radiology literacy of participants (Table IV. 2). The questions covered important topics including basic terminology, radiation safety precautions, and image content understanding. The questions did not focus on specific radiology types. Our radiological background was used to design the questions to measure patients' literacy levels in this field. After designing the questionnaire initially, we consulted a group of radiologists to develop and inform the questions further. The groups consisted of college students, health practitioners, and radiologists.

To assess the accuracy of our tool, we compared the results of the participants to the grades in their quiz. We gave 10 grades for each current answer in the radiology tool. This method had previously been used in a previous study that measured hypertension literacy [106, 109]. For the spinal report case, both groups took the same quiz, but the quizzes had different designs [120]. We then used Pearson correlation coefficients to determine the extent of the relationship

between the radiology literacy tool and the quiz results. The statistical analyses were performed using SPSS software.

3. Results

Participant characteristics are presented in Table IV. 1. The majority of the participants were under 49 years of age. The percentage of males was higher than the percentage of females as males made up 58.35% of the participant population. The percentage of those who had obtained a university degree or higher was higher in both groups as shown in Table IV. 1. The radiology report was presented in English and all participants were required to both speak and read English fluently. The proportion of participants who had English as a primary language was higher in both the intervention and control groups at 88.9% and 91.3%, respectively. There were income differences in the participants ranging from those who made more than \$10,000 a year to more than \$80,000 a year. The health and smoking status of the participants were also noted.

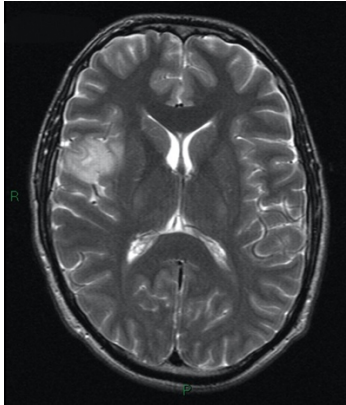
Table IV. 2 showed the Pearson coefficient and P-value for each question by finding the relationship between each question and the test results. Three questions (Questions 5, 9, and 13) were excluded because the P-value was $> .05$. Our radiology literacy tool consisted of 10 questions. When calculating the relationship between the new tool of radiology literacy and the quiz results for the intervention group and control group, we obtained a value of (Pearson 0.537, P .00) and (Pearson 0.517, P .00), respectively. In figure IV. 1, the radiology literacy tool had a good ability to measure the awareness of radiology (area under the receiver operator curve (95% CI: 0.72 (0.62-0.82))).

Table IV. 3 shows that radiology literacy increases based on education level. Additionally, radiology literacy appears higher for those with income less than \$10,000 with an average of 51.97 and decreases to 48.54 for those who have an income between \$20,000 and \$39,000. The radiology literacy rises again to the rate of 59.82 for people with income from \$60,000 to \$79,999 and is even higher for those who make more than \$80,000 at 61.10. We noted that radiology literacy among smokers was lower than in non-smokers at 46.90 and 57.30, respectively. The outcome of those with chronic diseases was to have lower radiology literacy than those who did not have diseases at a rate of 50 and 55.08, respectively.

Characteristics	Control Group		Intervention Group	
Age				
• <20–29 years	39.4%	126	42.6%	256
• 30–49 years	45.9%	147	43.2%	128
• 50+ years	14.7%	47	14.2%	42
Gender				
• Male	63.4%	203	53.2%	157
• Female	36.6%	117	46.8%	138
Level of education				
• Some school & high school	8.8%	28	7.8%	23
• Some college	27.5%	88	31.1%	180
• College degree and above	63.7%	204	61.1%	385
English is the first language				
• YES	91.3%	292	88.9%	263
• NO	8.8%	28	9.9%	33
Income				
• <\$10,00	9.1%	29	10.8%	32
• \$10,000–\$19,999	12.5%	40	14.9%	44
• \$20,000–\$39,999	24.7%	79	19.9%	59
• \$40,000–\$59,999	22.2%	71	22%	65
• \$60,000–\$79,999	18.8%	60	18.6%	55
• ≥\$80,000	12.8%	41	13.9%	41
Chronic condition				
• Yes	36.6%	117	36.8%	109

• No	63.45%	203	63.2%	187
Smoking				
• Yes	39.7%	127	38.9%	115
• No	60.3%	193	61.1%	181

Table IV. 1. Demographic Variables (Interventional Study)

NO	Question	Control group	Intervention group
1	The radiological modality that uses a magnetic field to create images of the inside of your body is (CT, MRI, NM, don't know)	(Pearson 0.357, P .00)	(Pearson 0.246, P .00)
2	The radiological modality that uses X-rays to create images of the inside of your body is (CT, MRI, NM, don't know)	(Pearson 0.395, P .00)	(Pearson 0.369, P .00)
3	The radiological modality that uses small amounts of radioactive material to create images of the inside of your body is (CT, MRI, NM, don't know)	(Pearson 0.309, P .00)	(Pearson 0.337, P .00)
4	All radiology modalities use radiation in the scans (yes, no, don't know)	(Pearson 0.180, P .001)	(Pearson 0.208, P .00)
5	CT uses radiation, which can cause cancer (yes, no, don't know)	(Pearson 0.068, P .223)	(Pearson - 0.012, P .838)
6	There is no limit to do many X-ray scans in per year (yes, no, don't know)	(Pearson 0.280, P .00)	(Pearson 0.339, P .00)
7	The body can filter all the radiation from the body at the end of the imaging scan day (yes, no, don't know)	(Pearson 0.117, P .036)	(Pearson 0.257, P .00)
8	This is a kidney image (yes, no, don't know) 	(Pearson 0.251, P .00)	(Pearson 0.264, P .00)
9	The case in the above image is (normal case, not normal case, don't know)	(Pearson 0.105, P .062)	(Pearson 0.012, P .835)
10	It's normal that radiology images appear in white and gray colors (yes, no, don't know)	(Pearson 0.213, P .00)	(Pearson 0.195, P .001)
11	All the imaging tests have the same preparation instructions (yes, no, don't know)	(Pearson 0.254, P .00)	(Pearson 0.333, P .00)
12	The radiology scan that requires no metal on the body is (Ultrasound, MRI, don't know)	(Pearson 0.275, P .00)	(Pearson 0.180, P .002)

13	Did you know that radiology images can be provided in three views as in the above image? (yes, no, don't know)	(Pearson 0.063, P .260)	(Pearson 0.015, P .796)
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Table IV. 2. The correlation between each question in the radiology literacy tool and the quiz grade

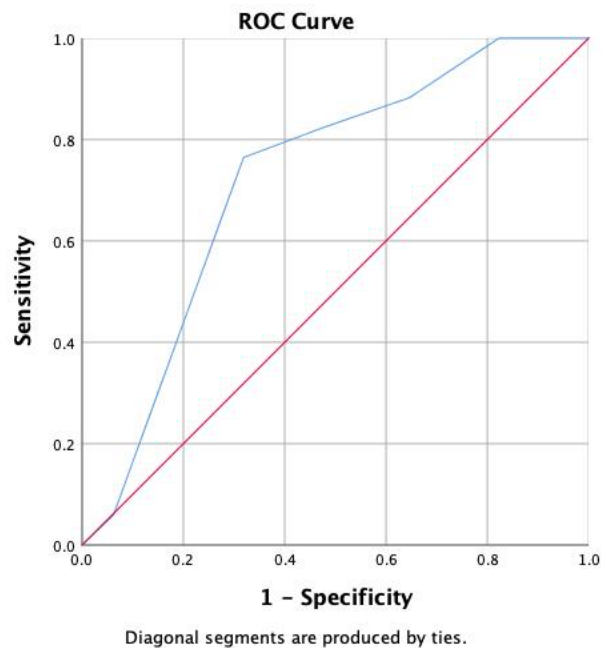


Figure IV. 1. Receiver Operating Characteristics (ROC) curve of patients' understanding of the quiz and their radiology literacy outcomes

Demographic characteristics	Average
Level of education	
• Some school & high school	44.31
• Some college	46.28
• College degree and above	57.64
Income	
• <\$10,00	51.97
• \$10,000–\$19,999	48.45
• \$20,000–\$39,999	47.46
• \$40,000–\$59,999	52.20
• \$60,000–\$79,999	59.82
• ≥\$80,000	61.10
Smoking	
• Yes	46.90
• No	57.30
Chronic diseases	
• Yes	50
• No	55.08

Table IV. 3. Demographic characteristics.

Total of 10 questions with a total score of 100 (10 points per question). This method used in previous study [1]. The mean of the radiology literacy was calculated for each of the characteristics of the study participants.

4. Discussion

Based on a review of previous studies, we did not find a study that designed a tool to measure radiology literacy. The closest study to what we are doing is the one that studied health literacy in vascular and interventional radiology knowledge of patients [104]. The materials available to vascular patients were collected from two websites, 25 resources from the Cardiovascular and Interventional Radiology Society of Europe (CIRSE) website and 31 resources from the Society of Interventional Radiology (SIR) website. Following the collection of these materials, 65 articles were analyzed for their specific level of readability using the following 10 quantitative scales: Flesch–Kincaid Grade Level, Flesch Reading Ease, Simple Measure of Gobbledygook, New Fog Count, Coleman–Liau index, Gunning fog index, Raygor Readability Estimate, Fry graph, and New Dale–Chall. The study concluded that the reading level of the subject being tested was too difficult for most to fully understand. In our study, instead of focusing on the level of radiology awareness of patients, we are focusing on the materials available to the patients. This study does not allow us to determine the radiology awareness of a specific group of people in society such as a rural or urban resident. We looked for studies that set standards for health literacy. There was also a study that measured hypertension literacy [106]. Some topics such as diabetes literacy had many studies. In the radiology field, most studies were concerned with increasing the productivity of radiologists and speeding up the report development process. There were a few studies that were working to simplify radiology reports. There was no study that was examining radiology literacy in patients.

In this study, we designed a tool to determine the extent of radiology literacy among patients. The questions were developed by a group of specialists in the radiology and health informatics fields. We tested the tool by presenting it to two groups, the intervention and

control groups. The same case was used with two different designs. The first design is currently in use and the other design was modified in a way that made it simpler without changing the content. The radiology literacy was measured using a tool that consisted of 10 questions. Three of the questions were excluded because the P-value was greater than .05 in one or both of the groups. The correlation factor between the radiology literacy tool and the quiz results for the intervention and controls groups was (Pearson 0.537, P .00) and (Pearson 0.517, P .00), respectively. We measured the radiology literacy for certain participant characteristics and found that radiology literacy increases as the educational level of the participants increases. There is a decline in awareness until the level of income reaches \$20,000 to \$29,999. At this point, the level of awareness begins to increase. Nonsmokers had a 10.4 higher awareness than smokers and people with chronic diseases were more likely to have a lower radiology literacy than healthy people at a rate of 5.08. Determining radiology knowledge and identifying where this knowledge is lacking is a key part in helping the health system address this knowledge deficit. For example, those who are in the middle-income category, smokers, or have chronic diseases can be targeted to increase their radiology literacy levels. The tool can also be used for residents in rural areas to develop health care in this region.

5. Conclusion

This study provides a tool that can measure the extent of health awareness in the radiology field. The study is the first of its kind and the first step in developing tools to measure radiology awareness. This study will help specialists in radiology modify or create new reporting methods by providing the specialists with knowledge about the general public's radiology awareness. The knowledge that the study provides will allow patients to be better understood and allow the radiology field to better meet patients' needs.

V. HEALTH CONSUMER SOCIAL ECONOMIC FACTORS AND HEALTH CONDITIONS AS PREDICTOR FOR HEALTH LITERACY IN RADIOLOGY DOMAIN

1. Introduction

Diagnostic radiology is involved in many health conditions including cancers and car accidents. Cancer is one of the primary challenges in the world and is the second leading cause of death in the United States of America [121]. The incidence of cancer in the United States is expected to increase between 2010 and 2020 [122]. The rate of cancer cases in men is expected to increase by 24.1%, which equates to approximately one million new cases. For women, the rate of new cancer cases is expected to increase by 20.6%, which equates to approximately 900,000 new cases [122].

Many studies examine how patients' involvement in their treatment contribute to the success of the treatment[88, 123-127]. This involvement is at odds with other obstacles that could impact treatment, the most important of which is a lack of health awareness [128-130]. The radiology field has many studies that show the desire of radiologists to give patients more power to access their radiology reports[131, 132]. Doctors are also anxious about discussing radiology treatments with patients as patients generally have low levels of radiology knowledge[30, 133]. There is an urgent need to know about the important factors that influence and determine the extent of radiology awareness [134-136]. This study will work to identify the most important factors of health consumer social economics and health conditions as a predictor for health literacy in the radiology domain.

2. Methodology

2.1 Study population & recruitment

We conducted this study through Amazon and obtained 616 total participants. The participants were given \$0.41 for their participation. The participants must have been a US citizen, must live in the United States, and be fluent in English. This study included participants from all 50 states. The sample was distinguished by age, ethnic, financial, health, religious, educational, and job status. The questionnaire was uploaded to Qualtrics and then linked to Amazon for publishing. The study was approved by the University of Wisconsin-Milwaukee (#20.230)

2.2 Study setting & statistical analysis

This study used SPSS software for data analysis. To assess the extent of radiation awareness, we used a tool developed in a previous study [137]. The tool used 10 questions to measure the extent of radiology awareness among people. Each participant was given a set of 100 points; each question was worth 10 points. The questions are listed below:

1. The radiological modality that uses a magnetic field to create images of the inside of your body is (CT, MRI, NM, don't know)
2. The radiological modality that uses X-rays to create images of the inside of your body is (CT, MRI, NM, don't know)
3. The radiological modality that uses small amounts of radioactive material to create images of the inside of your body is (CT, MRI, NM, don't know)
4. All radiology modalities use radiation in the scans (yes, no, don't know)
5. There is no limit to do many X-ray scans in per year (yes, no, don't know)

6. The body can filter all the radiation from the body at the end of the imaging scan day
(yes, no, don't know)
7. This is a kidney image (yes, no, don't know) (Figure V. 1)

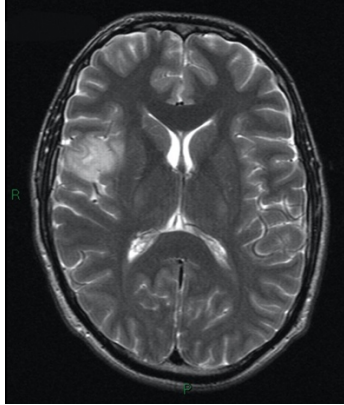


Figure V. 1. Brain axial MRI image

8. It's normal that radiology images appear in white and gray colors (yes, no, don't know)
9. All the imaging tests have the same preparation instructions (yes, no, don't know)
10. The radiology scan that requires no metal on the body is (ultrasound, MRI, don't know)

The 19 factors were divided into two groups, social-economic factors, and health conditions. We calculated the P-value for each factor through the Pearson Chi-square square and multiple linear regression to quantify the association between the characteristics and radiology literacy. We used the regression graph to show the association between social-economic factors and health conditions and how these factors relate to radiology literacy.

3. Results

The significant factors were divided into two groups: social-economic factors and health conditions from the main table (Table V. 1, 2, 3). The list of social characteristics include age, gender, level of education, smoking, income, insurance, race, insurance, and employment

status. Health status includes chronic diseases, disabilities, or disorder. Patient experience with any type of radiology scan and access to radiology reports is also included. Multiple linear regression indicated that 15 of the 19 social-economic factors and health conditions were significantly associated with radiology literacy ($P < .05$). Only 12 of the 19 factors were significant by using Pearson Chi-Square ($P < .05$). The r square linear of all the 19 factors was 0.201 as shown in Figure V. 3. Stepwise linear regression analysis demonstrated the r square linear of the nine factors, which are level of education, smoking, radiology experience, insurance status, white race, employment status, disability status, gender, and income at 0.209 (Figure V. 2).

Characteristics	Total out of 616
Age <ul style="list-style-type: none"> • <20–29 years • 30–49 years • 50+ years 	252 274 90
Gender <ul style="list-style-type: none"> • Male • Female 	360 256
Level of education <ul style="list-style-type: none"> • Some school • High school • Some college • College degree and above 	10 41 180 385
Religion <ul style="list-style-type: none"> • I belong to a formal religious group • I do not have a formal religion, nor am I a spiritual person • I consider myself spiritual, but not religious • Prefer not to say 	312 128 158 18
Smoking <ul style="list-style-type: none"> • Yes • No 	242 374

English is the first language <ul style="list-style-type: none"> • YES • NO 	555 61
Income <ul style="list-style-type: none"> • <\$10,00 • \$10,000–\$19,999 • \$20,000–\$39,999 • \$40,000–\$59,999 • \$60,000–\$79,999 • ≥\$80,000 	61 84 138 136 115 82
Parent status <ul style="list-style-type: none"> • No children • Has children 	311 305
Race <ul style="list-style-type: none"> • White • Black or African American & American Indian or Alaska Native & Other • Asian & Native Hawaiian or Pacific Islander 	392 75 149
Employment Status <ul style="list-style-type: none"> • Currently employed • looking for work • Unemployed and do not look for work 	492 71 53
Chronic condition <ul style="list-style-type: none"> • Yes • No 	226 390
Don't have any condition of Disability OR Disorder <ul style="list-style-type: none"> • Yes • No 	369 247
Don't have Insurance <ul style="list-style-type: none"> • Yes • No 	94 522
Seen a radiology report before <ul style="list-style-type: none"> • Yes • No 	417 199
Done radiology scanning before <ul style="list-style-type: none"> • Yes • NO 	468 148

Table V. 1. Demographic results

Characteristic	P value (Pearson Chi-Square)	P value (Multiple linear regression)
Age	.319	.000
Gender	.011	.000
Education	.000	.000
Religion	.618	.543
Smoking	.000	.000
language	.467	.675
Income	.000	.000
Race (White)	.000	.000
Race (Black or African American & American Indian or Alaska Native & Other)	.169	.015
Race (Asian & Native Hawaiian or pacific islander)	.003	.011
Insurance status	.000	.000
Employment status (Currently employed)	.125	.009
Employment status (Unemployed and do not look for work)	.027	.003

Table V. 2. Significant factors of the social-economic

Cartelistic	P value (Pearson Chi-Square)	P value (Multiple linear regression)
Chronic condition	.020	.013
Don't have any condition of Disability OR Disorder 12	.001	.000
Don't have Insurance 6	.000	.000
Seen Radiology report	.091	.000
History scanning with radiology	.001	.001

Table V. 3. Significant factors of the Health condition

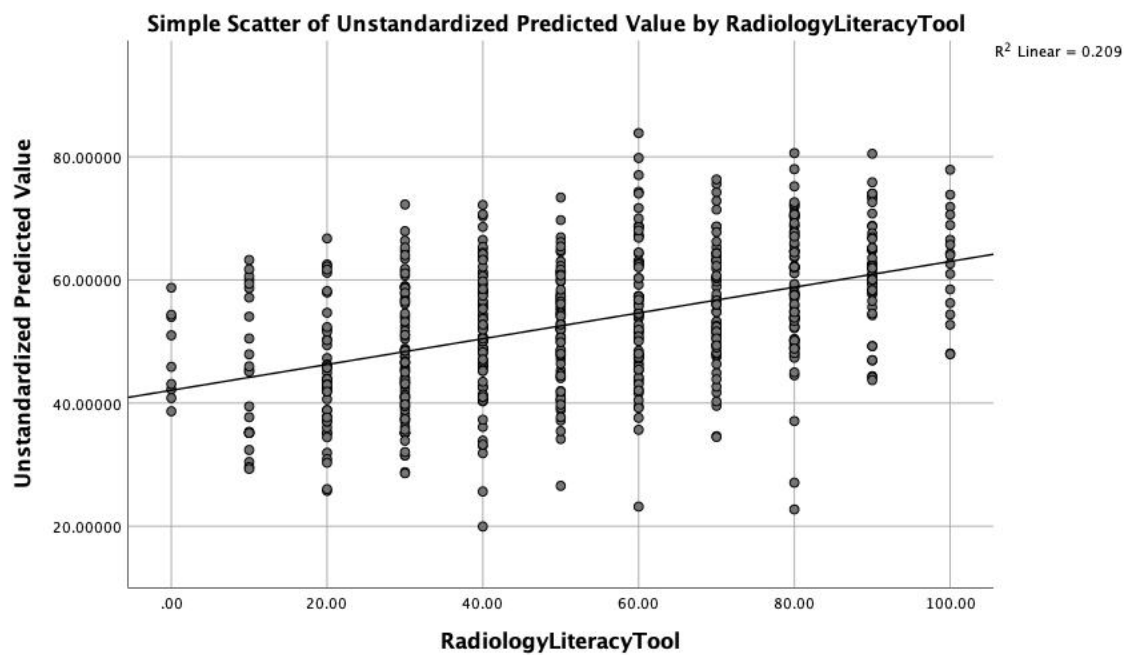


Figure V. 2. Scatter plots of the nine factors vs the radiology literacy tool

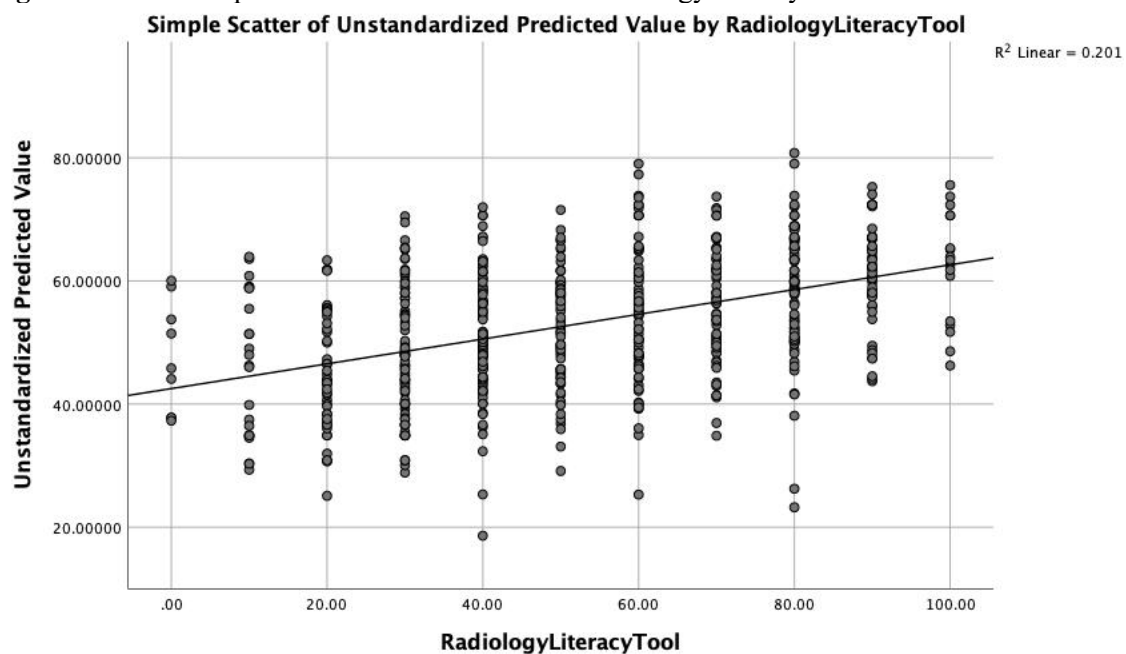


Figure V. 3. Scatter plots of the 19 factors vs the radiology literacy tool

There is a diversity in the rates of the participants and the nine characteristics that have been identified as having a good ability to predict radiology knowledge. The rate of radiology awareness is greater for women than men at 58.43 and 49.58, respectively. As for income, the highest level of awareness was for those whose annual income was greater than \$ 80,000 at 61.10. People with income from \$20,000 to \$ 39,999 have the lowest radiology awareness with

an average of 47.46. Whites were the majority of the participants and the results showed that their awareness was 56.12 while the rest of the races were at 48.12. For education, we noted that radiology awareness increases with an increase in level of education. The awareness of a radiology among high school students was slightly higher than students who had not completed college at a rate of 46.58 and 46.28, respectively. We also find that the rate of awareness among those suffering from health problems in disability or disorder is 48.18 and the rate of awareness among others is 56.58. Incapacity problems of disability or disorder include the following 11 components:

1. Mental Illness or Emotional Disturbance
2. Intellectual Disability
3. Autism Spectrum
4. Other Developmental Disability (Epilepsy, Cerebral Palsy, Neurological Impairment)
5. Alcohol-Related Disorder
6. Drug/Substance-Related Disorder
7. Opioid-Related Disorder
8. Mobility Impairment
9. Hearing Impairment
10. Visual Impairment
11. Speech Impairment

The results also showed that the awareness rate for those who worked was higher than those who did not work at 51.94 and 58.31, respectively. Employment status was considered to influence radiology awareness. Employment status also included those who were retired. The majority of our participants (468 participants) had health insurance while 94 participants had no insurance. The results showed that the level of radiology awareness for those who had

insurance was higher than those who do not have insurance at 55 and 43.30, respectively. The study also showed that awareness among smokers was 46.90, a score that was lower than that of non-smokers. The last radiological awareness indication was the patient's experience with radiology examinations. The study showed that this had a direct relationship between the indicator and the increase in radiology awareness rate.

Predictor	Charcharis	NO (Average-Literacy)	
Gender	Male	360	49.58
	Female	255	58.43
Race	White	392	56.12
	Other	224	48.12
Income	<\$10,00	61	51.97
	\$10,000–\$19,999	84	48.45
	\$20,000–\$39,999	138	47.46
	\$40,000–\$59,999	136	52.20
	\$60,000–\$79,999	115	59.83
	≥\$80,000	82	61.10
Level of education	Some school	10	35
	High school	41	46.58
	Some college	180	46.28
	College degree and above	385	57.63
Disability or disorder	Yes	247	48.18
	No	369	56.58
Employment status	Employed	492	51.94
	Not employed	124	58.31
Insurance status	Yes	522	55
	No	94	43.30
Smoking status	Yes	242	46.90
	No	374	57.30
History scanning with radiology	Yes	468	55.04
	No	148	47.43

Table V. 4. Predictive factors that have a high association with the radiology literacy tool

4. Discussion

No previous study investigated awareness of radiology using a similar measure as our study. The earlier versions of our study were based on a questionnaire that asked participants about the extent of their radiology knowledge [134-136, 138-140]. A study conducted in a European country using medical students in their final year of school investigated their

knowledge of interventional radiology (IR) [138]. A similar study was conducted in Canada on medical school students to determine their level of cognitive awareness of IR [134]. The study also worked to determine radiology awareness in students to help in the development of college curricula [134]. We found that many studies focused on awareness of radiation risks [141-143]. These previous studies were predominantly based on a subjective type of questionnaire. Previous studies had focused on particular radiology topics such as radiation protection. These studies could have been applied to several countries and also did not focus on the most important indicators that helped to determine radiology awareness. These studies focused on health workers such as doctors and medical assistants. Our study is unique because it relies on a scale that determines the level of radiology awareness. The factors were divided into two groups, consumer social-economic factors and health conditions. We have also identified the most important factors affecting the level of awareness in radiology through the p-value of Pearson Chi-square square and regression. We concluded that our model contains the most important indicators of radiology literacy using a stepwise linear regression. This type of regression analysis demonstrated that the levels of education, smoking, radiology experience, insurance status, white race, employment status, disability status, gender, and income were the strongest predictors of radiology literacy. This study will assist in the development of the cognitive level of the radiology field. The outputs of the study could be used in the development of medical college curricula and will also help in the process of writing radiology reports that work best for the majority of patients.

5. Conclusion

This study is unique as it diagnoses the most important factors impacting health awareness of the radiology field. We have succeeded in identifying factors by comparing social and health factors and using these to find links to radiology awareness. We used a scale that shows the extent of radiology literacy among study participants. This study will help researchers find ways to make patients the focus of various areas of radiology. The development of radiology, radiology reports, and medical school curricula are not immune to patients' understanding and needs.

VI. DESIGNING A CONSUMER-FRIENDLY RADIOLOGY REPORT USING A PATIENT-CENTERED APPROACH

1. Introduction

Radiology reports are one of the tools that enable patients to learn about their health [144]. Patients are able to obtain copies of their reports through an electronic portal or a paper copy directly from the radiology department [144]. In a previous study, we found that many health care providers do not provide a full radiology report to patients [92]. Only 98 out of 110 healthcare providers allow patients to obtain their reports, but not the images [92]. The reasons for these limitations relate to an overall lack of patient understanding of the complete radiology report [84, 92]. This issue could cause increased anxiety in patients and could even have negative health effects. Some studies have shown a lack of preference regarding radiologists providing images to patients [52]. The first target of the current radiology report is referring physicians, not the patients themselves [81]. Some studies have shown that patients have a desire to obtain their complete radiology report(s) [20, 27, 83].

A patient-friendly radiology report should be designed to increase patient understanding of the report. Patient desires should be recognized and included into the modified report. The previous study conducted a survey of four online discussion forums to determine patient needs and desires for their radiology reports [145]. Those sites were Yahoo Answers, Reddit.com, Quora, and Wiki Answers. The results of this study were used to design the radiology report model in this current study. The current study is intended to be used to develop various radiology reports.

2. Methods

2.1 Study population & recruitment

There were 616 participants recruited via a HIT posted by Amazon's MTurk. Our study was based on an interventional study and is divided into two groups, the intervention group (n = 296) and the control group (n = 320). The demographic of the two groups shows no significant difference except for gender (Table VI. 1). There is also no significant difference in health literacy between the two groups (Table VI. 2). The participants who completed the survey received \$0.41 USD in their Amazon.com account and had the same chance of being allocated to either the control or intervention group. The random assignment of the participants was done by computer using the online survey platform, Qualtrics.com. The study was approved by the IRB of the University of Wisconsin-Milwaukee (# 20.230).

Characteristics	Control Group		Intervention Group		P value (Pearson Chi-Square)
Age					.72
• <20–29 years	39.4%	126	42.6%	126	
• 30–49 years	45.9%	147	43.2%	128	
• 50+ years	14.7%	47	14.2%	42	
Gender					.01
• Male	63.4%	203	53.2%	157	
• Female	36.6%	117	46.8%	138	
Occupation					.25
• Radiologists	13.4%	43	12.8%	38	
• Health practitioner	23.4%	76	18.6%	55	
• Other	62.8%		68.6%		
	201		203		
Level of education					.60
• Some school & high school	8.8%	28	7.8%	23	
• Some college	27.5%	88	31.1%	92	

<ul style="list-style-type: none"> College degree and above 	63.7%	204	61.1%	181	
Race <ul style="list-style-type: none"> White Black or African American & American Indian or Alaska Native & Other Asian & Native Hawaiian or Pacific Islander 	62.8%	201	64.5%	191	.19
English is the language <ul style="list-style-type: none"> YES NO 	91.3%	292	88.9%	263	.319
Income <ul style="list-style-type: none"> <\$10,00 \$10,000–\$19,999 \$20,000–\$39,999 \$40,000–\$59,999 \$60,000–\$79,999 ≥\$80,000 	9.1%	29	10.8%	32	.73
Seen a radiology report before <ul style="list-style-type: none"> Yes No 	66.3%	212	69.3%	205	.42
Done radiology scanning before <ul style="list-style-type: none"> Yes NO 	75.6%	242	76.4%	226	.83
	24.4%	78	23.6%	70	

Table VI. 1. Demographic results of control group & intervention group

Health Literacy				P value (Pearson Chi-Square)		
<ol style="list-style-type: none"> How often are appointment slips written in a way that is easy to read and understand? (1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never How often are medical forms difficult to understand and fill out? (1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never How often do you have difficulty understanding written information your health care provider gives you? (1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never How often do you have problems learning about your medical condition because of difficulty understanding written information? (1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never How confident are you filling out medical forms by yourself? (1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never How confident do you feel you are able to follow the instructions on the label of a medication bottle? (1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never How often do you have someone help you read hospital materials? (1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never 				.94		
Group	Control			Intervention		
	Adequate	Marginal	Inadequate	Adequate	Marginal	Inadequate
Health Literacy	23.8% 76	58.1% 186	18.1% 58	23.5% 145	57.8% 356	18.7% 115

Table VI. 2. Health literacy level based on STOFHLA (Short Test of Functional Health Literacy in Adults) scores: inadequate health literacy (0–16), marginal health literacy (17–22), and adequate health literacy (23–36).

2.2 Survey design

In the pilot study, we provided participants with the same general design but used the following three cases: CT brain tumor, X-ray femur fracture, and MRI of the lumbar spine. The results of the pilot study showed that the design can be applied to any radiology cases or modalities. The majority of the patient questions in the previous study involved the MRI [145]. For this reason, one of the MRI cases was used in the study. The revised and original MRI lumbar spinal reports were provided to the participants based on group. The original MRI

report was provided to the control group (Figure VI. 1 and 2). The revised report was provided to the intervention group (Figure VI. 3, 4, 5). In the revised report, the following five images were included: original, modified, normal case (standard), worse case (standard), and images from anatomy atlas [146].

2.2.1 Revised report (Notes representations)

Based on the literature review, we organized the report to provide what we consider to be the “best” data. The best data are defined as the data that the reader can use limited thinking power to read and interpret [147-149]. Many studies have recommended using different colors to improve understanding [150, 151] and also confirmed that data must be displayed effectively [149, 152, 153]. To achieve both of these goals, data must be connected and presented in an understandable way. Our new design features the following characteristics:

1. Definitions were provided for any medical terminology. These terms were also underlined.
2. Report structure was modified to be more organized.
3. Different colors were incorporated to improve report navigation.
4. Report includes timeframe for treatment as well as instructions and resource information.
5. A summary table was incorporated with some general recommendations (Figure VI. 5).

2.2.2 Revised report (image visualizations)

For the images, study participants were provided with two radiology images, the revised and original images. In the first design, patients were only able to see the original images

(Figure VI. 1). In the second design, a total of five images were included (Figure VI. 3). The original image will be provided unchanged and the second case will include the modified images that are intended to make the report more understandable and easier to comprehend (Figure VI. 3). The modified image is supported by many studies that suggest that providing both images can be useful [154, 155]. Two of the other images will be standard radiology images that show the normal and worst-case scenarios for a patient's particular indication. These images can help the patient compare his or her image with other examples (Figure VI. 3). The image of what is "normal" can be an image that has been taken from a volunteer patient and saved in the database. The fifth image will be in .jpg format and will come from an atlas of images of the target organ(s) (Figure VI. 3) [146]. The revised design would like to take advantage of how radiologists learned how to read images while in medical school and will apply these general principals to patients and other non-radiologists. The education programs for radiologists were reviewed as we worked to find ways to create a mental representation of the human body [156]. Radiologists are often asked to look at radiographs of healthy cases and then look at abnormal cases. The modified, standard, and atlas images can allow for the process to proceed more smoothly and the task could also be given to assistants to provide them with valuable training.

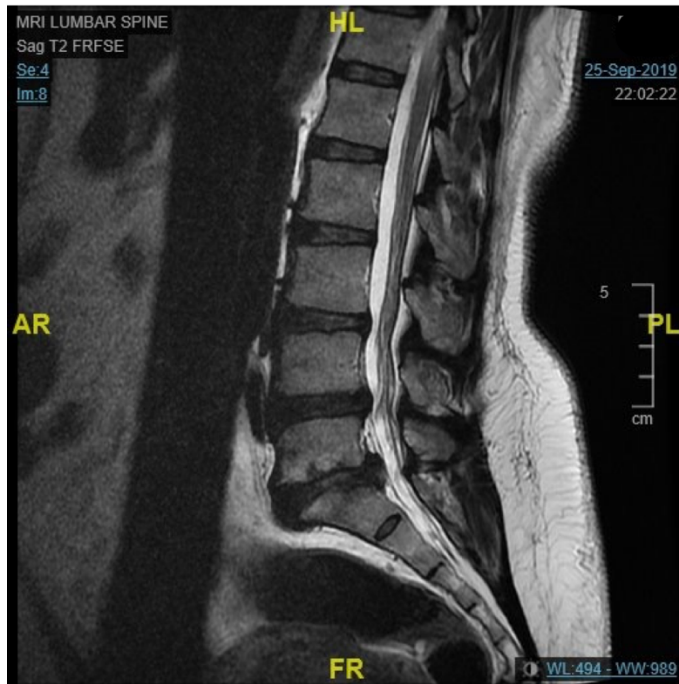


Figure VI. 1. Original design of the MRI Lumbar spine image

- Technique: Multiple sequential MRI of the spine was obtained pre IV gadolinium administration.
- Comparison: None.
- FINDINGS: Mild straightening of the lumbar spine likely due to muscular spasm, otherwise the alignment is maintained. No evidence of acute or chronic fracture. Conus medullaris and cauda equina nerve roots are unremarkable.
- At L3-L4 level, there is mild diffuse disc bulge indenting the thecal sac without significant spinal canal stenosis, however there is mild bilateral neural foraminal narrowing, slightly more on the right along with facet joint arthropathy and ligamentum flavum hypertrophy.
- At L4-L5 level, there is diffuse disc bulge, altogether with ligamentum flavum hypertrophy and facet joint arthropathy resulting in mild to moderate spinal canal stenosis and bilateral neural foraminal narrowing, moderate on the left and moderate to severe on the right.
- At L5-S1 level there is fatty end plate degenerative changes with end plate irregularities. Reduced disc height with diffuse disc bulge and posterior broad-based central disc protrusion compressing the lateral recesses bilaterally and both traversing S1 nerve roots. Together with the facet joint arthropathy and ligamentum flavum hypertrophy of the diffuse disc bulge causing bilateral moderate neural foraminal stenoses. No significant thecal sac compression.
- Conclusion: Multilevel degenerative disc disease as detailed above, for clinical correlation.

Figure VI. 2. Original design of the MRI Lumbar spine report

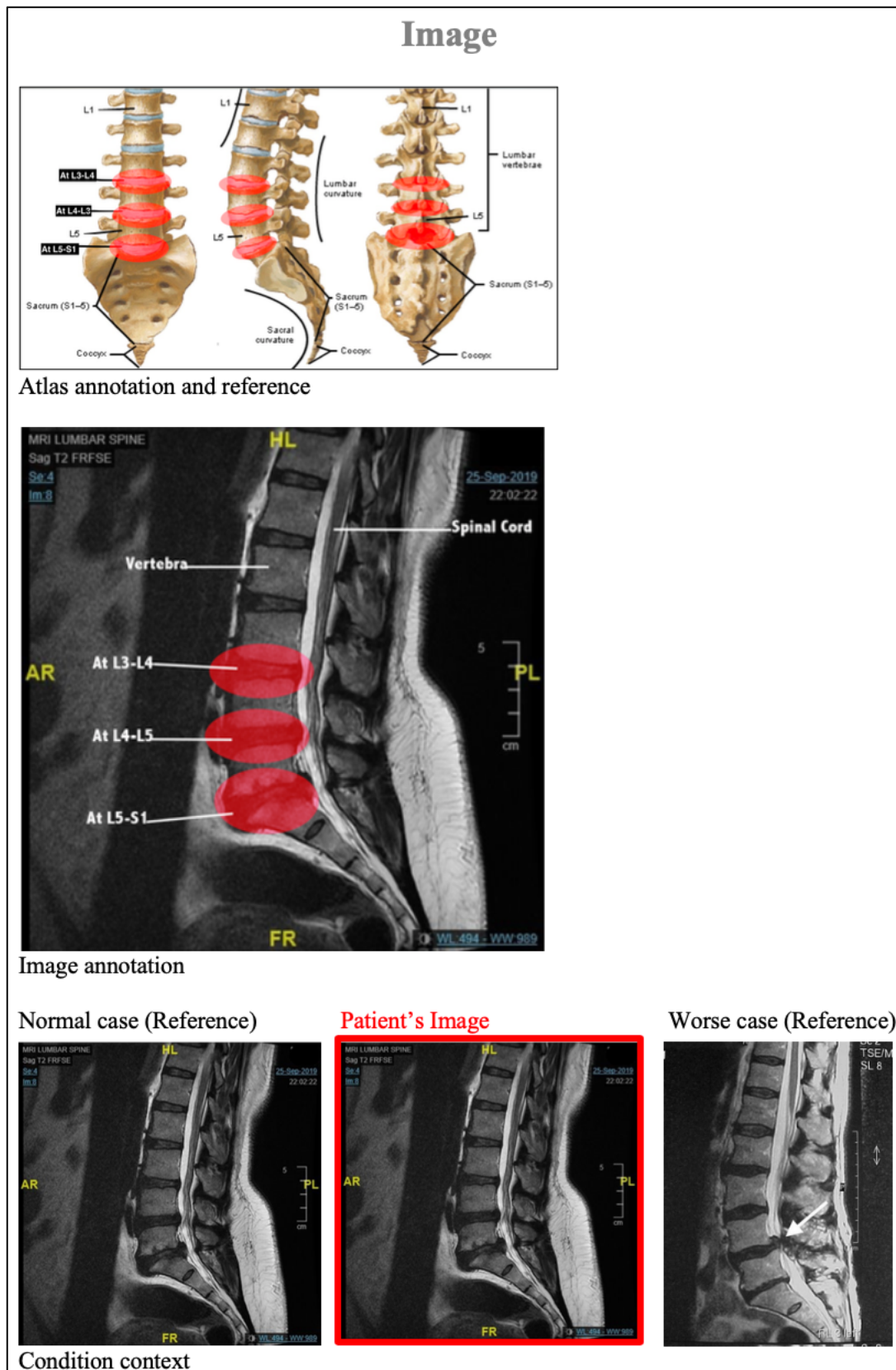


Figure VI. 3. Revised design of the MRI Lumbar spine image

Notes

Patient name: XXXXX
 Patient Name: XXXXX
 ID: 000000000
 Age: 45
 Sex: Male

Doctors
 Referring physician: Dr. [REDACTED]
 Radiologist: Dr. [REDACTED]
 Procedure: MRI Lumbar spine


FINDINGS: Patient has three issues	Terminology & Explanation
<p>1. At L3-L4 in the image There is mild diffuse disc bulge indenting the <u>thecal sac</u> without significant spinal canal <u>stenosis</u>, however there is mild <u>bilateral neural foraminal</u> narrowing, slightly more on the right along with <u>facet joint arthropathy</u> and <u>ligamentum flavum</u> hypertrophy.</p>	<p>Thecal sac: A tube of dura mater that surrounds the spinal cord Dura mater: The tough outermost membrane enveloping the brain and spinal cord Stenosis: The abnormal narrowing of a passage in the body Bilateral neural foraminal: It occurs when the small openings between the bones in your spine, called the neural foramina, narrowed or tighten Facet joints are a set of synovial, plane joints between the articular processes of two adjacent vertebrae An arthropathy: A disease of a joint ligamentum flavum: Joint Hypertrophy: The enlargement of the cells Posterior The back part A disc protrusion The spine is intact but bulge when one or more of the discs are under pressure.</p>
<p>2. At L4-L5 in the image There is diffuse disc bulge, altogether with ligamentum flavum <u>hypertrophy</u> and facet joint arthropathy resulting in mild to moderate spinal canal stenosis and bilateral neural foraminal narrowing, moderate on the left and moderate to severe on the right.</p>	<p>To translate medical jargon into consumer-oriented lay language please copy any full text and post it in this link http://clinicalnotesaid.org</p> <p>For more information about your case</p> 
<p>3. At L5-S1 in the image There are fatty end plate degenerative changes with end plate irregularities. Reduced disc height with diffuse disc bulge and <u>posterior</u> broad-based central <u>disc protrusion</u> compressing the lateral recesses bilaterally and both traversing S1 nerve roots. Together with the facet joint arthropathy and ligamentum flavum hypertrophy of the diffuse disc bulge causing bilateral moderate neural foraminal stenoses. No significant thecal sac compression.</p>	

Figure VI. 4. Revised design of the MRI Lumbar spine report

Summary

The discs in the spine are showing signs of narrowing and irregularities which is usually due to wear and tear. These abnormalities are seen at least in 3 levels as in the patient image.

L3/L4

Mild degenerative disease-causing bilateral nerve compression. Right more than left.

L4/L5

Moderate degenerative disease causing bilateral moderate to severe nerve compression, right more than left.

L5/S1

Moderate degenerative disc disease causing bilateral moderate nerve compression.

1) Cause of the condition:

Usually is age-related wear and tear, sometimes can be due to trauma.

2) Impact on the patient's physical function:

It is a common cause of low back pain and may be associated with numbness or muscle weakness.

3) Factors that could make the conditions better or worse:

It could be aggravated by wrong posture or wrong exercises, may be relieved by painkillers or laying back.

4) Self-care advice:

Avoid heavy lifting, bed rest, physical therapy, consult a professional and avoid self-diagnosis.

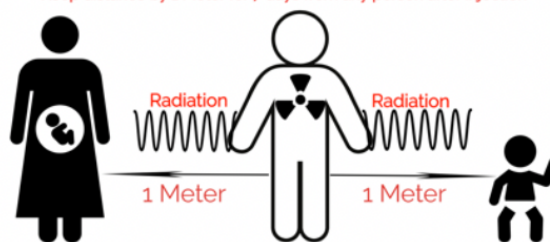
For more information, you should discuss your case with your doctor

Next appointment

Location: Main hospital
Department: Nuclear medicine
Procedure: Whole body bone scan
Date: 2019, Dec 10
Time: 10:15am

Instructions

Keep distance by 1 Meter for 7 days from any person after injection



Please, scan the following barcode for the rest of instructions



Figure VI. 5. Revised design of the MRI Lumbar spine report

2.3 Study setting & statistical analysis

The minimum sample size for each group was 257 participants based on a calculation with G*Power 3.1 with alpha 0.05 and desired power 0.80. Data were downloaded from the Qualtrics.com as an SPSS file for the organization and analysis. The comparison of the two groups was done using Mann–Whitney–Wilcoxon (MWW). The following five concepts were used to evaluate the new design: understanding, cosmetic appearance, perceived ease of use (PEU), acceptance, and preference. Both groups had the same questions about the sociodemographic and health literacy section. Each participant was then assigned randomly by computer to one of the groups. Two surveys will used, one based on the original report structure and the other based on the revised report structure. The control group will have access to the original design of the MRI lumbar spine report. The intervention group will have access to the updated MRI lumbar spine report. The 17 questions will fall under the five concepts as follows: understanding (n = 5) as a quiz, cosmetic appearance (n = 2), PEU (n = 4), acceptance (n = 2), and preference (n = 4). Only 11 questions were provided to the intervention group as additional questions that explored the new design specifically.

2.4 Hypothesis

1. The proposed radiology design will improve patient understanding of the radiology report
2. The proposed radiology design will improve the cosmetic appearance of the radiology report
3. The proposed radiology design will improve the PEU of the radiology report
4. The proposed radiology design will improve the acceptance of the radiology by patients

5. The proposed radiology design will improve the preference of the radiology report among patients
6. The new design will be easier to read than the previous design

3. Results

The design of the radiology report is something that patients can use to better manage their health. Our study has shown that the new design is more readable and understandable than the current design. We noticed that the quiz results in the intervention group were better than the control group by .30 ($P < .05$). The quiz is designed to reflect patient understanding of the radiology report. As a result, we accept our hypothesis that the new radiology design will improve patient understanding of the radiology report. In the second part, participants were more satisfied with the way that the new design looked ($P < .05$) (Table VI. 3). The “looks” of the new design include images and notes. Based on these results, the second hypothesis has been accepted. For PEU, the new design showed that the ability of participants to determine locations where issues appear in the images and understand the content increased by 1.80 ($P < .001$) (Table VI. 3). Based on these results, we accept the hypothesis that the new design will improve the PEU of the radiology report. Figure VI. 6 shows that 46.28% of the intervention group agreed that the ability to understand terminology increased. Additionally, 43.58% of participants agreed that they are comfortable with their ability to access more information about report terminology and their case. Figure VI. 7 showed that 42.57% of participants agreed that adding annotations and additional colors increased understanding. The new design contains additional features such as providing an anatomical portrait from the atlas dictionary for the target organ(s). Figure VI. 8 shows that 43.24% of participants found the atlas image helpful in allowing them to understand the radiology image. Additionally, 44.93% of participants preferred the use of annotations and color in the atlas image [146].

The acceptance of the new radiology report design improved by 0.59 ($P<.001$). This improvement shows that participants were satisfied with how image and notes were presented. Based on these results, we accept the hypothesis that the new design will improve the overall acceptance of the radiology report. Patients prefer to receive the radiology reports using the new design as shown by the improvement of 1.06 ($P<.001$). Figure VI. 9 and 10 both show the acceptance and desire to add features to the radiology report including instructions, barcodes, and a summary table with recommendations. Based on these results, we accept our hypothesis that the new design will improve the preference of the new radiology report. The new design was more readable than the old design based on the improvement of 4.14 ($P<.001$).

Concept	Item	(Average) Original Design (Control group)	(Average) Revised Design (Intervention group)	Difference	P Value (Mann- Whitney)
Understanding	Quiz of 5 questions	2.16	2.51	0.30	.015
Cosmetics appearance	I think that the format and appearance of the notes in the report are easy to look at	6.72	7.11	0.38	.007
Cosmetics appearance	I think that the appearance of the image in the report are easy to read				
Perceived Ease of Use	I am comfortable with my ability to find information in the images and notes.	12.64	14.44	1.80	.000
Perceived Ease of Use	I am comfortable with my ability to figure out the location of issues in the image.				
Perceived Ease of Use	In general, I am comfortable with my ability to understand the content in the images and notes.				
Perceived Ease of Use	I am comfortable with my ability to understand this report and the severity of the case				
Acceptance	In general, I am satisfied with the way this image is presented	6.82	7.41	0.59	.000
Acceptance	In general, I am satisfied with the way the notes in the radiology report are presented				

Preference	I would like to receive my radiology report in this design	14.03	15.10	1.06	.000
Preference	I prefer having my next appointment and instructions in the radiology report				
Preference	I prefer having definitions of the medical terms in the radiology report				
Preference	I prefer having an anatomy atlas image of the same of my case in the radiology report				
Overall		42.44	46.57	4.14	.000

Table VI. 3. Comparison of the original design & revised design

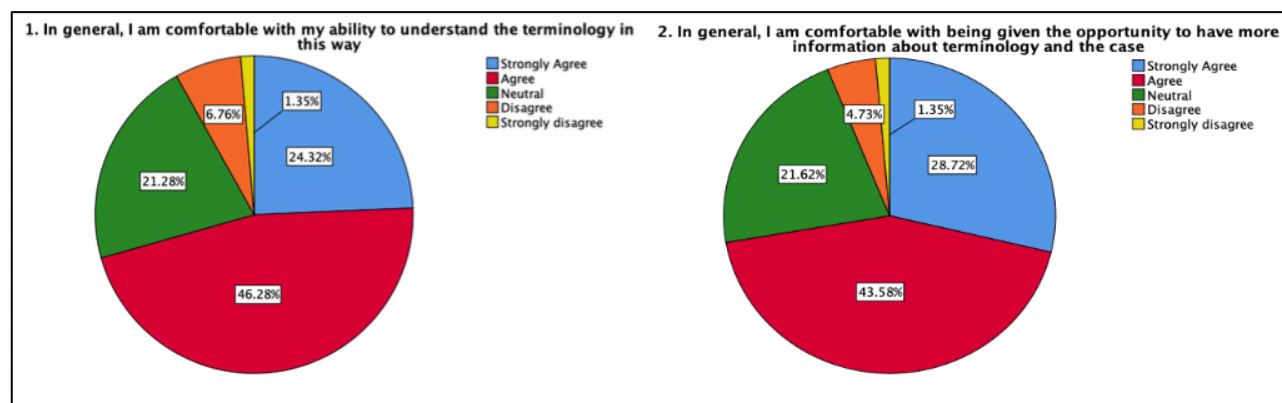


Figure VI. 6. PEU of patient regarding the terminology

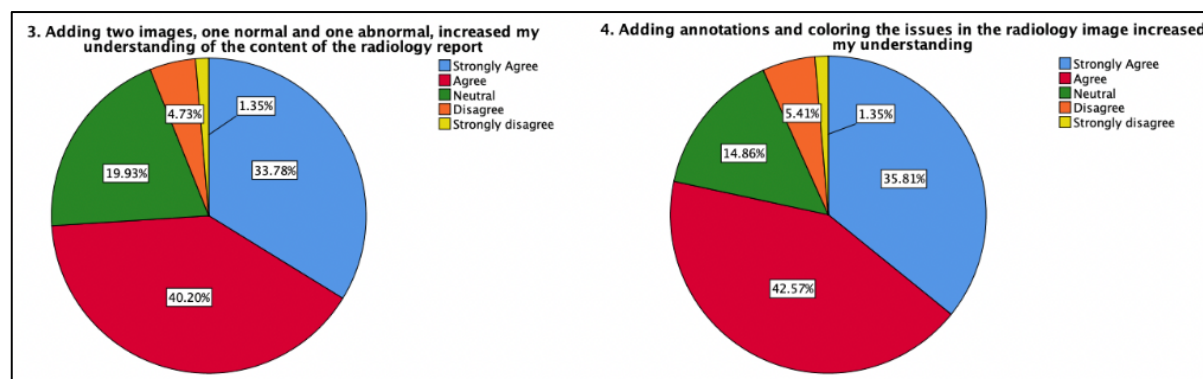


Figure VI. 7. PEU of adding two scenarios and annotations on image

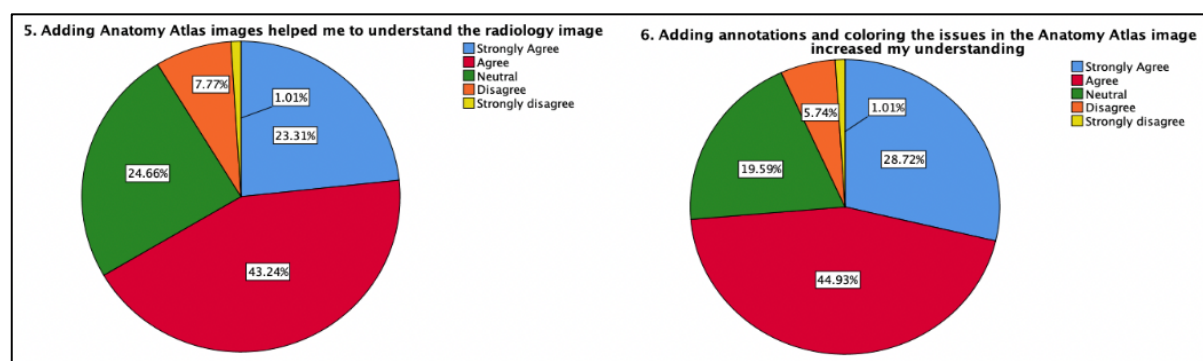


Figure VI. 8. PEU of adding anatomy atlas image with annotations

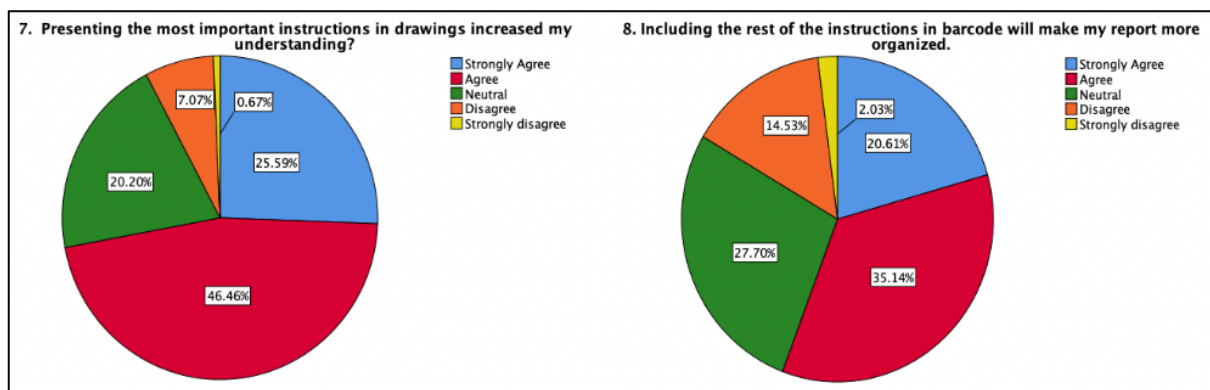


Figure VI. 9. PEU of adding instructions in icons and barcodes

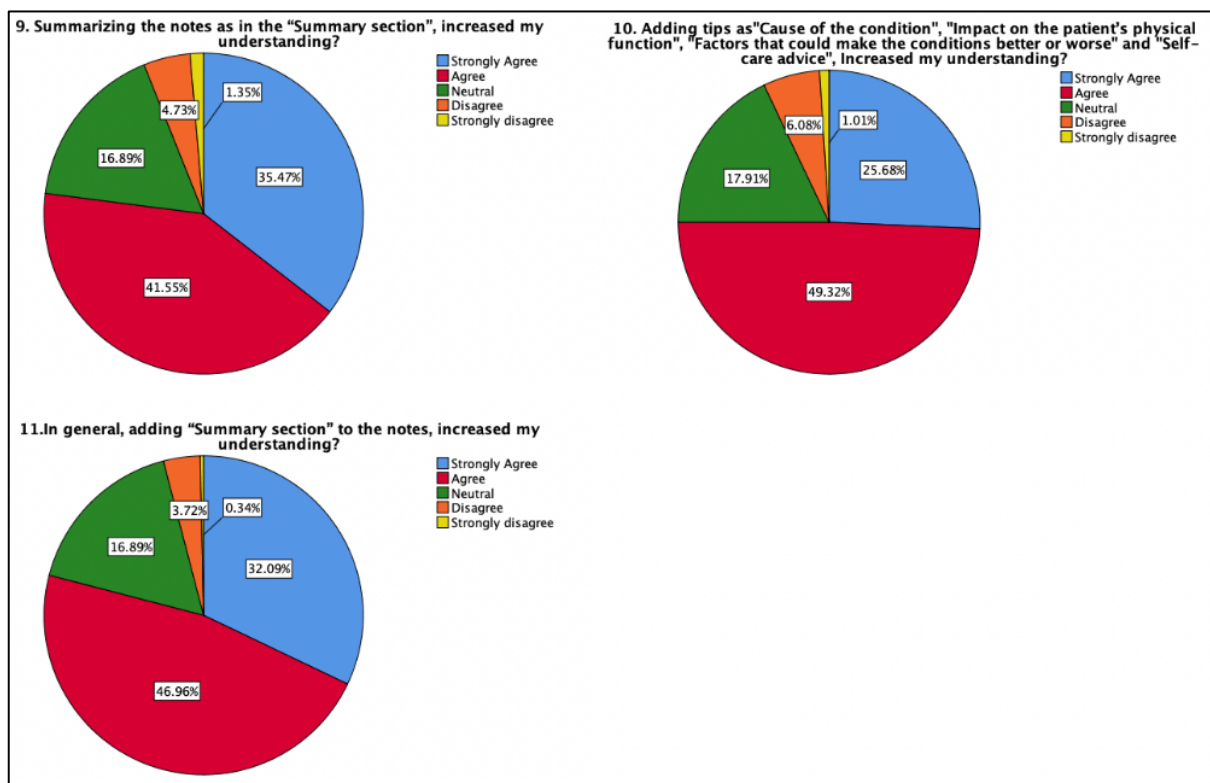


Figure VI. 10. PEU of adding summary section to the report

4. Discussions

Currently, radiology reports are intended for physician use, not patient use [81]. For this reason, some studies have attempted to develop a radiology report that is suitable for patient understanding. Some studies have attempted to develop patient understanding of radiology images [154]. In one study, an explanation feature was added to the images to test patient understanding. The results of the study showed that the modification enhanced patient understanding of the radiology images. Prior work also presented a patient-friendly radiology report for lung cancer screening using a design that depends on feedback from patient advisory groups. The design contained the following: information before the scan, results, and recommendations based on the scan [16]. While these studies were useful, they did not possess patient inclusivity. For example, the first study focused on developing images without examining the radiology explanation in the report and the second study did not provide the original patient image in the report. Since the study did not submit the original report, patients did not have the opportunity to share the reports with consultants.

Our study provides a more patient-friendly radiology report that is applicable for all radiological examinations. We focused on facilitating radiology images and radiologist notes to allow for easier navigation between the two. The notes were divided into the following six sections: the original report, explanation of medical terms, a brochure that related to the patient's particular indication, report summary, and an upcoming appointment reminder. The original report was re-organized and provided without any changes to the content of the report itself. We merged the report with the terminology section by placing a line between the medical terminology section and the original report. The medical terminology section provides the patient with the opportunity to access links that provide further explanation of the terminology. The brochure helps to explain the general medical condition through the barcode provided in

the report. The shortcut section provides a simple explanation of the patient's condition along with general advice. In the upcoming appointment section, we placed important patient information. The patient was provided with his or her original image along with four additional images to facilitate patient understanding of the images.

This study showed that patients can have a high level of understanding of radiology reports if the reports are re-organized and improved. The findings show that the new design is more patient friendly and understandable than the current report. Additionally, the improvements in our design were not related to age, gender, economic status, or ethnic background and health literacy. The participants had a variety of socio-demographic traits (Table VI. 1). We believe that the improved radiology design could increase patient engagement and the enhancements could increase patient understanding of the report. If the patient understands more about his or her report, this could decrease the time that physicians spend talking to patients about the report. This is the first study, to our knowledge, that designs a universal radiology report with this level of comprehensiveness.

5. Conclusion

Our study was able to produce a patient-friendly radiology report with a patient-centered approach. The study relied on exploring patient opinions and desires by collecting the questions posted by patients in online forums. The design was approved of by patients at all socio-demographic levels. We believe that this design can be used effectively by both patients and radiologists.

VII. DISCUSSION AND CONCLUSION

At the beginning of the dissertation, we were concerned with the current radiology report. To investigate this concern, we conducted a scan of previous studies about radiology reports and found that previous studies involved several points about the radiology field. The majority of studies focused on patient and physician satisfaction with current radiology reports. The studies also focused on the understanding of x-ray images using additional notations on images. The notations focused on coloring or location issues in the image, but did not address any issues with the notes. One of the studies designed a radiology report that was more easily understood for patients, but these improvements were only applicable for those who had lung cancer imaging.

The studies did not provide a true solution for current radiology report issues. Diagnosing issues with the current radiology reports is important, but does not ultimately solve a problem. Previous studies about the diagnosis or designs were useful, but did not meet our goals. This dissertation will work to track the problem, diagnose the problem, and provide an appropriate solution for the problem.

First study

After examining the opinions of patients and doctors, we needed to determine the reality of the reports presented in the electronic portals. The aim of the first study was to discuss the gap between the patient web portal and the contents of the full radiology report. The significance of this first goal was to determine the reality of what is contained in electronic portals. The results showed that the vast majority of health portals do not allow access to the entire radiology report. We found that there was a reluctance among health providers to provide this full report to patients and that most providers tended to provide the radiologist's notes without any images. The health providers justified this decision by identifying the negative ramifications of patients being provided the images, but not fully understanding what the

images show. The providers claimed that patients could not be expected to understand the difficult images and that the images could create unnecessary anxiety. The additional patient anxiety could result in doctors having to spend additional time with patients to explain the images and reduce the anxiety. This study was critical in allowing us to understand the extent of the gap between patients and the current reality of radiation reports. The results increased our conviction to proceed with the creation of patient-friendly radiology report design.

Second Study

Our second step was to track what patients were writing on social media about their radiology reports. We collected a variety of radiology questions posted on social media. The results of our work showed a correlation between the problems that patients had with the way that reports and images were presented. The following is a summary of common issues with the radiology reports:

1. Report representation – this refers to issues involving font size, colors, unstructured information, too much information, and confusing content
2. Image visualization – this refers to issues related to the image itself such as resolution, contrast, enhancement, annotation, and color usage
3. Understanding – this refers to questions related to patient understanding including what items require more explanation, unclear medical terms, and general confusion about content

Third & Forth study

This dissertation showed us that there are some overlooked aspects that we can cover. First, we needed to design a tool to measure patients' radiology literacy. We created a 10-question tool to measure the radiology awareness and believe that this tool will be one of the first tools that can be used to measure this type of awareness. Second, we identified the most important factors of health consumers' social, economic, and health conditions to

determine if these items were predictors of health literacy in the radiology field. Our study provided promising results about predictive factors. If we had a greater number of participants, we believe that we could have a better result.

Fifth study

We designed a radiology report that we believe is closer to patient understanding. The new report design outperformed in all six concepts when compared to the current design (Figure VI. 3, 4, 5). The new report demonstrated acceptance of the following six hypotheses:

1. The proposed radiology design will improve patient understanding of the radiology report
2. The proposed radiology design will improve the cosmetic appearance of the radiology report
3. The proposed radiology design will improve the PEU of the radiology report
4. The proposed radiology design will improve the acceptance of the radiology report by patients
5. The proposed radiology design will improve the preference of the radiology report among patients
6. The new design will be easier to read than the previous design

The questionnaire also showed participants' acceptance of the added features in the new design. These features are listed below:

1. Adding two scenarios and annotations on image
2. Adding anatomy Atlas image with annotations
3. Adding instructions in icons and barcodes
4. Adding summary section that written in a lay language

We successfully presented a patient-friendly radiology report design. This design can be applied to any type of radiography. We believe that our design will contribute to a significant improvement in radiology reports. What distinguishes this dissertation from others is that patients were the main focus of the design. We hope that our work will encourage other researchers to present new radiology report designs that have patients' needs and understanding as the primary focus.

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SURVEY

- **Sociodemographic**

1. Age

- a. <20 years
- b. 20–29 years
- c. 30–39 years
- d. 40–49 years
- e. 50–59 years
- f. 60–69 years
- g. 70+ years

2. Gender

- a. Male
- b. Female
- c. Other

3. Occupation

- a. Radiologist
- b. Health practitioner
- c. Other

4. What is your highest level of education?

- a. Some school
- b. High school
- c. Some college
- d. College degree and above

5. ZIP:

If you're in the United States, what's your current zip code:
[zip selection drop list]

6. Race:

- a. White
- b. Black or African American
- c. American Indian or Alaska Native
- d. Asian
- e. Native Hawaiian or Pacific Islander
- f. Unknown

7. Parental Status (select all that apply)

- a. No children
- b. Has minor children, NOT in client's custody
- c. Has children over 18 years old
- d. Expectant parent

- e. Has minor children, in client's custody
 - f. Unknown
8. What best describes your religious preferences? (check one)
- a. I belong to a formal religious group
 - b. I do not have a formal religion, nor am I a spiritual person
 - c. I consider myself spiritual, but not religious
 - d. Unknown
9. Employment Status (check one - select the first outcome that applies)
- a. Competitive and integrated employment
 - b. Other employment
 - c. Non-paid work position (volunteer)
 - d. Unemployed and looking for work
 - e. Not In Labor Force: unemployed but not looking for work, retired, homemaker, student, incarcerated, or psychiatric inpatient
 - f. Unknown
10. Is English the language you most commonly speak at home?
- Yes No
11. Income
- a. Some school
 - b. High school
 - c. Some college
 - d. College degree and above
12. Have you ever seen a radiology report before?
- Yes No
13. Have you had any conditions that needed radiology images for diagnosis? Such X-Ray, CT, MRI, Ultrasound, and PET
- Yes No
14. Do you have any chronic conditions?
- Yes No
15. In the last 12 months, did client smoke cigarettes, vape or use tobacco products?
- Yes No
16. Disability or Disorder (Select all that apply)
- a. Mental Illness or Emotional Disturbance
 - b. Intellectual Disability
 - c. Autism Spectrum
 - d. Other Developmental Disability (Epilepsy, Cerebral Palsy, Neurological Impairment)
 - e. Alcohol Related Disorder

- f. Drug/Substance Related Disorder
- g. Opioid Related Disorder
- h. Mobility Impairment
- i. Hearing Impairment
- j. Visual Impairment
- k. Speech Impairment
- l. Don't have any condition

17. Chronic Medical Condition (Select all that apply)

- a. Hyperlipidemia (High blood fat/High cholesterol)
- b. Cancer
- c. High Blood Pressure
- d. Diabetes
- e. Obesity [based on BMI*, if not then subjective judgment]
- f. Heart attack
- g. Stroke
- h. Other Cardiac Condition
- i. Pulmonary (Emphysema, Chronic Obstructive Pulmonary, Asthma)
- j. Alzheimer's Disease or Dementia
- k. Kidney Disease
- l. Liver Disease (Cirrhosis, Hepatitis A/B/C)
- m. Endocrine Condition (High or Low thyroid, Pituitary , Adrenal disease)
- n. Progressive neurological condition (Multiple Sclerosis, Cerebral palsy, Amyotrophic lateral sclerosis (ALS))
- o. Traumatic Brain Injury
- p. Joint and connective tissue disease (Lupus, Rheumatoid, Unknown arthritis, Osteoporosis, Osteoarthritis)
- q. Other chronic medical condition(s)
- r. Don't have any condition

18. Health Insurance Coverage (Select all that apply)

- a. Medicaid
- b. Medicare
- c. Private Insurance
- d. Child Health Plus
- e. Other Health Insurance
- f. Don't have any insurance

• **Health literacy evaluation**

19. How often are appointment slips written in a way that is easy to read and understand?

(1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never

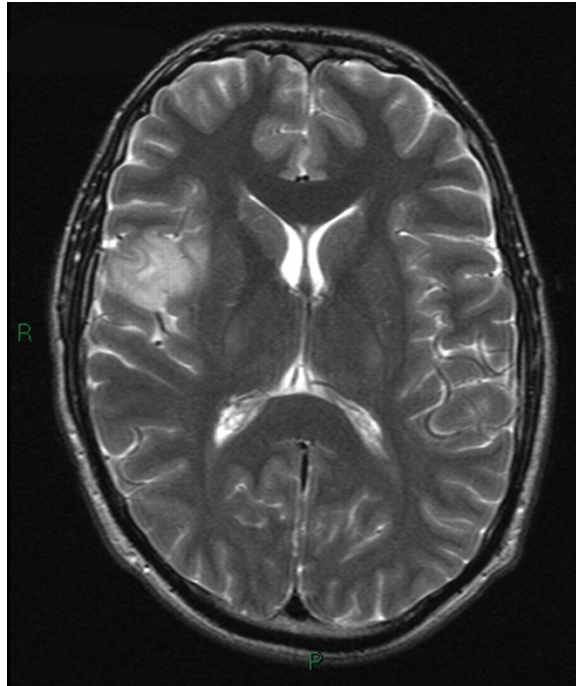
20. How often are medical forms difficult to understand and fill out?

(1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never

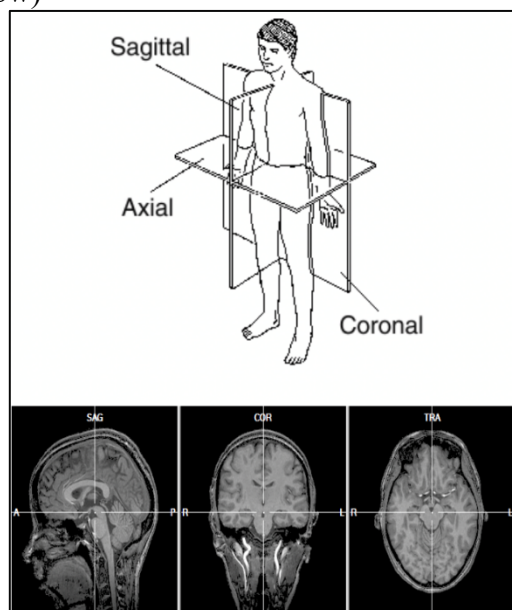
21. How often do you have difficulty understanding written information your health care provider gives you?
(1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never
22. How often do you have problems learning about your medical condition because of difficulty understanding written information?
(1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never
23. How confident are you filling out medical forms by yourself?
(1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never
24. How confident do you feel you are able to follow the instructions on the label of a medication bottle?
(1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never
25. How often do you have someone help you read hospital materials?
(1) Always (2) Often (3) Sometimes (4) Occasionally (5) Never

- **Radiology literacy evaluation**

26. Radiological modality that uses a magnetic field to create images of the inside of your body is (CT, MRI, NM, don't know)
27. Radiological modality that uses X-ray to create images of the inside of your body is (CT, MRI, NM, don't know)
28. Radiological modality that uses small amounts of radioactive material to create images of the inside of your body is (CT, MRI, NM, don't know)
29. All radiology modalities use radiation in the scans (yes, no, don't know)
30. CT use Radiation, which can cause cancer (yes, no, don't know)
31. There is no limit to do many X-ray scans in per year (yes, no, don't know)
32. the body can filtrate all the radiation from the body at the end of the imaging scan day (yes, no, don't know)

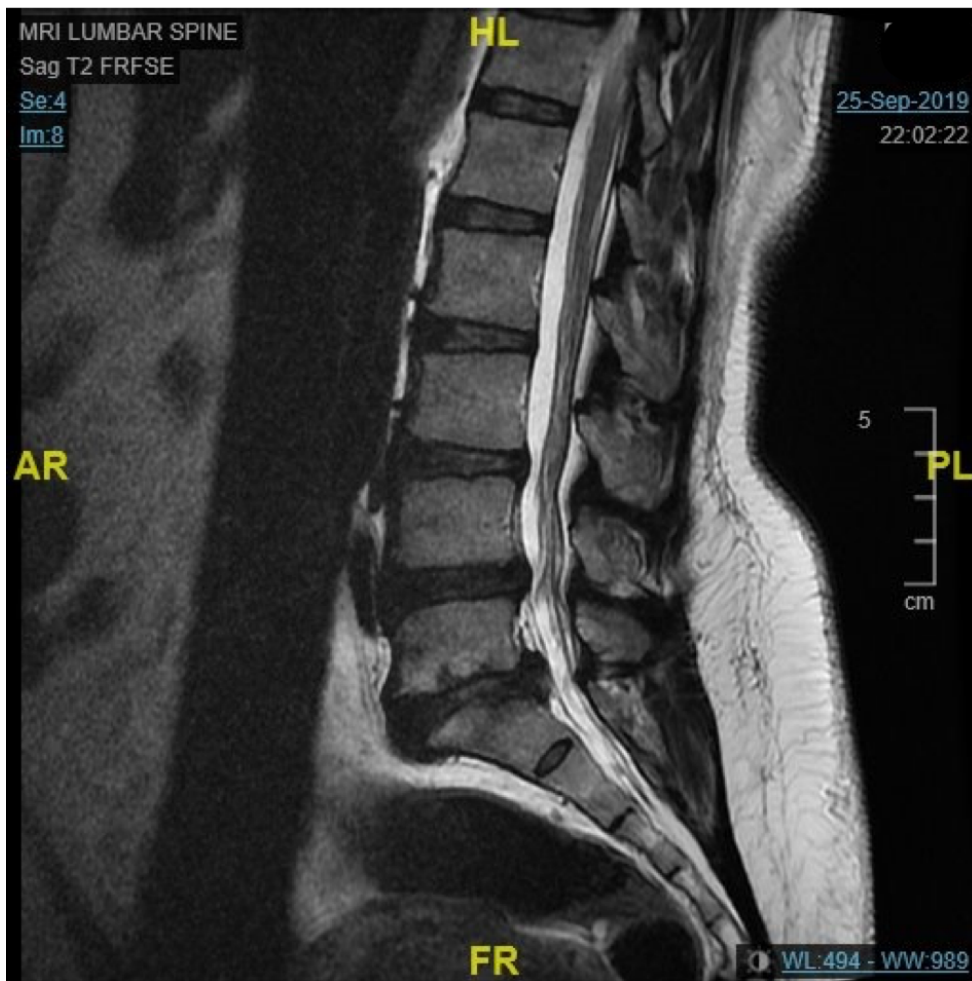


33. This is a kidney image (yes, no, don't know)
34. The case in the above image is (normal case, not normal case, don't know)
35. It's normal that radiology images appear in white and gray colors (yes, no, don't know)
36. All the imaging tests have the same preparation instructions (yes, no, don't know)
37. The radiology scan that requires no metal on the body is (Ultrasound, MRI, don't know)



38. Did you know that radiology images can be provided in three views as in the above image? (yes, no, don't know)

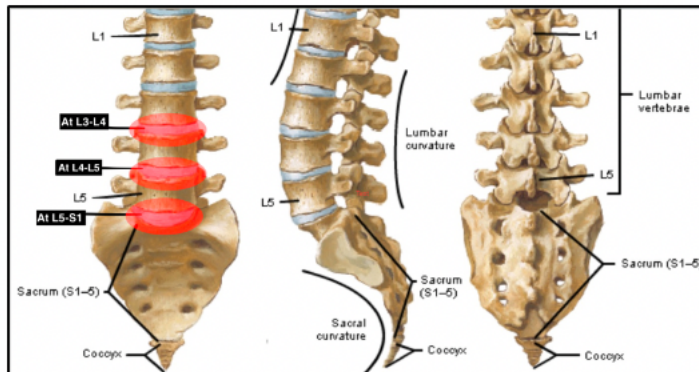
Current design (control group)



- Technique: Multiple sequential MRI of the spine was obtained pre IV gadolinium administration.
- Comparison: None.
- FINDINGS: Mild straightening of the lumbar spine likely due to muscular spasm, otherwise the alignment is maintained. No evidence of acute or chronic fracture. Conus medullaris and cauda equina nerve roots are unremarkable.
- At L3-L4 level, there is mild diffuse disc bulge indenting the thecal sac without significant spinal canal stenosis, however there is mild bilateral neural foraminal narrowing, slightly more on the right along with facet joint arthropathy and ligamentum flavum hypertrophy.
- At L4-L5 level, there is diffuse disc bulge, altogether with ligamentum flavum hypertrophy and facet joint arthropathy resulting in mild to moderate spinal canal stenosis and bilateral neural foraminal narrowing, moderate on the left and moderate to severe on the right.
- At L5-S1 level there is fatty end plate degenerative changes with end plate irregularities. Reduced disc height with diffuse disc bulge and posterior broad-based central disc protrusion compressing the lateral recesses bilaterally and both traversing S1 nerve roots. Together with the facet joint arthropathy and ligamentum flavum hypertrophy of the diffuse disc bulge causing bilateral moderate neural foraminal stenoses. No significant thecal sac compression.
- Conclusion: Multilevel degenerative disc disease as detailed above, for clinical correlation.

New design (intervention group)

Image



Atlas annotation and reference

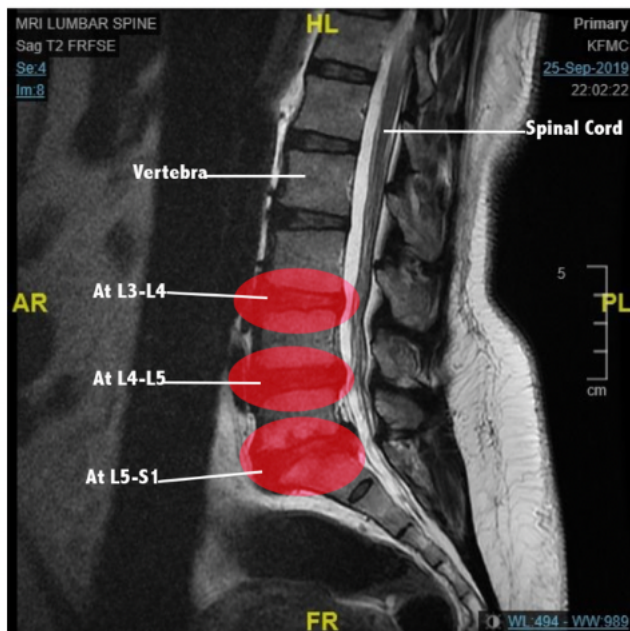
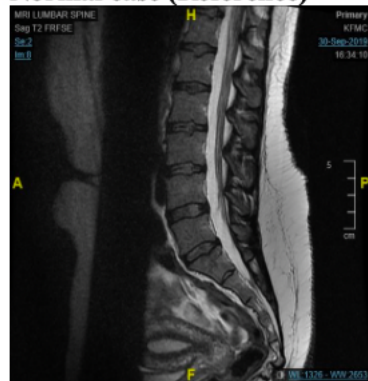


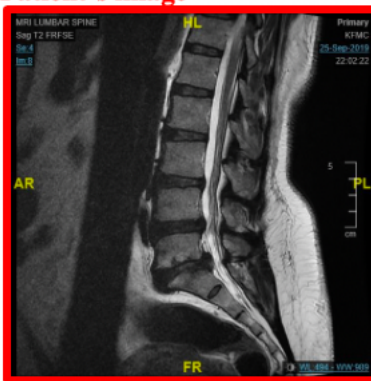
Image annotation

Normal case (Reference)



Condition context

Patient's image




Worse case (Reference)



Notes

Patient name: XXXXX
 Patient Name: XXXXX
 ID: 000000000
 Age: 45
 Sex: Male

Doctors
 Referring physician: Dr. [REDACTED]
 Radiologist: Dr. [REDACTED]
 Procedure: MRI Lumbar spine

FINDINGS: Patient has three issues	Terminology & Explanation
<p>1. At L3-L4 in the image There is mild diffuse disc bulge indenting the <u>thecal sac</u> without significant spinal canal <u>stenosis</u>, however there is mild <u>bilateral neural foraminal</u> narrowing, slightly more on the right along with <u>facet joint arthropathy</u> and <u>ligamentum flavum</u> hypertrophy.</p>	<p>Thecal sac: A tube of dura mater that surrounds the spinal cord Dura mater: The tough outermost membrane enveloping the brain and spinal cord Stenosis: The abnormal narrowing of a passage in the body Bilateral neural foraminal: It occurs when the small openings between the bones in your spine, called the neural foramina, narrowed or tighten Facet joints are a set of synovial, plane joints between the articular processes of two adjacent vertebrae An arthropathy: A disease of a joint ligamentum flavum: Joint Hypertrophy: The enlargement of the cells Posterior The back part A disc protrusion The spine is intact but bulge when one or more of the discs are under pressure.</p>
<p>2. At L4-L5 in the image There is diffuse disc bulge, altogether with ligamentum flavum <u>hypertrophy</u> and facet joint arthropathy resulting in mild to moderate spinal canal stenosis and bilateral neural foraminal narrowing, moderate on the left and moderate to severe on the right.</p>	
<p>3. At L5-S1 in the image There are fatty end plate degenerative changes with end plate irregularities. Reduced disc height with diffuse disc bulge and <u>posterior</u> broad-based central <u>disc protrusion</u> compressing the lateral recesses bilaterally and both traversing S1 nerve roots. Together with the facet joint arthropathy and ligamentum flavum hypertrophy of the diffuse disc bulge causing bilateral moderate neural foraminal stenoses. No significant thecal sac compression.</p>	
	<p>To translate medical jargon into consumer-oriented lay language please copy any full text and post it in this link http://clinicalnotesaid.org</p> <p>For more information about your case</p> 

Summary

The discs in the spine are showing signs of narrowing and irregularities which is usually due to wear and tear. These abnormalities are seen at least in 3 levels as in the patient image.

L3/L4

Mild degenerative disease-causing bilateral nerve compression. Right more than left.

L4/L5

Moderate degenerative disease causing bilateral moderate to severe nerve compression, right more than left.

L5/S1

Moderate degenerative disc disease causing bilateral moderate nerve compression.

1) Cause of the condition:

Usually is age-related wear and tear, sometimes can be due to trauma.

2) Impact on the patient's physical function:

It is a common cause of low back pain and may be associated with numbness or muscle weakness.

3) Factors that could make the conditions better or worse:

It could be aggravated by wrong posture or wrong exercises, may be relieved by painkillers or laying back.

4) Self-care advice:

Avoid heavy lifting, bed rest, physical therapy, consult a professional and avoid self-diagnosis.

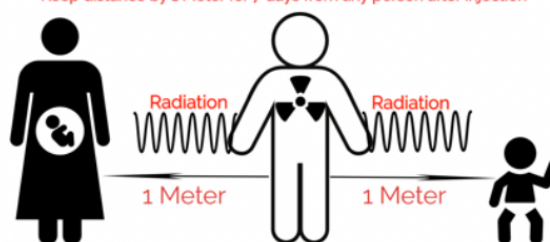
For more information, you should discuss your case with your doctor

Next appointment

Location: Main hospital
Department: Nuclear medicine
Procedure: Whole body bone scan
Date: 2019, Dec 10
Time: 10:15am

Instructions

Keep distance by 1 Meter for 7 days from any person after injection



Please, scan the following barcode for the rest of instructions



- **Quiz**

39. According to the report (Notes) the discs in the spine are

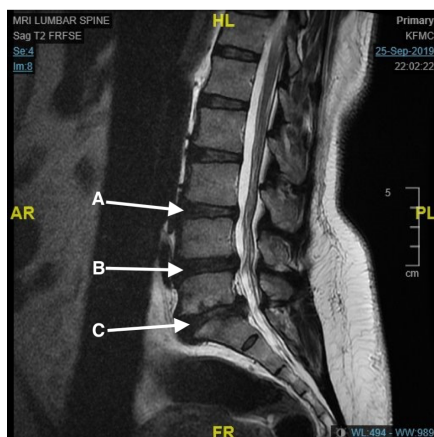
- a. Fine
- b. Severely damaged
- c. Showing signs of narrowing and irregularities
- d. I do not know

40. According to the report (image and notes), can you determine the location of the issues?

- a. At L3 L4
- b. At L4 L5 & L5 S1
- c. At L3 L4 & L4 L5 & L5 S1
- d. I do not know

41. According to the report (Image), can you determine the location of the L5 S1 in the following image

- a) A
- b) B
- c) C
- d) I do not know



42. According to the report (notes), the terminology word “Stenosis” means:

- a) The abnormal narrowing of a passage in the body
- b) A disease of a joint
- c) Fever in the body

d) I do not know

43. According to the report (notes), the terminology word “Hypertrophy” means:

a) Inflammatory condition of the liver

b) Bone infection

c) The enlargement of the cells

d) I do not know

- **General Questions (Both groups)**

44. I think that the format and appearance of the notes in the report look easy on my eye

Strongly
Disagree

Disagree

Neutral

Agree

Strongly Agree

☐☐☐☐☐

45. I think that the appearance of the image in the report look easy on my eye

Strongly
Disagree

Disagree

Neutral

Agree

Strongly Agree

☐☐☐☐☐

46. I am comfortable with my ability to find information in the images and notes.

Strongly
Disagree

Disagree

Neutral

Agree

Strongly Agree

☐☐☐☐☐

47. I am comfortable with my ability to figure out the location of issues in the image.

Strongly
Disagree

Disagree

Neutral

Agree

Strongly Agree

☐☐☐☐☐

48. In general, I am comfortable with my ability to understand the content in the images and notes.

Strongly Disagree Disagree Neutral Agree Strongly Agree

☐ ☐ ☐ ☐ ☐

49. I am comfortable with my ability to understand this report and the severity of the case

Strongly Disagree Disagree Neutral Agree Strongly Agree

☐ ☐ ☐ ☐ ☐

50. In general, I am satisfied with the way this image is presented

Strongly Disagree Disagree Neutral Agree Strongly Agree

☐ ☐ ☐ ☐ ☐

51. In general, I am satisfied with the way the notes in the radiology report are presented

Strongly Disagree Disagree Neutral Agree Strongly Agree

☐ ☐ ☐ ☐ ☐

52. I would like to receive my radiology report in this design

Strongly Disagree Disagree Neutral Agree Strongly Agree

☐ ☐ ☐ ☐ ☐

53. I prefer to add my next appointment and instructions in the radiology report

Strongly Disagree Disagree Neutral Agree Strongly Agree

☐ ☐ ☐ ☐ ☐

54. I prefer to add definitions of the medical terms in the radiology report

Strongly Disagree Disagree Neutral Agree Strongly Agree

☐ ☐ ☐ ☐ ☐

55. I prefer to add an anatomy atlas image of the same of my case in the radiology report

Strongly Disagree Disagree Neutral Agree Strongly Agree

☐ ☐ ☐ ☐ ☐

- Only for group of New design (intervention group)

56. In general, I am comfortable with my ability to understand the terminology in this way

Strongly Disagree Disagree Neutral Agree Strongly Agree

☐ ☐ ☐ ☐ ☐

Radiology Report

Patient name: XXXXX
Patient Name: XXXXX
ID: 000000000
Age: 45

Doctors
Referring physician: Dr. [REDACTED]
Radiologist: Dr. [REDACTED]

Sex: Male

MRI Lumbar spine 25-Sep 2019	Terminology & Explanation
FINDINGS:	Thecal sac: A tube of dura mater that surrounds the spinal cord
1 At L3-L4 level There is mild diffuse disc bulge indenting the thecal sac without significant spinal canal stenosis, however there is mild bilateral neural foraminal narrowing, slightly more on the right along with facet joint arthropathy and ligamentum flavum hypertrophy.	Dura mater: The tough outermost membrane enveloping the brain and spinal cord Stenosis: The abnormal narrowing of a passage in the body An arthropathy: a disease of a joint

57. In general, I am comfortable with being given the opportunity to have more information about terminology and the case

Strongly Disagree Disagree Neutral Agree Strongly Agree

☐ ☐ ☐ ☐ ☐

To translate medical jargon into consumer-oriented lay language please copy any full text and post it in this link
(<http://clinicalnotesaid.org>)

For more information about your case



58. Adding two images, one normal and one abnormal, increased my understanding of the content of the radiology report

Strongly Disagree

Disagree

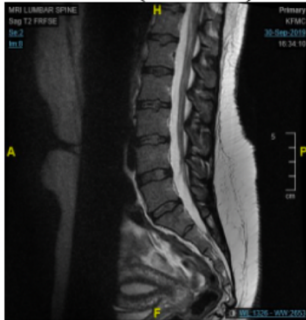
Neutral

Agree

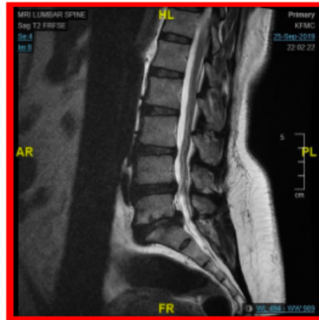
Strongly Agree



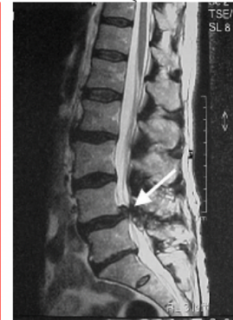
Normal case (Reference)



Patient's Name



Worse case (Reference)



59. Adding annotations and coloring the issues in the radiology image increased my understanding

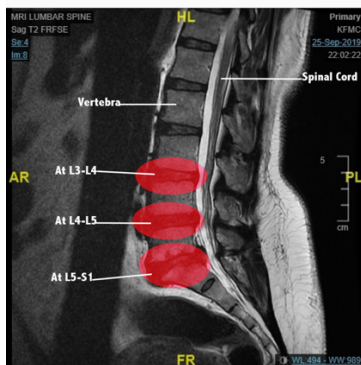
Strongly Disagree

Disagree

Neutral

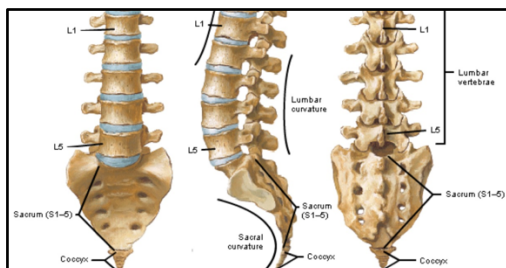
Agree

Strongly Agree



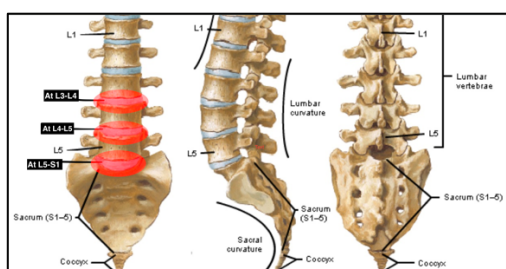
60. Adding Anatomy Atlas images helped me to understand the radiology image

Strongly Disagree Disagree Neutral Agree Strongly Agree



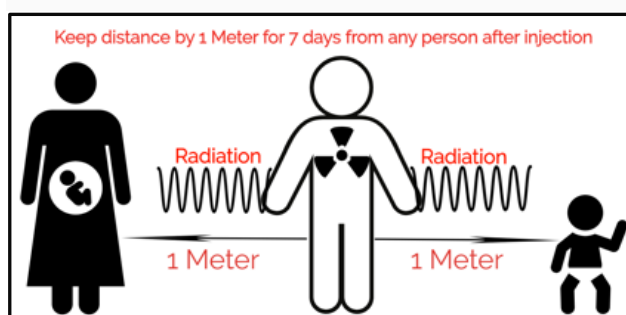
61. Adding annotations and coloring the issues in the Anatomy Atlas image increased my understanding

Strongly Disagree Disagree Neutral Agree Strongly Agree



62. Presenting the most important instructions in drawings increased my understanding?

Strongly Disagree Disagree Neutral Agree Strongly Agree



- 63. Including the rest of the instructions in barcode will make my report more organized?
- 64. Adding tips as "Cause of the condition", "Impact on the patient's physical function", "Factors that could make the conditions better or worse" and "Self-care advice", Increased my understanding?
- 65. Summarizing the notes as in the "Summary section", increased my understanding?
- 66. In general, adding the "Summary section" to the notes, increased my understanding?

CURRICULUM VITAE
Mohammad Alarifi

EDUCATION

- **King Saud University, School of Applied Medical Science – Riyadh, SA**
 - **B.S. in Radiological Science – 2008/2009.**
- **Indiana University, School of Informatics, IUPUI – Indianapolis, IN, U.S.A.**
 - **M.S. in Health Informatics – Graduation: May 2016, GPA 4.00/3.91.**
 - **Certificate in Health Info Admin BS- Spring 2014**
 - **GPA 4.00/3.56.**
 - **M.S. Thesis: The Barriers And Benefits Of Report Writing Related To Radiologists' Use Of AVR In Saudi Arabia**
 - **University of Wisconsin-Milwaukee- Milwaukee, USA**
 - **Doctoral candidate in Health Sciences (Health Informatics) Current GPA 3.87**

WORK EXPERIENCE

- August 2010 to present Instructor at Applied Medical Science Collage Intern at King Saud University, Riyadh, Saudi Arabia
- Gave several lectures and presentation inside and outside the Medical Imaging Administration at King Fahad Medical City, Riyadh, Saudi Arabia. These lectures were pertaining to both radiological and non-radiological issues in both English and Arabic languages.

PUBLICATION

- Alarifi, M. Saptarshi, P. Josette, J. Aldosary, A. Cichoya, J. (2015). Perception of Voice Recognition for Radiology Reporting: Case Study from Saudi Arabia. BHI-2016 International Conference on Biomedical and Health Informatics. Las Vegas, USA.
- Participated in 1ST INTERNATIONAL SAUDI SCIENTIFIC HEALTH INFORMATICS CONFERENCE, 2015
- Alarifi, M., Patrick, T., Jabour, A., Wu, M., & Luo, J. (2020). Full Radiology Report through Patient Web Portal: A Literature Review. International Journal of Environmental Research and Public Health, 17(10), 3673.
- Gichoya, J. W., Alarifi, M., Bhaduri, R., Tahir, B., & Purkayastha, S. (2017, July). Using cognitive fit theory to evaluate patient understanding of medical images. In 2017 39th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) (pp. 2430-2433). IEEE.
- Anand Kulanthaivel, M. I. S., Kshirsagar, M., Alarifi, M., Oklak, M., & Jones, J. F. Almost Zero Error Basepair-based Record Alert (AZE BRA)–A Genomic Clinical Decision Support Tool.