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Diagnostic Musculoskeletal Imaging: How Physical Therapists Utilize Imaging in Clinical Decision-Making

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By

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Approval Page

We hereby certify that this dissertation, submitted by name, conforms to acceptable standards and is fully adequate in scope and quality to fulfill the dissertation requirement for the Health Professions Division Program.

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To the most influential women in my life; thank you! My mother, who has been a shining example of lifelong learning and ongoing intellectual curiosity. But most importantly, my wife. Her patience and kindness have kept me going during my studies.

Abstract

This qualitative study describes how physical therapist experts in musculoskeletal disorders evaluate and interpret imaging studies and how they employ imaging in clinical decision-making. The informants are physical therapists who are certified orthopedic clinical specialists (OCS) and/or fellows of the American Academy of Orthopaedic Manual Physical Therapists (AAOMPT). The study employed web conferencing to display patient cases, record screen-capture videos, and to conduct interviews. Informants were observed and their activity video-captured as they evaluated imaging studies and, afterwards, interviews were employed to explore the processes they utilized to evaluate and interpret the images and to discuss imaging-related clinical decision-making, including possible functional consequences of changes seen in the images, contraindications to treatment, and indications for referral. The interviews were transcribed and analyzed in the tradition of grounded theory.

This study found that the informants' evaluation of imaging studies was contextual and non-systematic, guided by the clinical presentation. The informants used imaging studies to provide deeper understanding of clinical findings and widen perspectives, arriving at clinical decisions through the synthesis of imaging, clinical findings, and didactic knowledge. They tended to look for imaging evidence of interference with normal motion, rather than evidence of pathology. Overall, the informants expressed conservative views on the use of imaging, noting they would rather use clinical findings and treatment response than imaging findings as a basis for referral to other health care professionals.

Using imaging studies to support clinical decision-making can provide physical therapists a wider perspective when planning treatment interventions. By showing physical therapists' approach to interpreting imaging studies and how this relates to their clinical decision-making,

the findings of this study could contribute to discussions of the place of imaging in physical therapist practice, as well as help set objectives for imaging curricula in professional-level and continuing education.

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Chapter 1: Introduction

The purpose of this study is to explore and describe how physical therapist experts in the treatment of musculoskeletal disorders evaluate and interpret imaging studies and how they use imaging studies in clinical decision-making. The study explores these topics through analysis of one-on-one interviews based on screen-capture videos of informants' evaluation of imaging studies.[1-3] This chapter will explain the purpose of the study and discuss its significance as it relates to clinical decision-making and physical therapists' use of imaging studies.

Problem Statement

There is growing physical therapist interest in imaging, reflected in increasing emphasis on imaging in physical therapist education,[4,5] in articles about the place of imaging in physical therapy,[6,7] books on imaging for physical therapists,[8-12] and books on examination and treatment of musculoskeletal disorders that emphasize the contribution of imaging.[13,14] Physical therapists have also made significant contributions to imaging research.[15-20] But while physical therapists show increasing interest in imaging and their view of imaging as an adjunct to treatment seems favorable,[21,22] little is known about how they evaluate and interpret imaging studies and how they use imaging in clinical decision-making.

Imaging studies may provide the physical therapist with information not available from other sources; information that may be important for treatment planning, although it is not known how physical therapists employ this information in clinical practice.[23] Some authors have made the case that physical therapists should evaluate imaging studies for potential functional disturbances.[23-26] Barr recommended that physical therapists evaluate imaging studies for signs of impediments to motion, instability, or other functional disturbances, since radiologists do not

routinely address those areas in their radiographic reports.[23] Still, the use of images to indicate functional disturbances must be tempered by the limited evidence of the ability of imaging studies to predict musculoskeletal function.[27,28] Furthermore, physical therapists could use imaging studies of musculoskeletal conditions in order to help set treatment goals[26] or add insight into limitations that may apply to treatment.[23]

Imaging has primarily been considered the domain of radiologists, although other health care professionals have described their approach to the evaluation of imaging studies in clinical decision-making.[29,30,31,32,33] However, direct evaluation of imaging studies by physical therapists is rarely described[34,35] and evidence of imaging-related decision-making by physical therapists is mostly in the form of case studies that demonstrate the intersection of imaging and physical therapy. These case studies often focus on the reasons for patient referrals to imaging rather than how physical therapists evaluate imaging studies to guide patient examination and treatment.[36-38] Descriptions of imaging curricula for professional-level physical therapy students also provide limited insight into how physical therapists evaluate imaging studies[4] and the development of objectives for imaging education is in its early stages.[4,39]

Purpose of the Study

Physical therapists' professional bodies have noted their position on imaging. The APTA House of Delegates published a position paper stating that physical therapists should be able to order, perform, and interpret selected imaging studies[40] and the Normative Model of Physical Therapist Professional Education (Normative Model) emphasizes the place of imaging in physical therapist education. The Normative Model specifies that physical therapists should be able to identify the need for imaging studies and compare the value of different imaging methods, as well as use the results of imaging of the musculoskeletal system and other body systems in

patient management.[41] The Guide to Physical Therapist Practice states that physical therapists may utilize information from other health care professionals, including the results of diagnostic imaging.[42] None of these documents goes into detail about the place of imaging in physical therapist practice, how physical therapists should evaluate imaging studies, how imaging can aid clinical decision-making, or what should be the objectives for imaging education.

The purpose of this study is to describe what processes physical therapist experts in musculoskeletal disorders use to evaluate and interpret imaging studies and how they employ imaging in clinical decision-making. Describing how physical therapy experts evaluate imaging studies and use them to guide clinical decision-making may inform curriculum development and help set objectives for imaging in physical therapist education. It may also inform discussions about the role of imaging in physical therapists' practice and clinical decision-making while supporting physical therapists in providing quality, cost-efficient patient care.

This qualitative study employed individual interviews based on three cases of musculoskeletal disorders that included patient history, complaints, examination findings, and imaging studies. The interviews were conducted using computer-based communication that made it possible for the researcher to share the cases, show the imaging studies associated with the cases, and to share control of the computer. This, in turn, allowed him to observe and do screen-capture recordings of the informants' evaluation processes. These recordings formed the basis of interviews that explored the informant's view of the significance of the imaging findings and discussed potential functional consequences of changes seen in the images, as well as indications for caution or need for referral to another health care professional based on the imaging findings. These interviews, along with the researcher's observation of the evaluation processes as seen in the screen recordings, provided insight into how informants evaluated the

imaging studies and integrated them into their clinical decision-making. The interviews were analyzed in the tradition of grounded theory.

Clinical Decision-Making

Clinical decision-making is grounded in clinical reasoning.[43] Decision-making processes used by clinicians tend to depend on the clinicians' experience and level of expertise,[44] as well as their perspectives.[45-47] Clinical decision-making by physical therapists is influenced by their practice epistemology and ontology[48] and may differ between physical therapists of different specialties.[45,49] As an example, physical therapists in orthopedic practice tend to lean towards the hypothetico-deductive processes in gathering and processing of information.[46,47]

Several different clinical decision-making models have been described, including the hypothetico-deductive, heuristic, and pattern recognition models. Hypothetico-deductive reasoning is a general reasoning strategy that involves gathering of information about the patient to construct a hypothesis.[50] This form of reasoning represents a generic approach that can be used even when the clinician does not possess organized knowledge related to the problem at hand.[51,52] According to this model, the clinician creates novel solutions to clinical problems, based on analytic processing of the information gathered, resulting in the generation of a provisional hypothesis that is subsequently evaluated based on available data and either confirmed or rejected. This process can be repeated, resulting in a refined hypothesis on which a new diagnosis is made.[52] This approach takes on several stages, cue recognition, hypothesis generation, cue interpretation, and hypothesis evaluation.[53] The hypothetico-deductive model is predicated on the assumption that all pertinent knowledge is available and accurate, an assumption that can be called into question since clinical decisions are often made under conditions of uncertainty.[54]

In contrast to the hypothetico-deductive model stands the heuristic model. A heuristic is a clinical decision-making strategy that is not based on assessing all potentially available information, but rather focusing on few relevant facts that have strong predictive value.[52,55] The heuristic often takes the form of decision-making algorithms or clinical pathways, such as the Canadian cervical-spine rules, [56] the Ottawa knee[57] and ankle[58] rules, and American College of Radiology (ACR) criteria for the appropriateness of choosing imaging studies for different clinical conditions.[59,60] Heuristics are best suited to rapid decision-making, producing solutions that are as close to the best decision as possible.[52,55]

The least rigorous clinical decision-making model is pattern recognition based in exemplar knowledge.[61,62] This model is commonly used by seasoned experts.[63] This decision-making approach requires structured knowledge based on memorization of a great number of case representations that the clinician can compare to the current case. Pattern recognition is characterized by rapid unconscious retrieval of exemplars that make it possible for experts to match the case at hand to cases in memory and then make category judgments.[61,62] In other words, the expert can rapidly draw on a reserve of analogies to the current clinical situation to aid clinical decision-making. Experts employing pattern recognition to solve clinical problems do not engage in feature-by-feature analysis, they are more likely to solve problems rapidly and unconsciously like a chess master.[64] The application of pattern recognition is commonly found in studies on radiologists' expertise.[65]

Beyond the clinical decision-making models discussed above, clinical decision-making models can be discussed in terms of two contrasting paradigms.[53] Banning, in a review of current literature on clinical decision-making models, proposed two main models, the information-processing model, rooted in the hypothetico-deductive approach to diagnosis, and the intuitive-humanist model.[53] Intuition has been defined as understanding without the

conscious use of reason. According to the intuitive-humanist model, the clinician uses the synthesis of empirical and personal knowledge, rather than the scientific approach of hypothesis testing, as a benchmark for creating accurate propositions. The intuitive-humanist model is best suited for application in ambiguous and uncertain situations.[53] The pattern recognition demonstrated in radiological expertise is considered an example of intuitive clinical decision-making.[65-68]

As physical therapists increasingly practice in direct access, their initial clinical decision-making centers on whether the patient is a candidate for physical therapist treatment. The physical therapist must decide whether to treat the patient or refer to other health care professionals, based on their patient examination. This may include screening for so-called medical condition "red flags" that may indicate that the patient is not suitable for treatment by a physical therapist.[69,70] Thus, the ability to determine if patients should be treated or referred to other health care professionals is an important part of physical therapists' clinical decision-making.[26] Although most state practice acts do not include language that allows physical therapists to refer patients for imaging studies, physical therapists may be asked for recommendations for or against imaging. As a part of their clinical decision-making, physical therapists may need to identify when imaging is needed for the best patient outcome.[23]

Some US physical therapists currently have the right to order imaging studies. In the state of Wisconsin, physical therapists can order imaging studies[71] and physical therapists in the United States (US) Army, Navy, and Air Force, have been credentialed since the 1970's to order imaging studies, following special training.[6] Physical therapists in the Public Health Service, Indian Health Service, and the Veterans Administration Health System,[72] as well as in the Bureau of Prisons, also have the right to order imaging studies.[6] This expansion in scope of practice seems to have been successful in terms of quality of patient care and cost of service.[73-75]

Although most physical therapists in the US do not have the right to order imaging studies, physical therapists in many countries do have that right. However, special training required in most of these countries.[72,76,77] In Norway, the right to order imaging studies is limited to certified manual therapists[76] and in Britain only extended-scope physical therapists[77-79,80] can order imaging. In Canada, while the ability to interpret diagnostic imaging studies is considered an entry level requirement for the Canadian Physiotherapy Competency Examination, ordering imaging studies is still considered an advanced function.[81]

Even if most physical therapists do not have the right to order imaging studies, several authors have emphasized that, for integration of imaging into physical therapy practice, physical therapists need to be familiar with indications for musculoskeletal imaging. This includes knowing the risks and benefits, as well as limitations of the clinical applicability of imaging findings.[6,23,25] According to Deyle, physical therapists have the knowledge required to make informed recommendations for imaging based on the physical examination and based on treatment results that are not consistent with expectations.[25] Their ability to do this seems to rest on physical therapists' diagnostic abilities.[74,82] Furthermore, to be able to make recommendations for imaging studies, the therapist must be knowledgeable about the sensitivity and specificity of various diagnostic imaging studies for the suspected condition.[25]

Expertise

The informants in this study are physical therapist experts in the treatment of musculoskeletal disorders who are fellows of AOMPT and/or hold OCS certification. Physical therapy experts in the evaluation and treatment of musculoskeletal disorders were chosen because they have strong foundational knowledge of the musculoskeletal system and musculoskeletal disorders.[83] Furthermore, in studies of clinical decision-making that include

imaging-related decision-making, physical therapists with OCS certification have performed better than other groups of therapists.[35,84]

Studies of expertise in health care have in recent years shifted away from previous emphasis on the hypothetico-deductive model to a greater focus on knowledge organization and retrieval.[85] These studies have found that medical experts[51] rely heavily on pattern recognition, not the step-by-step reasoning that is characteristic of the hypothetico-deductive model.[61,62] Research shows experienced physicians consistently perform better on tests of competence in spite of scoring lower than medical residents on tests of knowledge.[86,63]

While studies of medical expertise have focused on clinical decision-making and diagnostic accuracy,[87] studies of physical therapy expertise have gone beyond diagnosis to also look at the characteristics of experts' treatment interventions and interactions with their patients.[88-91] Numerous studies have been conducted on the characteristics of physical therapist experts, as identified on the basis of clinical outcomes,[92] years of practice,[91] or on nominations from colleagues.[90] The consensus of these studies is that physical therapist experts are patient-centered with a strong knowledge base and skills in differential diagnosis. They tend to be lifelong learners, with broad knowledge of movement related to their clinical specialty, and a focus on patient education.[88-91,93]

Research Questions

The research questions asked in this study are: 1) What processes do physical therapist experts in musculoskeletal disorders use to evaluate and interpret musculoskeletal imaging studies? 2) How do physical therapist experts in musculoskeletal disorders utilize musculoskeletal imaging studies to guide clinical decision-making?

Importance and Contribution of Study

With the attainment of direct access in all 50 states, physical therapists are increasingly involved in autonomous practice.[94] This is supported by emerging models of primary care,[95,96] where there may be a significant role for physical therapists as first-contact practitioners for problems of the musculoskeletal system.[74,97,98] The augmented physical therapist role in the management of musculoskeletal disorders aligns with APTA's Vision Statement, which states that by 2020:

> …..physical therapy will be provided by physical therapists who are doctors of physical therapy, recognized by consumers and other health care professionals as the practitioners of choice to whom consumers have direct access for the diagnosis of, interventions for, and prevention of impairments, activity limitations, participation restrictions, and environmental barriers related to movement, function, and health.[99]

According to a 2003 statement by the APTA Board of Directors, direct access entails the responsibility to screen for medical disease and to refer to other health care professionals in cases of "medical needs beyond the scope of physical therapist practice."[100] In direct access, appropriate referrals to other health care professionals and services form an integral part of the clinical decision-making process. Accordingly, physical therapists should be able to recognize when imaging studies are needed to improve patient outcomes and be skilled at using information from imaging studies. Barr stated, "To fulfill the Guide's expectations for patient management, physical therapists must become educated users of diagnostic imaging capable of making appropriate referrals to the experts in imaging: radiologists."[23(665)] Increased physical therapist use of imaging calls for increased emphasis on imaging education.[6] Boyles stated, "Though it is important to add more evidence to support physical therapists' use of imaging, a

more fundamental issue is whether physical therapists can be educated to demonstrate competencies in performing such duties." Physical therapists seem to be progressing towards fulfillment of that requirement. According to a recent survey by Boissonnault et al., most professional-level doctor of physical therapy (DPT) academic programs include imaging as a separate course, as well as imaging integrated into other courses.[4]

In 2015, the Imaging SIG of the Orthopedic Section published a manual to serve as a guideline for musculoskeletal imaging in professional-level physical therapist programs.[24] Most of the Imaging SIG's manual is devoted to instructional materials to assist faculty in the development of imaging curricula with recommendations for curricular content, as well as samples of instructional activities, syllabi, test questions, and other forms of evaluation. Furthermore, the authors provided examples of outcomes and objectives that are aligned with the Normative Model and the CAPTE Criteria. The recommended curricular content is focused on basic imaging principles, properties of commonly used imaging modalities and choice of imaging modalities related to common musculoskeletal conditions for each region according to imaging guidelines. However, according to the authors, the most important instructional activities are those that give students "the opportunity to develop clinical decision-making skills in the judicious integration of imaging in patient management." This is evident in the manual's emphasis on imaging guidelines and the selection of appropriate imaging modalities.[24] The authors, furthermore, emphasize that physical therapists must be familiar with the legal framework within which they practice. They stress that imaging instruction for physical therapists should employ imaging-related language that aligns with state physical therapy practice acts and licensing board's rules and regulations, as well as the CAPTE criteria and scope of practice as defined in APTA documents and the Normative Model.[24]

The findings of the study presented here may assist educators in further developing imaging instruction for physical therapists, as increased emphasis on imaging may be required in physical therapist education. At this time, there is lack of consensus on what should be the objectives for imaging education.[4,24] Furthermore, this study may contribute to discussions about the place of imaging in physical therapists' practice and its value for clinical decision-making, which might support physical therapists in providing the best and most cost-efficient patient care for best patient outcomes. For these reasons, it is important to describe how physical therapy experts currently evaluate and interpret imaging studies and how they use them to guide clinical decision-making. The study should be valuable for both educators and practicing physical therapist clinicians.

Definition of Terms

Clinical decision-making: Making a choice between possible options related to diagnosis and intervention.[54] Examples are:

- Heuristic reasoning: A clinical decision-making strategy by which the clinician is able to rapidly make decisions using simple algorithms, often in the presence of incomplete information.[55]
- Hypothetico-deductive reasoning: A method of reasoning that involves gathering information from the patient to construct a hypothesis, which then is tested.[50]
- Pattern recognition: A clinical decision-making approach, based in exemplar knowledge. It is characterized by the ability to organize clinical representations into patterns and to rapidly identify findings that fit or do not fit those patterns.[51]

Clinical reasoning: The process of thinking through the patients' clinical presentation for the purpose of clinical decision-making.[43]

Contextual imaging evaluation: Evaluation of imaging studies that varies between different images and patient scenarios, but does not follow a set evaluation approach.

Direct physical therapy access: Evaluation and treatment of a patient by a physical therapist without a prior physician referral.[94]

Exemplar knowledge: Exemplar knowledge, which underlies pattern-recognition, is the storage and retrieval from memory of cases that allow clinical judgments by comparisons of the features of a case at hand with cases stored in memory.[62]

Holistic image evaluation: A mode of imaging evaluation analogous to facial recognition. It rests on an initial global analysis of the retinal image to identify possible abnormalities.[66] For the purposes of this study, this includes identification of imaging findings without the use of systematic search strategies.

Imaging studies: The images produced by imaging modalities. For this study, this includes only musculoskeletal radiographs, computerized tomography (CT), and MRI.

Internet Mediated Research: Remote acquisition of data from or about human participants using the internet, in either quantitative or qualitative research. The use of videos as a basis for an interview (video-stimulated recall)[101] is an example of this, as is web conferencing that allows interviewing at a distance, while sharing documents, videos, and images.[102]

Physical therapist experts: For the purposes of this study, physical therapists with OCS certification, fellows of AAOMPT, or physical therapists that have completed fellowship residency.

Physical therapist imaging: Any use of imaging by physical therapists to assist clinical decision-making and/ or inform the physical therapist about the patient's condition.

Radiographic clinical decision rules: Rules that by simple algorithms or brief history and examination identify when imaging studies are needed. This is exemplified by the Canadian cervical-spine rules,[56] the Ottawa knee[57] and ankle[58] rules, as well as the ACR appropriateness criteria.[59,60]

Systematic approaches for evaluation or radiographs: This is exemplified by the ABCs (alignment, bone density, cartilage, and soft tissues) approach for evaluation or radiographs according to which bony alignment, bone density, cartilage, and soft tissues are evaluated according to several criteria, as well as the predictor variables for bone and musculoskeletal disorders.[26] Another example is the seven elements of fracture descriptions.[103]

Summary

This study explores how physical therapists evaluate and interpret imaging studies and physical therapists' use of imaging studies in clinical decision-making. Physical therapist interest in imaging and their use of imaging studies is growing. However, little is known of how they evaluate and interpret imaging studies or how they utilize them to aid clinical decision-making. Although in most states, physical therapists cannot refer patients for imaging studies, an important element of imaging-related clinical decision-making by physical therapists relates to whether the physical therapist needs to obtain an imaging study for best practice decisions.

Physical therapists may require imaging studies to predict functional disturbances and limitations to motion in a way that may inform treatment decisions. The findings of this study may assist educators in defining objectives and outcomes of imaging education, as well as promoting discussion of imaging-related clinical decision-making and the place of imaging in physical therapist practice. Increasing physical therapists use of imaging in clinical practice underscores the importance of better understanding of physical therapists' evaluation of imaging studies and imaging-related clinical decision-making.

Chapter 2: Literature Review

Introduction

Little is known about physical therapists' use of imaging studies in clinical decision-making. Descriptions of physical therapists' use of imaging are largely limited to case reports that demonstrate the intersection of imaging and physical therapy in a series of case reports that highlight the place of imaging in physical therapist patient management.[36,104-106] Application of findings from radiographs and MRI to supplement evaluation and to guide the treatment of the TMJ, have been described[34] and one study was found on imaging diagnosis by physical therapists.[35] Other descriptions of physical therapists' application of musculoskeletal imaging studies to guide clinical decision-making were not found in existing literature. This chapter will provide a review of existing literature that informs this study; the use of imaging by physical therapists, their practice paradigms, clinical decision-making, and expertise. Furthermore, the chapter will discuss educational support of physical therapist imaging.

Use of Imaging by Physical Therapists

Physical therapists seem to favor ready accessibility to imaging studies. Wilcox et al. found that the ease of access to imaging studies influenced how frequently physical therapists viewed imaging studies and how viewing the images affected plans of care and outcomes.[107] The authors studied the effect of making a picture archiving and communication system (PACS) available to physical therapists in a hospital setting on the percentage of imaging studies viewed. Wilcox et al. compared the proportion of imaging studies viewed by physical therapists before and after the implementation of a PACS, by comparing film library records for a three-month period prior to the implementation to PACS records after the implementation. The authors found that prior to implementation, the therapists viewed one percent of available

imaging studies, but this percentage rose to 28% during the second month after the implementation and to 84% during the fifth month. The authors also surveyed participants about the perceived value of the PACS implementation and found that post-implementation all participants placed high value on being able to use radiological assessment in clinical practice and the majority of participants felt that in most cases viewing imaging studies altered or improved their treatment plans.[107] This study has several weaknesses, most significantly the low number of participants (12) and the lack of statistical analysis. The external validity of the study is also limited by the fact that it was conducted only at one academic hospital.

Physical therapists appear to have a favorable view of using the results of imaging studies in clinical practice. Little and Lazaro surveyed physical therapists in California on their attitudes towards imaging, as well as their use of imaging studies and imaging information in clinical practice.[22] The survey instrument consisted of statements rated on a five-point Likert scale. The survey was sent to 500 randomly selected physical therapists, 120 of whom responded. Of the 120 respondents, 35% were male and 65% female, with a mean age of 41.58 years and a mean of 13.97 years of practice. The authors did not inquire about specializations, such as OCS, but most respondents worked in outpatient settings, although they did not provide a percentage. The authors found that 70% of the respondents agreed or strongly agreed with the statement that it was important to be able to review information about imaging studies and 83.4% agreed or strongly agreed that they used radiographic and MRI information in clinical practice, when available, across all patient groups. The participants in this study considered imaging to be an important tool to aid clinical decision-making. Eighty-five percent agreed or strongly agreed with the statement that imaging helped them understand the patients' disease process, while 81.6% agreed or strongly agreed that imaging information improved diagnosis, prognosis, and

interventions, and 87.5% agreed or strongly agreed that imaging information helped them identify contraindications to examination and treatment.[22]

The value of this study is limited because the above findings for "radiographic and MRI information" do not distinguish between reading radiographic reports and viewing the images. Thus, the study gives limited insight into the participants' view of the value of viewing imaging studies for clinical decision-making. Other limitations include low response rate (24%) and self-selection of respondents, which may have resulted in over-representation of physical therapists with an interest in imaging. Finally, the survey instrument was not validated and included numerous items for which the authors did not report any findings.

In his discussion of Rocabado's approach to imaging of the TMJ, Agustsson described the use of imaging studies by physical therapists for visualization of evidence of impediment to motion, instability, or other functional disturbances.[34] With Rocabado's approach, radiographs and MRIs are used to supplement evaluation, as well as to guide treatment. Radiographs are used to evaluate the position of the condyle of the mandible within the mandibular fossa for an initial assessment of articular disk displacement and for evaluation of arthritis. Since the position of the upper cervical spine segments can influence movement of the TMJ, radiographs of the cervical spine are employed to detect abnormal subcranial position and to demonstrate improvement in position and function following treatment. Furthermore, Rocabado used serial MRIs during different degrees of mouth-opening to evaluate abnormal position of the articular disk of the TMJ, as well as to guide and monitor treatment.[34] This use of serial MRI imaging has not been described for lumbar spine, shoulder, and knee. The descriptions above relate to the use of imaging to guide treatment of the TMJ, while the vignettes used in this current study relate to the lumbar spine, shoulder, and knee. However, the importance of this account is that

it is the only description of physical therapists using their own evaluation of imaging studies to guide and monitor treatment.[34]

One study was found addressing imaging-diagnosis by physical therapists. Morris et al. studied the ability of practicing physical therapists to identify musculoskeletal conditions on conventional radiographs, MRI, and CT scans. The authors presented the imaging studies with and without accompanying clinical vignettes.[35] The authors sent a survey to all licensed physical therapists in Ohio and analyzed the 866 surveys that were completed for radiographic diagnostic accuracy. The conditions displayed in the survey were CT scans of cervical spine fractures, a radiograph of avascular necrosis (AVN), and MRIs of anterior cruciate ligament (ACL) injury. Both the CT and the MRI were presented in all three orthogonal planes, but the radiograph was only presented in the antero-posterior (AP) view.

The authors found that, without an accompanying clinical vignette, 48.2% of respondents correctly identified the ACL injury, 30.9% identified the cervical spine fracture, and 5.5% identified the avascular necrosis. The diagnostic accuracy significantly improved for all three of the conditions with the addition of the clinical vignette, to 61.3% for the ACL injury, 36.4% for the cervical spine fracture, and 25.6% for the avascular necrosis - the greatest improvement being in the diagnosis of AVN. The authors looked at factors associated with diagnostic accuracy and found that for the cervical fracture and the ACL injury, therapists that were OCS certified and those with other APTA certifications performed significantly better than those without APTA certifications. Physical therapists practicing in outpatient settings performed significantly better on the ACL case than those in non-outpatient settings.[35]

While the purpose of Morris et al.'s study differs from this current study, which is concerned with evaluation processes rather than diagnostic accuracy, the study of Morris et al. is important

because it is the first study of radiographic diagnostic accuracy by physical therapists. It is, furthermore, important because Morris et al. found that OCS certified physical therapists showed greater diagnostic accuracy than did other physical therapists. That finding supports the use of OCS certified physical therapists as subjects for a study of physical therapists' clinical use of imaging studies.

The Morris et al. study has several limitations. It only included physical therapists in Ohio and the clinical vignettes had not been externally validated. Other shortcomings of the study included that only one imaging modality was used for each case. That is not how imaging studies are typically evaluated. According to best-evidence guidelines for imaging, radiography, not MRI, should be the first study for suspected ACL injury. The MRI would then be interpreted with reference to the radiographs.[108] Finally, there were weaknesses in the design of the case vignettes. In the case of patient with AVN, the vignette provided enough information to make it likely the participants did not need to view the radiograph to make the diagnosis. In another case, there were more than one possible diagnoses and the diagnosis the authors designated as the right one, may not have been the most obvious one.[35]

While few authors have discussed direct evaluation of imaging studies by physical therapists for diagnosis[35] or for the purpose of guiding treatment interventions,[34] several authors have addressed how physical therapists can integrate imaging into clinical practice.[6,14,23,25] Barr discussed the integration of imaging into physical therapy practice and identified five main areas of imaging competence for physical therapists.[23] In his view, the physical therapist needs to be able to: 1) Recognize when imaging is needed for the sake of completing the patient examination, 2) integrate information from the radiologist's report into the treatment plan, 3) visually understand the image, to gain information that may not be included in the radiologist

report, 4) identify when imaging is needed, and when not, for the best patient outcome, and 5) communicate about imaging studies with radiologists and other physicians.

Knowing when to recommend imaging to complement the patient examination is, according to Barr, still the most important aspect of physical therapists' use of diagnostic imaging.[23] But, physical therapists also need to evaluate imaging studies, not to challenge the radiologist who bears the ultimate responsibility for the diagnosis, but because of information that might be important to the physical therapist's treatment plan but not be included in the radiologist's report.[23]

Clinical Decision-Making

Clinical decision-making is grounded in clinical reasoning and is based on the clinician's knowledge, experience, and practice paradigms.[43,40,41] Jones and Rivett described clinical reasoning as the thinking process that allows the clinician to take the most appropriate action and to make the best clinical decisions. The authors described clinical reasoning "as a process of reflective enquiry comprising three elements –cognition, metacognition, and knowledge."[43(4)] According to Jones and Rivett, the clinical reasoning process can be seen as a collaborative affair. This process is shaped by the attributes of the therapist, including knowledge and experience, as well as the attributes of the patients, including their needs and beliefs.[43]

Decision-making, in general, is described as the process of making a choice between possible courses of action.[54] But, clinical decision-making is more complicated. In the clinical context, it is not always possible to choose amongst clearly defined, limited number of options for developing a plan of care.[54] Health care professionals must reach decisions, taking into account multiple considerations, in a dynamic and often stressful environment. Clinical decisions are frequently made under conditions of uncertainty and often without all the

information required. To further challenge this process, the decision-making environment may change while decisions are being made. The goals underlying the decisions may also be in flux, be poorly defined, or contradictory. The recent emphasis on the collaborative nature of the clinical decision process, with participation by patients and other health professionals, adds to this complexity.[54]

Clinical decision-making has been discussed with reference to information processing theory,[53] which has been the basis of research into how healthcare professionals gather and process information. According to information processing theory, reasoning is restricted by the limitations of memory. To counteract this limitation, humans have developed cognitive strategies, exemplified by clinical decision-making models, to allow efficient decision-making based on complex information.[44] Several clinical decision-making models exist; the hypothetico-deductive, the heuristic model,[52,55] and pattern recognition, based in exemplar knowledge.[61,62]

It is the consensus of research in clinical decision-making that clinicians use different processes depending on their paradigms and expertise.[44] Depending on the individual's level of expertise, different decision-making processes may be evoked. Kulatunga-Moruzi et al. studied the clinical decision-making of expert dermatologists, general practitioners, and residents when presented with skin lesions. The participants were eight dermatologists with 3–20 years of experience, 12 general practitioners with 11–15 years of experience, and ten family medicine residents in their second year.[63] The participants received verbal descriptions and/or pictures of common skin lesions. The verbal descriptions of the lesions consisted of information about the type of lesion, according to classification of such lesions, descriptive information about the lesion, such as shape, size, and color, and the location of lesion, as well as the age and gender of the patients. The 40 pictures of skin lesions used were presented in random order; 20 that were

typical manifestation of diseases, as judged by experts, and 20 judged to represent atypical manifestations of the diseases.[63]

The authors assigned the practitioners to one of two groups, a) a group that received a verbal description of the lesion and then a picture of the lesion and b) a visual (picture only) group. The participants in the first group were asked to make a diagnosis based on the verbal description only and were then shown the corresponding picture of the lesion and were again asked to make a diagnosis. The second group was asked to make a diagnosis based on the picture only, with no verbal description. The authors found that residents performed best and general practitioners worst when participants made a diagnosis based only on a verbal description. When the description was followed by a picture of the lesion, again, residents did best. However, when presented only with a picture, experienced dermatologists performed best, but the residents worst.[63]

This suggests that increased experience leads to increased reliance on visual exemplars and that the verbal account detracted from the experts' ability to interpret pictures of lesions. The authors concluded that the experts may already have had a diagnosis in mind from the verbal description and that that an incorrect diagnosis may have persisted while viewing the image. This would be particularly detrimental to the experts that did not do well with the verbal descriptions, but already had a mental reservoir of image exemplars upon which to draw.[63]

Physical Therapist Practice Paradigms as it Relates to Clinical Decision-Making

Physical therapist clinical decision-making cannot be fully discussed outside the context of practice epistemology. Practice epistemology refers to what clinicians consider to be knowledge and how this knowledge is employed in clinical practice.[48] This, in turn, reflects underlying beliefs about ontology; the nature of reality. Epistemology and ontology influence how physical

therapists practice and have a bearing on what is considered expertise.[109] There is evidence that clinical decision-making approaches differ between physical therapists of different specialties and, furthermore, that this difference may be founded in their practice epistemologies.[45,46,49]

In a qualitative study of the practice paradigms of Norwegian physical therapists, Thornquist found fundamental differences between three groups of physical therapists, as far as core beliefs and approach to examination and treatment.[46,47] The participants in her study were manual therapists, psychomotor therapists, and district (home-health) therapists. Manual therapists are defined by the Norwegian Physiotherapy Association as physical therapy specialists in injuries and disorders to the musculoskeletal system that focus on manipulation, soft tissue mobilization, stretching, and strengthening, based on a specific examination of the musculoskeletal system.[110] Their training is comparable to that of fellows of AAOMPT, consisting of two-years full-time post professional curriculum.[110] Psychomotor therapists are characterized by their focus on "readjustment" of the whole person. They regard the body as an integrated physical-psychological entity and emphasize the interaction between emotions, breathing, muscle function, posture, and movements. In Norway, manual therapists and psychomotor therapists typically work in private practice. Both groups need post-graduate training in order to practice, are recognized as specialists by health-authorities, and receive a higher rate of reimbursement than do other physical therapists.[47] District therapists are employed by the municipalities to treat older people in their own homes. Their treatment focus is on prevention and health-maintenance through ergonomic adjustments to the home and improvement of overall patient function.[111]

Thornquist used video recordings of clinical interactions, five videos for each of the three groups. She, furthermore, performed 30 one-on-one interviews with the participants where she sought insight into their intentions, concentrating on the meaning they ascribed to their actions.

She did not describe her methods of analysis, but said she leans towards phenomenological and hermeneutic traditions.[46]

Thornquist found that the approaches to examination, treatment, and patient interaction employed by manual therapists, district therapists, and psychomotor therapists differed. The groups of therapists seemed to operate within different frameworks and direct their attention towards different aspects of the patients. They interpreted information differently, drew different conclusions from their examinations, and constructed different treatment plans. The manual therapists focused on signs and symptoms in the traditional sense, as indicators of pathology. They "were concerned with the body as a functional system primarily from a biomechanical perspective. They paid most attention to the local and delimited, the symptom-giving and neighboring region(s) thereby aligning themselves to traditional biomedicine."[46] Manual therapists tried through functional diagnosis to identify the tissues involved and the focus of their concern was typically on local restrictions of motion. Their clinical examinations tended to focus on passive movements, specific tests of joint mobility, and other tests aimed at identifying involvement of different tissues. Their treatment plans addressed the motion restrictions directly.[46]

The psychomotor therapists, similarly, did not focus on motion or strength at individual joints. Their emphasis was on the correlation between general and local conditions, as well as the relationship between the body and the patient's life experiences. When examining the patient, they examined the whole body, regardless of the location of symptoms. The treatments proposed by the psychomotor therapists were more general in nature than treatments proposed by manual therapists and not directed at a local dysfunction. Their focus was on the whole person and on the patient's potential for change.

The district therapists tended to focus on the patient's function and activity level and on the relationship between the patient and the environment, as well as their ability to take care of themselves and master their domestic situation. They did not emphasize strength or motion at individual joints. Their focus was on the extent of active movement, everyday function, and the functional consequences of disease. District therapists viewed functional problems from a social and environmental perspective and viewed functional ability in relation to the demands of the patient's environment. They emphasized the patients' own views, as well as the views and expectations of other family members, such as a spouse. The district therapists' main concern was the restrictions experienced by the patient and possible solutions to the problems the patient faced.[46]

The approaches to the patient interviews also differed between the three groups.[46] Thornquist found that manual therapists, similar to physicians, were in charge of the dialogue and did this by deciding the topics of discussion during the interview and by asking mainly closed-ended questions. In contrast, the psychomotor therapists' dialogue was semi-structured. The manual therapists' patient interviews focused on specific, limited findings and during the interview, they would give information or explanations to the patients. This contrasts with the psychomotor therapists who sought more information about the patient's experiences and sought their views instead of primarily educating them. The manual therapists seemed to operate with a view of the body and the person inhabiting that body as unrelated phenomena.

Regarding the interviews, Thornquist found characteristics that were common to the manual therapists and the psychomotor therapists. There was a tendency by both groups to adjust the patient's views to their own frame of reference, presumably focusing on what they knew best. Furthermore, both groups seemed unaware of their own underlying assumptions of how they arrived at what they considered clinical facts through their interview and examination.

The district therapists sought to elicit the patients' views and were mainly concerned with their patients' overall abilities. Consequently, although they paid attention to symptoms and signs in the traditional sense, they did not seek detailed understanding of the specific conditions, rather focused on the patients' capabilities, how they moved and acted. This group was less interested than the psychomotor and manual therapists in controlling the dialogue and placed emphasis on the patients' own views and expectations.[46]

Thornquist, discussing the focus of traditional medicine, stressed that, as humans, we tend to structure our world according to our paradigms; that there is no such thing as purely objective observation.[47] All perceptions are colored by our assumptions. Medicine, for example, has primarily been concerned with the observable and measurable, in accordance with the biomedical model. This model is based on certain assumptions about the nature of being and on positions about what counts as relevant and valid knowledge. In the biomedical model, clinicians search for the limited and localized, emphasizing that signs and symptoms are manifestations of underlying pathology that must be identified and treated.[47] According to the biomedical model, the value of diagnostic information grows in proportion to its reliability. Measurements are considered particularly valuable, so there is a reliance on diagnostic technology, such as imaging, for gathering information. According to the biomedical model, the interpretation of observable clinical signs is up to the clinician, who decides what is relevant, depending on the clinician's frame of reference.[47]

The biomedical model may impart diagnostic activity taken out of personal and social context, with the characteristics of the individual seen as a distraction on the path to diagnosis. This can lead to the separation of the body from the self, possibly leading to fragmentation of care and to medicalization.[47] In contrast, the biopsychosocial model holds that objective bodily information and the patient's descriptions of his/her condition are not categorical opposites.

According to this model, the body reflects the patient's habits, routines, and practices and can be a "continuous source of information and knowledge."[47] Thornquist argued that, in spite of their differences, most physical therapists are likely to subscribe the biopsychosocial model to some degree. In the biomedical model, the primary object is the "inner" body that hides the underlying pathology, but, in contrast, physical therapists tend to focus on the dynamic, immediate, and visible body. As a group, physical therapists tend to emphasize observation, examination, and patient history. They perform their diagnostic work during direct encounters with patients, use technical tools sparingly, and infrequently send patients for diagnostic workup.[47]

Thornquist's research is significant because it provides a framework for discussion of manual therapist clinical decision-making. Her findings are consistent with those of May and Dennis who found that experts in orthopedic physical therapy frequently processed information in a manner consistent with the hypothetico-deductive approach.[45] Manual therapists' reliance on the biomedical model seems at odds with what is known about physical therapist expertise.[109] Research on expertise in different physical therapy specialties indicates that experts are characterized by multi-dimensional knowledge and collaborative clinical reasoning.[90,92] Some authors have suggested that adherence to the biomechanical model may be at odds with the complex and multifaceted clinical reasoning process that has been described in studies on physical therapist expertise.[109,112]

Clinical Decision-Making in Physical Therapy

Few studies have been conducted on clinical decision-making models in physical therapist practice[45,88] and no studies were found on the use of pattern recognition or exemplar

knowledge for diagnosis or clinical decision-making by physical therapists. May and Dennis studied the nature of data gathering and information-processing for clinical decision-making by expert physical therapists in private practice, rehabilitation centers, and hospitals in the US and Australia.[45] The authors surveyed the physical therapists, using a 48-item survey instrument they developed. The survey asked the physical therapists about their preferred sources of information, as well as their cognitive style preference. The participants, expert practicing clinicians, were nominated by elected officers at the national, state, or section level. The authors received 638 usable responses from 784 participants, 54.5% from the US and 45.5% from Australia. They grouped participants into six major practice areas, orthopedics, neurology, general practice, geriatrics, cardiopulmonary, and education. Half of the participants were either in orthopedics or neurology.[45] May and Dennis looked at participants' data gathering and cognitive styles and classified participants into four categories according to the McKenney and Keen cognitive style paradigm; the receptive, preceptive, systematic, and intuitive styles.[113] The first two of these styles, the receptive and preceptive styles, relate to the data

gathering phase of decision-making. The receptive style is characterized by suspending judgment until all data have been collected, with emphasis placed on detail and the implications of each piece of data. This is consistent with the hypothetico-deductive approach. The preceptive style, however, is characterized by a focus on relationships between findings, even in the absence of complete data, and by seeking findings that do not fit expectations. There are two cognitive styles related to information processing, the systematic style and the intuitive style. The systematic style is characterized by a methodical approach. The intuitive style is less linear and considers multiple approaches simultaneously, with a perspective on the whole problem. [113]

May and Dennis found that the physical therapists' preferred source of information in all types of practices was the physical therapists' own patient assessment, while most therapists perceived physicians' orders to be of limited value. This, however, varied according to country of practice. Twenty-eight percent of Australian orthopedic therapists valued physicians' orders, while 46% of US therapists did. Of other sources of information, many physical therapists found radiographs to be a valuable source, although this was far more common among Australian physical therapists (57%) than US therapists (26%).[45] The authors also found that physical therapists in private practice settings were more likely to identify with the receptive data gathering style than those employed in hospitals and were more likely to identify with the systematic style of information processing than those employed in rehabilitation center setting.[45]

There was also a difference in cognitive styles according to specialization. In the US, physical therapists in cardiopulmonary and neurological practice had a more positive attitude towards the preceptive style of data gathering than did physical therapists in orthopedic practice, who leaned towards the receptive style. As far as information processing, orthopedic physical therapists had a more positive attitude toward the systematic style than did physical therapists in general practice and cardiopulmonary physical therapy. Female physical therapists, in both the US and Australia, identified significantly more with the preceptive mode of data gathering. Physical therapists' preference for cognitive styles was not influenced by years of practice.[45] Thus, the findings of May and Dennis are in agreement with those of Thornquist,[46,47] arguing that orthopedic physical therapists tend to lean more towards hypothetico-deductive processes in gathering and processing of information.

When independently managing patients with musculoskeletal disorders, a key element of physical therapist clinical decision-making relates to the ability to determine which patients are

suited for physical therapists treatment.[26] Jette et al. found that physical therapists working on a direct access basis, can accurately identify which patients should be referred to other health care professionals.[84] The authors recruited 394 physical therapists from a random sample of 1000 members of the Private Practice Section of the APTA. Twenty-five percent of the participants were OCS certified, fellows of AAOMPT, or had other formal recognition of expertise in orthopedics, and 79% of participants had practiced more than ten years. The authors conducted a survey using twelve hypothetical case scenarios, on which they based questions about clinical decision-making. The validity of the cases was strengthened by developing them from current literature regarding symptoms and risk factors, as well as descriptions of medical problems that might mimic musculoskeletal problems. The cases were reviewed, on two separate occasions, by four physical therapists considered by the authors to be experts in musculoskeletal problems.[84]

The participants responded to a questionnaire created by Jette et al. that allowed classification of patient management decisions as either correct or incorrect. For each case, the physical therapists were asked to determine if they would provide physical therapy intervention or refer the patient to a medical professional**.** The authors calculated the percentage of correct referral decisions for each case and found that correct decisions were made 87.3% of the time for musculoskeletal conditions and 87.8% for noncritical medical conditions. Participants with an orthopedic specialty were significantly more likely to make a correct management decision for cases involving musculoskeletal conditions.[84] Jette et al. concluded that physical therapists with expertise in orthopedics were highly likely to make correct clinical decisions as to when referral to a physician is indicated**,** not only for musculoskeletal conditions, but also for non-critical medical conditions.[84]

Numerous limitations apply to this study. The survey instrument and the cases scenarios were constructed by the researchers and although the case scenarios were reviewed by expert physical therapists, no physicians reviewed the cases, which could have strengthened the validity of cases based on medical conditions. Finally, the information provided with each case was limited and it is not known how well the cases correspond to actual distribution of diagnoses in private practice. This study, however, is important because it demonstrates the ability of physical therapists to identify when it is appropriate to refer patients to other health care professionals and when it is safe to treat patients that display signs and symptoms that may indicate non-musculoskeletal pathologies. Furthermore, the study of Jette et al. is relevant to this current study because informants were asked about indications for caution or referral based on case vignettes and/ or imaging studies.

There is evidence that physical therapist recommendations for imaging studies are appropriate and may decrease costs associated with the care of musculoskeletal disorders as well as the radiation burden for patients.[74,80,82,114] The ability to appropriately recommend musculoskeletal imaging rests on diagnostic capabilities that allow the therapist to determine when the patient displays signs and symptoms that require input from other health care professionals, including when imaging studies are indicated.[82,114] The diagnostic abilities of physical therapists, related to musculoskeletal conditions, as well as their ability to determine when imaging studies may be indicated has been shown to equal or surpass that of physicians from a variety of specialties.[74,82-84,115]

McGill compared the practices of physical therapists and family physicians in a military hospital setting in providing musculoskeletal primary care.[74] The authors performed a retrospective medical records review of data from 149 randomly selected patients seen by family physicians (n=95) or physical therapists (n=54). None of the patients seen by physical

therapists had been referred to physical therapy by a physician. The author compared the two groups of practitioners for the return-to-duty rate of their patients, as well as the use of medications and imaging studies. McGill found 50% higher return-to-duty rates for patients treated by physical therapists, as compared to patients treated by family physicians ($p < 0.0001$). He also found that the rate of radiology referrals by the physicians was 82.11% compared with only 11.11% by the physical therapists ($p<0.0001$). In view of the fact that most imaging guidelines aim for a conservative use of imaging studies,[57,59,60,116] low referral rates for imaging studies by physical therapists that have the right to refer for imaging[73,80] seem to indicate appropriate decision-making by physical therapists regarding referrals or recommendations for imaging.

McGill's study is subject to several limitations. It used retrospective data and the distribution of musculoskeletal problems between the groups was uneven. The physicians saw far more cases of ankle pain and lumbar pain than the physical therapists. With a mean age of 29 and 84% males, the population of patients is also not representative of the general population.[74] Furthermore, the study cannot be generalized to physical therapists outside the military because non-military physical therapists are generally not credentialed to order imaging studies.

Imaging studies are considered widely overused[117-120] and numerous steps have been taken to counteract overuse of imaging. This has primarily been done with the publication of educational materials and official guidelines.[121] The most significant step in reducing the number of imaging studies has been the development of easy-to-use clinical decision rules for several musculoskeletal conditions that clearly specify when imaging is needed. The best known of these are the highly sensitive and specific Canadian cervical-spine rules,[56] Ottawa knee rules,[57] and Ottawa ankle[58] rules. These rules, which are primarily employed in emergency

departments, were developed by a team of emergency medicine physicians. By taking a short history and performing a simple examination, these rules make it possible to avoid unnecessary imaging, while not resulting in any significant fractures being overlooked.[116] Physical therapists have widely embraced these rules[6,23,122] and have been shown to apply the Ottawa ankle rules accurately.[114]

Springer et al. compared the application of the Ottawa ankle rules by military physical therapists to the application by orthopedic surgeons.[114] The study looked at the application of the Ottawa ankle rules on 153 sequential patients with acute ankle or foot injuries of less than ten-day duration. The patient sample included nine clinically significant ankle and/ or mid-foot fractures. Two physical therapists with military credentials as neuro-musculoskeletal physician extenders and five orthopedic surgeons with specialty training in orthopedic sports medicine independently evaluated the patients according to the Ottawa ankle rules. Based on this evaluation, participants determined if imaging studies were needed to confirm or rule out fractures. The recommendations for or against imaging were then compared to the radiographic diagnoses of fractures made by radiologists who were blinded to the participants' recommendations.

The authors found significant agreement between the two groups of practitioners. There were no false negative findings for either group. The sensitivity was 100% for both orthopedic surgeons and physical therapists for both foot and ankle fractures. Specificity was identical (79%) for identification of foot fractures, but for identification ankle fractures, orthopedic surgeons scored 46% while physical therapists scored 40%.[114] This study supports the ability of physical therapists to use heuristic clinical decision-making, based on simple patient examination, to determine when imaging studies are needed. Furthermore, given 100% sensitivity in identifying fractures, the study supports the ability of physical therapists to make

accurate clinical decisions as to whether to treat or not treat as well as whether to refer a patient to another specialist. The weaknesses of the study include no description of clinicians' background, years of experience, and clinical specialization for the physical therapists. Furthermore, the applicability of these results is limited by the fact that all the participants were military physical therapists; certified physician extenders.

The ability to appropriately recommend imaging studies for musculoskeletal disorders rests not only on the ability and willingness to apply clinical decision rules for imaging referrals,[56-58] but on skills in performing a differential diagnosis[74,82] The appropriateness of referrals may be estimated by comparing clinical diagnoses to imaging diagnoses. Moore et al. performed a retrospective study of physical therapists' clinical diagnostic accuracy (CDA) for musculoskeletal conditions compared to documented MRI findings.[82] The authors compared physical therapists that had undergone military post-graduate specialty training in neuro-musculoskeletal evaluation to orthopedic surgeons and non-orthopedic providers, physicians and podiatrists.[82] The sample consisted of all patients referred for musculoskeletal MRI at an army community hospital over a period of 18 months. Of those patients, 142 were seen by physical therapists, 172 by orthopedic surgeons, and 243 by non-orthopedic providers. For each provider group, the agreement between clinical diagnosis entered in a radiographic database and MRI diagnosis was presented as a percentage. The authors found statistical differences in CDA between physical therapists (CDA=74.5%) and non-orthopedic providers (CDA=35.4%) and between orthopedic surgeons (CDA=80.8%) and non-orthopedic providers, but no significant difference between physical therapists and orthopedic surgeons. Furthermore, the authors found a higher physical therapist CDA (90.9%) for patients seen through direct access, although statistical significance was not reported for this finding.[82]

Moore et al. concluded that physical therapists can accurately diagnose musculoskeletal conditions and can identify the need for further imaging to inform the patients' plan of care.[82] The concordance between physical therapists' diagnostic findings and MRI findings indicates that appropriate imaging referrals by physical therapists may be framed by their ability to evaluate musculoskeletal disorders. These findings are consistent with outcomes from studies of diagnostic concordance between physical therapists and orthopedic surgeons in Canada and Britain.[123,124]

The study by Moore et al. has several weaknesses. The first is selection threat. In a retrospective study, there is no guarantee of group equivalence as far as the complexity of the cases seen by each group of practitioners. Furthermore, the authors do not describe a standardization of review for the MRI studies. Finally, operational definitions for diagnostic agreement are lacking. It is not clearly stated if the radiologists and the main-researcher, a physical therapist, were blinded to whether the diagnosis they were confirming was made by a physician or a physical therapist.

The ability of physical therapists to make clinical decisions related to patients with musculoskeletal disorders, particularly physical therapists with orthopedic specialization, seems to rest on strong foundational knowledge. Childs et al.[83] used a validated test to assess knowledge in managing musculoskeletal conditions. This test had previously been administered to medical students, residents, and medical specialists in a study of their knowledge about the management of musculoskeletal conditions.[125] The study sample consisted of 174 physical therapy students and 182 physical therapists in the uniformed services. The authors found that physical therapists with at least 1 year of experience in the US military and/or U.S. Public Health Service averaged a score of 75.9% on the test, while the physical therapist students achieved an average score of 66.2%. Physical therapists with board-certification (OCS and/or sports clinical

specialists) scored significantly higher than those without specialization; 81.3% vs. 73.7% for physical therapists without board certification.[83] An earlier study had reported outcomes for physicians on the same examination.[125] Freedman and Bernstein studied medical students, interns, and residents in various medical specialties and found orthopedic physicians scored on average 74% and medical interns 60% on the examination.[125] Childs et al. concluded that the study supports findings of previous studies showing that physical therapists can provide safe and efficient care for patients with musculoskeletal disorders.[83]

In summary, physical therapists, in particular board certified physical and therapists with military post-graduate training, have demonstrated solid knowledge of musculoskeletal disorders and strong overall clinical decision-making ability in the management of musculoskeletal disorders in a direct access environment.[83,115] This includes the ability to refer patients when additional testing or consultation with other health care professionals is required.[82-84,115] The studies discussed above provide support for the use of physical therapists with OCS certification as subjects for this study.

Expertise

Expertise has been discussed since the times of the ancient Greeks and the medieval guilds defined and nurtured expertise as it related to their trades, while at the same time monopolizing the application of the required skills and knowledge.[126] Expertise does not simply result from the number of years in practice, but from time spent on deliberate practice.[127] While experience may be central to expertise, the quality of the experience and the quality of received feedback is thought to be most important, which may explain reported non-linear relationship between years of practice and expertise.[128]

Two basic approaches have been used in the study of expertise,[129] studies based on independent rating systems such as the Elo rating system for expertise in chess and studies that compare novices to experts. Studies comparing novices and experts are grounded in the assumption that fundamental capacities and reasoning abilities are similar for experts and novices and that, with training, the novice can attain expertise. The appeal of this approach is that it places expertise on a continuum and allows it to be defined in relative terms. This 'relative' approach assumes that expertise is gained through acquisition of domain knowledge, with emphasis on the amount of accessible knowledge and quality of the knowledge representations. Expert-novice comparisons focus on how one can enable the less skilled to become more skilled.[129] Studies on expertise in the health care professions most commonly compare novices and experts.[65,85,130]

Over the last three decades, there has been a change in the focus of studies of medical expertise. There has been a shift away from previous emphasis on the hypothetico-deductive model to an emphasis on knowledge organization and pattern recognition.[85] Recent studies have generally found that the expert's diagnostic approach is dictated primarily by experience and less by the use of basic scientific knowledge. Indeed, experts have been found to recall fewer details about cases than do residents and to be less likely to draw on pathophysiological knowledge when solving clinical problems.[130] This is corroborated by what is known about the effect of age on medical expertise. While older physicians consistently perform worse than residents on knowledge tests, they do better on tests of competence.[85]

Thus, medical experts seem to rely on familiarity with patterns of clinical presentations or on pattern recognition, based in exemplar knowledge. Exemplar knowledge seems to be a key element in diagnostic expertise[131] and has been shown to be associated with greater diagnostic success than the hypothetico-deductive approach.[51] However, there are inherent problems in

investigating exemplar knowledge, since it is difficult to apply a 'think-aloud' approach to the investigation of a phenomenon that may be largely unconscious.[62] Experts may have difficulties explaining the processes underlying their expertise and as Taylor stated, "they are like fish that do not notice the water in which they are swimming."[132] Therefore, exemplar knowledge is often studied in the visual domain, using studies of expertise in dermatology[63] and imaging.[133]

Physical Therapist Expertise

The informants in this study are experts in musculoskeletal physical therapy, fellows of AAOMPT or physical therapists with OCS certification, recruited from a prior unpublished Delphi study.[134] Expertise in physical therapy has been studied over the last 30 years,[135] using experts in physical therapy identified on the basis of knowledge, skill, experience,[136] professional qualifications, authorship of books or articles,[137] clinical outcomes,[92] years of practice,[91] or nominations from colleagues.[90] Unlike most studies of medical expertise that focus on diagnostic accuracy,[87] numerous studies of physical therapy expertise have looked beyond diagnostics and decision-making, to therapeutic outcomes[92,93] and the characteristics of experts manifest in performance of treatment interventions, interactions with patients, and management of the treatment environment.[88-91] Although early studies on expert clinical decision-making in physical therapy investigated the hypothetico-deductive model for clinical decision-making,[138-141] there has been a trend towards broader, more descriptive approaches based on models of clinical reasoning that contrast with the hypothetico-deductive model and allow for the representation of the complexity and diversity of clinical reasoning.[88,89]

Jensen et al. performed a series of qualitative studies of expert practice in physical therapy.[89-91] The authors compared novice and expert physical therapists and examined how these two groups practiced, as well as the way in which they were different and how these

differences developed. They looked at the characteristics of the physical therapists and the organizational settings, as well as tools and treatment techniques. In their first study, eight physical therapists at three different levels of experience, were studied using observation, audio-recordings of treatment sessions, interviews of the physical therapists, and reviews of patient records.[91] The physical therapists were all practicing in an outpatient orthopedic setting, treating patients with musculoskeletal problems.

Using grounded theory, the authors identified five themes that distinguished novice therapists from experienced therapists: 1) therapists' allocation of time, 2) impact of the therapeutic environment, 3) types and uses of patient information, 4) degree of responsive interaction, and 5) therapist's integration of interactions. The authors found that, compared to novices, experienced therapists spent more time on hands-on care and on gathering and evaluating information. They also spent more time educating patients and on social interchange with patients. They were also better at handling interruptions of treatment interventions than were novices. While the study revealed important differences in knowledge and treatment between novices and experts, the authors stressed that this study was only the first in a series of studies planned for the purpose of exploring the multiple dimensions of clinical practice.[91]

In 2000, Jensen et al. studied a group of 12 physical therapist experts in geriatrics, neurology, orthopedics, and pediatrics.[89] The experts were nominated by officers of the APTA, with the exception of experts in orthopedics who were chosen from participants in a Delphi study of leaders in manual therapy and by the Orthopedic Section of the APTA. The authors performed reviews of patient records and interviewed patients and therapists about clinical decision-making and clinical skills, based on videotapes of treatment sessions. The authors viewed the videos with the therapists while asking questions about their clinical reasoning, clinical decision-making, and the knowledge base underlying clinical decisions. The authors

carried out these interviews throughout each episode of care and augmented the interviews with notes from the patient charts. Themes common to experts were identified to form a theoretical model that focused on 1) a multidimensional, patient-centered knowledge developed through reflection, 2) clinical reasoning processes founded in collaborative problem solving with the patient, 3) function-related movement assessment, and 4) caring and commitment to patients.[89]

Experts were found to have deep, patient-centered knowledge, to be motivated to be lifelong learners, and to have broad knowledge of movement related to their clinical specialty. They shared an emphasis on patient education. Experts were aware of their own cognitive processes during data collection, were able to detect inconsistencies in data, and were comfortable with ambiguity.[89] The authors speculated that in students and novices, knowledge, clinical reasoning, and philosophy are separate entities, but in the expert, these come together to form largely overlapping domains.[89] The authors emphasized that physical therapy experts are aware of the limits of their knowledge and abilities and that they demonstrated metacognition with awareness of their own thought processes during the patient evaluation.[89]

Resnik et al. published studies on expertise in physical therapy, selecting experts based on patient outcomes for treatment of lumbar pain.[92,93] Resnik and Hart performed a retrospective analysis of the Focus on Therapeutic Outcomes (FOTO) database of 24,276 patients with lumbar syndromes, treated by 930 physical therapists at 354 outpatient facilities.[92] The therapeutic outcomes data consisted of self-reported health-related quality of life (HRQL) data collected at the start of treatment and at discharge. The HRQL measures included the overall health status measure (OHS), the physical component summary (PCS) of 12-Item Short-Form Health Survey (SF-12), and the physical functioning scale (PF-10). These measures are all widely accepted instruments for measuring patient outcomes.

Resnik and Hart classified physical therapists that achieved HRQL improvement above the 90th percentile as experts and physical therapists who achieved a mean HRQL improvement between the 45th and 55th percentiles as average. The authors then compared these two groups on demographic data and found experts could not be distinguished from average therapists based on years of clinical experience, sex, or professional degree. The experts, however, had fewer patients in the FOTO database than did average therapists, which could be explained based on a smaller caseload, although this cannot be stated conclusively. The group of therapists classified as experts included six therapists with advanced orthopedic clinical certification, while the group of average therapists included none ($P<.05$).[92]

The importance of Resnik and Hart's study is twofold. First, the authors found a relationship between success in treating patients with lumbar pain and having an advanced orthopedic certification. Second, the number of years of practice did not define experts.[93] The limitations that apply to the first study[92] include those that apply to all retrospective studies, potentially missing data and a selection bias that may adversely affect external validity. Furthermore, the quality of the collected data cannot be ascertained, as there is a possibility of input errors of questionnaire data by both patients and clinical staff. Finally, using only HRQL data to determine treatment success may paint an incomplete picture. Manual therapists, for example, typically place greatest value on findings from the clinical examination, such as measurements of mobility and function, not just on patient reports.[46]

By classifying experts on the basis of their therapeutic outcomes, Resnik and Hart's study[46] served as a basis for a second study by Resnik and Jensen where subjects were chosen on the basis of FOTO outcomes.[93] Resnik and Jensen studied the characteristics of average and expert physical therapists, as identified by treatment outcomes in the FOTO database.[92,93] The authors

used a multiple case study design, collecting both qualitative and quantitative data that they analyzed based on grounded theory.

Resnik and Jensen randomly selected 30 expert and 30 average therapists, as determined on the basis of therapeutic outcomes in the first study[92] and recruited six participants from each group. Both groups contained experienced and novice therapists. The subjects were not told about the classification underlying the study and thus did not know if they were categorized as expert or average. At the outset, participants were asked for a copy of their curriculum vitae and a statement regarding their philosophy of management of patients with low back pain. The authors employed semi-guided interviews, conducted by the principal investigator, with follow-up interviews or written communication as needed for gathering more data for testing emerging hypotheses. Using cross-case analysis, four key categories emerged: knowledge base, clinical reasoning, values, and virtues. The authors summarized their findings to develop an initial theoretical framework and the "central phenomenon."[93]

The authors found that therapists classified as experts in the study emphasized patient empowerment and patient-centered care where patients were viewed as active participants in their own treatment. Other expert traits included skills in differential diagnosis, self-reflection, and a strong knowledge base. They possessed multidimensional knowledge gained from professional education, clinical experience, continuing education, teaching, and professional interaction with colleagues. Inquisitiveness was another quality that distinguished expert therapists. The pre-professional preparation of experts was characterized by diverse academic backgrounds, such as occupational therapy and veterinary science, coupled with work experience. The therapists classified as average had greater variety in their clinical practice, were more involved in administrative tasks, with five out of six not reporting consulting other colleagues.[93]

Resnik and Jensen acknowledged several limitations related to their study. First, because the study included only a specific group of therapists, the findings cannot be generalized to a broader population. Secondly, their research method did not allow analysis of clinical reasoning as it related to actual treatment sessions or specific clinical examples. Thirdly, the selection and classification of therapists were based on retrospective analysis of clinical data and thus subject to limitations that apply to the use of retrospective data, which may threaten external validity. These include lack of control over initial data collection and uncertainty about the training process for data collection and adherence to FOTO guidelines, as well as patient and therapist selection bias.[93]

What is known about physical therapist expertise supports the decision to employ therapists with advanced credentials for this current study.[134] Experts are more likely to possess advanced certifications and in several studies of clinical decision-making, including imaging-related decision-making, physical therapists with OCS certification have outperformed other groups of therapists.[35,84]

Expertise in Evaluation of Imaging Studies

"Radiology is a discipline broken down into two processes; the process of perception and the process of cognition."[142 (77-78)]

Although limited research has been conducted on the personal characteristics of radiologists or the role of different cognitive styles associated with imaging expertise, expertise is generally considered the result of training. It is not due to personal characteristics or innate abilities. Radiologists' imaging expertise is domain-specific. When tested on searching pictorial scenes for hidden targets, radiologists have not been found to possess visual skills superior to that of laymen.[143] This is consistent with findings from other fields.[144] Comparisons of experts and novice radiologists show that novices have difficulties distinguishing one anatomical structure

from another, grouping features according to anatomical and physiological characteristics, and in discerning normal from abnormal.[132] Novices are more likely than experts to accept the first plausible explanation for an apparent abnormality and overlook other findings. They are also less likely than experts to unify findings relating to multiple body systems into a single diagnosis[132] and to accurately determine if radiographic findings are clinically relevant.[86] Since the radiologist's expertise is characterized by the ability to recognize patterns and to notice findings that do not fit the patterns, it is not surprising that the diagnostic ability of expert radiologists is characterized by pattern recognition.[145]

Expertise in imaging is not only a perceptual skill.[86] While identifying abnormal features in a radiograph is certainly a perceptual activity, understanding the nature of the abnormalities, "the process of cognition,"[142] is highly dependent on background knowledge.[66,146] For a radiologist, the perception process, representing the first glimpse of the image, is followed by clinical decision-making that relates what the radiologist sees in the image to the clinical significance of those findings.[65] Recognizing abnormal patterns requires solid conceptual knowledge[147] that allows the radiologist to draw conclusions about the significance of abnormalities.[148] The novice radiologist may match the expert's factual knowledge, but the expert is more likely to accurately determine if the findings are relevant to the clinical problem at hand.[86] Again, exemplars play a key role. According to Wood, visual mastery comes from long hours of viewing a large numbers of unique configurations and storing "thousands of patterns that are synthesized into an organized, searchable, mental matrix of diagnostic meaning and pathological features."[86] However, although there are reasons to believe what is known about radiologists' evaluation processes may apply to physical therapists as well,[134] physical therapists' expertise in evaluating imaging studies has not been studied.

Several studies have confirmed that expert radiologists are capable of rapid identification of abnormalities in images.[62] Kundel et al., studying expertise in pulmonary imaging, found that experienced radiologists could identify 70% of lesions on chest radiographs when presented with the images for just 200 milliseconds, a time period too brief for moving the eyes.[133] Mugglestone et al. repeated this experiment using mammographs and found 51% diagnostic accuracy with a 200 millisecond exposure to the images, increasing only to 69% when the radiologists were given unlimited time to study the images.[149] These studies suggest that not only do expert radiologists rely on pattern recognition, but they analyze the whole image at a glance and are able to locate abnormalities on the basis of this global analysis.[150]

Twenty years after the initial study, Kundel et al. confirmed expert radiologists' use of holistic image evaluation, using eye-tracking technology.[66] The authors explained holistic image evaluation as the initial global analysis of the retinal image that may lead to identification of abnormalities. According to Kundel et al., this global analysis involves a shift from a slow search-to-find approach to a faster, holistic mode, as used in facial recognition. Using this process, the radiologist evaluates the entire image at a glance and fixates the location of an abnormality. However, the expert radiologists in the study did not solely rely on first impressions. The holistic evaluation was followed by a focal analysis employing search-to-find strategies. The global analysis seemed to allow the expert radiologist to distinguish between normal and abnormal presentations, while the search that followed allowed for confirmation or negation of the initial impression of an abnormality, as well as identification of other, less obvious, abnormalities. This search was accomplished by scanning the image in segments, a process referred to as saccades. Saccades are characterized by rapid movements of the eye between points already identified based on the holistic evaluation. The authors found that expert radiologists did not abandon

the holistic perception during the focal analysis. The holistic perception was simultaneously active, seemingly, to maintain the stability of the perception.[66]

Leong et al. came to similar conclusions for radiologists and orthopedic surgeons evaluating musculoskeletal imaging studies. These authors conducted an eye-tracking study where they found that experts immediately identified the fractures but subsequently spent more time searching for further associated abnormalities than did less experienced participants.[65] This is consistent with the two-stage evaluation pattern described by Kundel et al.[66]

Using eye tracking technology, Wood et al. investigated the nature of the performance advantage of expert radiologists when reading musculoskeletal radiographs.[68] The participants in their study were 10 third-year radiography students (novices), 10 pre-fellowship radiology trainees with one to three years of training (intermediates), and 10 post-fellowship radiologists, who constituted the experts in this study. The participants were shown ten skeletal radiographs, normal radiographs and radiographs showing fractures, ranging from the obvious to the subtle. All patient information was removed. The experts showed significantly more diagnostic accuracy than that shown by novices ($p<0.001$) and intermediates ($p = 0.017$). The experts were also faster than novices were ($p=0.001$) in making a diagnosis and more confident in their findings than novices ($p=0.001$) and intermediates ($p=0.005$). The differences were particularly evident in the subtler fractures.

In this study, Wood et al. found the time required to locate the fracture was inversely related to diagnostic accuracy. They concluded that the performance advantage of the experts was based on superior pattern recognition skills, evidenced by shorter time required to identify the fracture and less time spent searching the image. They further concluded that novices, due to their lack of exemplar knowledge, cannot employ rapid, holistic perception of the entire field

of vision and so searched the whole image, using the high-resolution foveal vision to discover anomalies.[68]

Educational Support for Imaging-Related Clinical Decision-Making

From what is known about expertise, there are parallels between higher-order learning and expert clinical decision-making. Expert clinical decision-making involves identification of patterns, exemplifying the higher-order cognitive levels of analysis and synthesis, as well as the aggregation and reorganization of knowledge from different sources.[151] Having a well-organized framework of knowledge contributes to expert decision-making and problem solving by helping the clinician identify missing information. Furthermore, a sense of the hierarchy of knowledge helps establish priorities for evaluation and treatment.[152]

Clinical decision-making is supported by current trends in education, characterized by a shift away from memorization to organization of knowledge, as exemplified by emphasis on critical thinking and in the use of concept maps in medical education.[152,153] According to constructivist theorists, such as Bruner and Ausubel,[153] and proponents of critical thinking, such as Paul and Elder,[154] it is of critical importance to be able to assimilate new concepts into existing knowledge models.

Knowledge is no longer seen as transmitted and received, individuals actively construct their own knowledge. Accordingly, there is a trend away from classroom instruction toward self-directed learning, of which online education is a good example.[155] In online education, learning is seen more as a collaborative undertaking than a top-down activity[156] and learner engagement is considered a key ingredient.[157]

Imaging education is gaining importance in current professional level DPT education. Most DPT programs include imaging curriculum as a separate course or as integrated into other courses. In a recent survey, Boissonnault et al. investigated how physical therapist programs integrate imaging into their curriculum, as well as what imaging content is included in the curriculum, how students' competence is assessed, and faculty qualifications for teaching imaging.[4]

The authors modelled the survey instrument after a previous instrument used to study manipulation instruction in physical therapist curricula.[158] The survey instrument was initially reviewed by three expert physical therapists that were teaching physical therapist imaging at the first professional, as well as the post-professional levels. Following that, the survey was revised and sent to seven physical therapist experts responsible for teaching imaging. Based on their feedback, the survey was finalized. The survey was sent to faculty responsible for teaching imaging in each program or to program directors, if it was not known who taught imaging.

Responses were received from 155 (75.2%) of the 206 physical therapist programs in the US. Of these, 152 programs offered the DPT degree and the remaining three planned on doing so in 2014-15. Of the 155 programs, 152 (98.1%) included imaging in their curricula. Those that did not, cited lack of qualified faculty or lack of time, or that they did not consider imaging an entry-level skill. Of the programs that included imaging, 142 (93.4%) employed physical therapists to teach imaging. Seventy-five percent of the imaging faculty were practicing clinicians. One hundred and forty (92.7%) of the DPT programs introduced imaging in the first or second year and 76 (50%) offered a standalone imaging course. Furthermore, 57% of programs also integrated imaging into clinical sciences. The classroom lecture format was most commonly used, followed by online courses. Students were assessed for competence in the following areas: Identifying normal imaging anatomy (90.7%), identifying skeletal pathological changes

(87.4%), and utilizing clinical guidelines for referring patients to diagnostic imaging (86.8%). Although in most programs the emphasis was on the musculoskeletal system (76.3%), other areas included adult neurology (9.2%) and the cardiopulmonary system (7.7%).[4]

In spite of this considerable emphasis on imaging in physical therapist education, Boissonnault et al. stated that there are no accepted standards for what should be included in the imaging curriculum in professional-level physical therapist education.[4] The authors concluded that the variability in imaging instruction pointed to a need to develop consensus on imaging instruction within the profession and suggested the development of curricular resources consisting of instructional and evaluative materials. Furthermore, the authors recommended the development of a manual to provide guidance to faculty teaching imaging in physical therapist programs.[4]

Summary

The current literature does not discuss clinical decision-making processes used by physical therapists' in evaluation of imaging studies. There are no descriptions of how physical therapists use imaging studies to guide treatment of musculoskeletal disorders. However, several authors have discussed how physical therapists may integrate imaging into clinical practice.[6,14,23,25] The literature shows a favorable attitude by physical therapists towards increased access to imaging studies, as well as towards the use of imaging studies and/ or radiographic reports in clinical practice.

Clinical decision-making by physical therapists, primarily in direct access, may start with a decision regarding whether the patient is a candidate for physical therapist treatment and should be treated and/or referred to other health care professionals. Physical therapists, particularly in the military, have been shown to be capable of making these decisions and to

safely manage patients in a direct access environment.[74,84] Physical therapists may need to make recommendations as to whether imaging studies are indicated and the literature shows that physical therapists are capable of appropriate decision-making regarding recommendations for imaging, which may rest on their ability to conduct an accurate differential diagnosis.[82] Physical therapists' clinical decisions may depend both on their experience and their practice paradigms.[46,47]

Studies on US, Norwegian, and Australian physical therapists indicate that orthopedic physical therapists and manual therapists tend to lean towards the hypothetico-deductive model and rely on systematic data gathering for decision-making. Physical therapist experts have been found to have a strong knowledge base. They tend to be lifelong learners with broad knowledge of movement and to be patient-centered with a focus on patient education. The use of pattern recognition, central to medical expertise, has not been studied as it relates to physical therapists' clinical decision-making. Furthermore, imaging-related physical therapist expertise has also not been studied previously.

Instruction in imaging is now included in almost all professional-level physical therapist curricula. The emphasis is typically on musculoskeletal imaging anatomy and pathology, as well as the use of clinical guidelines to recommend imaging for patients. While most professional-level physical therapy programs include imaging instruction, the development of objectives for imaging education and the determination of acceptable competencies in this field in its early stages. The variability in imaging instruction points to a need for developing consensus on imaging instruction.

Chapter 3: Methodology

"Put bluntly, if you don't know what you are likely to find, your project requires methods that will allow you to learn from the data what the question is.[1(29)]

Introduction – Research Design

The goal of this study was to describe how physical therapist experts in musculoskeletal disorders evaluate and interpret imaging studies and how they employ imaging in clinical decision-making. The focus was on understanding those processes from the informant's perspectives. For this reason, a qualitative interview approach was chosen. The interviews allowed the researcher to explore informants' views, to probe their responses, and to obtain accounts of their experiences and beliefs.[1(30)] This chapter will provide an overview of the methodology utilized, including participant selection, interview process, and technology used for the interviews. It will also present the organization and analysis of the data, as well as discuss the research ethics and trustworthiness of the study.

This study was conducted in the tradition of grounded theory, which uses inductive reasoning to formulate a theory. Grounded theory was chosen for this study, since it is suited to interview data and observations, in addition to being suited for understanding processes.[1(60)] Grounded theory, which is possibly the most widely known and comprehensive of the qualitative research approaches,[159] has been described as a collection of research strategies combined to form an approach to data and analysis.[1(2)] Several schools or forms of grounded theory have been described.[3,160] In this study, the Straussian paradigm of grounded theory is followed. It is more structured and better suited to beginning qualitative researchers.[161] The Straussian paradigm utilizes data analysis that includes three levels of coding, open, axial, and selective coding.[161] Broadly speaking, this approach was followed in the current study.

This study involved one-on-one interviews with 18 informants that either had an OCS certification or had completed AAOMPT fellowship training. The study employed the GoToMeeting (GTM) web conferencing application[162] to display three case vignettes and the images accompanying these cases (Appendix 1: Cases). The informants read the cases and viewed the imaging studies after which the informants' evaluation of the imaging studies was recorded with participants' consent, using screen-capture videos. Following the evaluation of the imaging studies, the primary researcher interviewed the informants while playing back the screen capture videos of the imaging evaluation. The interviews followed an approach referred to as the general interview guide.[163] The researcher asked three pre-determined questions that probed informants about the process they used to evaluate the images. These questions asked about: 1) areas of interest in the images as indicated by the informants in the screen capture videos, 2) possible functional consequences of changes seen in the images, and 3) clinical decisions based on the imaging studies' including the need for caution or referral. The interviews were videotaped with the web conferencing tool so that the audio track of the videos synchronized the interview with what was taking place on the screen. This included the videos of the informant's prior screen activity (video-within-video). The primary researcher transcribed and analyzed the interview recordings in the tradition of grounded theory, using NVivo 10 qualitative software (NVivo).[164]

Web conferencing allows researchers to work with geographically dispersed informants and makes it possible to display videos and images in order to communicate phenomena that cannot be described verbally.[102,165] Furthermore, web conferencing allows a wide array of interaction, such as sharing of computer control. In this study, the informants not only viewed cases and images. A part of the interview process involved giving the informants control of the researcher's computer. This allowed for observation and screen capturing of the informants'

evaluation of images and for subsequent interviews that were based on these screen-capture videos. The interviews were saved as video recordings.

The use of videos to support interviews has been referred to as video-stimulated recall, which is a process during which informants have a chance to view a video of their actions as a basis for an interview.[101] This method has been used to investigate patient-physician interactions.[166-168] It can facilitate recall of events that informants might otherwise not remember correctly[89,169] and augment case-information provided to informants, resulting in higher-order cognitive processes, when compared to processes triggered by the written cases alone.[170]

In the current study, the video recordings had additional benefits beyond those listed above. By recording the movements of the pointing device (mouse), which the informant used to indicate areas of interest in the imaging studies, it was possible to free informants from having to state their observations in radiographic and anatomical terms. This approach allowed them to simply refer to "that change in shade" or to "this area." Thus, the screen activity was recorded separately to free participants from having to state their observations while they evaluated the images. But, in cases where it was difficult to synchronize the interview with the playback, the researcher allowed the interview to progress free of the playback and revisited the video or imaging studies as needed when the informant talked about specific findings. Furthermore, the screen-capture of the movements of the mouse while informants evaluated the imaging studies provided a separate set of data for analysis.

Participant Selection and Recruitment

Although no group of physical therapists has been identified as experts in imaging, fellows of AAOMPT and physical therapists with OCS certification were considered likely to have

characteristics that made them suitable subjects for this study. Several studies have indicated superior clinical decision-making by physical therapists with OCS[35,83,84] and fellows of AAOMPT. Those therapists are expected to recognize the radiological appearances of common musculoskeletal syndromes.[171,172] Of the 18 informants in the study, 12 had completed manual therapy fellowship training.

Participants in this study were experts in musculoskeletal physical therapy evaluation and treatment who responded to a recruitment survey in a prior unpublished Delphi study (Appendix 2: Invitation to Study).[134] The inclusion criteria in the Delphi study were: 1) Being a physical therapist with OCS certification and/ or AAOMPT fellowship and 2) having a minimum of three years of clinical practice. The primary researcher felt it necessary to ensure minimum clinical experience, although the relationship between years of practice and expertise is not linear[128] and at least one study on physical therapist expertise found that years of practice do not define experts.[93] The exclusion criteria for this current study included: 1) Involvement in the pilot interviews prior to the study, 2) Having reviewed the cases in this study for content validity, and 3) Current or past involvement in similar research on imaging for physical therapists. Therapists that responded yes to the question about involvement in research on physical therapist imaging were asked about the nature of that research. This was done to ascertain that the research was not similar to this current study. None reported involvement in a similar study, thus none were excluded on these grounds.

Two physical therapists were included in the study that did not meet the inclusion criteria of having an OCS certification or AAOMPT fellowship. However, both had completed the AAOMPT fellowship training and were awaiting fellowship notification. These participants were, at the time, teaching musculoskeletal physical therapy to students in the second term of a professional-level DPT program, and subsequently were awarded AAOMPT fellowship status.

Eighteen of the 46 physical therapists approached agreed to participate in the study (see Table 1).

Table 1: Informants in Interview Study

Participants	Gender	Highest academic degree	Orthopedic certification	Years practicing physical therapy	Current area of practice	Mean current % patient-care time in ortho/ musculoskeletal	Current/ prior participation. in research on imaging for PTs
AB	M	PhD (orthop.)	FAAOMPT pending	6-10 years	Academic institution	10%	No
CD	M	DPT	OCS	16-20 years	Private practice	0%	Yes
EF	M	DPT	OCS	16-20 years	Hospital (inpatient), private practice, and academic institution	100%	No
GH	F	DPT	FAAOMPT pending	6-10 years	Private practice, academic institution	90%	No
IJ	F	DPT	FAAOMPT and OCS	>21 years	Private practice	100%	No
KL	M	DPT	FAAOMPT	3-5 years	Private	20%	No
MN	M	DHSc	FAAOMPT	>21 years	Hospital (outpatient)	10%	Yes
OP	F	PhD (PT)	FAAOMPT and OCS	16-20 years	Hospital (outpatient), hospital (inpatient), and academic institution	100%	No
QR	M	DSc	FAAOMPT and OCS	16-20 years	Hospital, outpatient	20%	Yes
ST	M	DPT	FAAOMPT and OCS	6-10 years	Hospital (outpatient), hospital (inpatient), educational facility, and medical group	100%	No
UV	F	DPT	FAAOMPT and OCS	16-20 years	Academic institution	80%	No
WX	F	DPT	OCS	3-5 years	Private practice	100%	No
YZ	F	DPT	FAAOMPT and OCS	6-10 years	Academic institution	N/A	No
BA	F	BSc	OCS	16-20 years	Private practice and academic institution	100%	Yes
DC	M	DPT	FAAOMPT and OCS	>21 years	Academic institution and private practice	100%	No
FE	M	DPT	FAAOMPT and OCS	11-15 years	Academic institution	10%	No
HG	F	DPT	FAAOMPT and OCS	6-10 years	Hospital (inpatient), private practice, and academic institution	100%	No
JI	F	DPT	FAAOMPT and OCS	11-15 years	Academic institution	100%	No

Five pilot interviews were conducted by the primary researcher. The interviews involved physical therapists who had not participated in the previously conducted Delphi study.[134] All five of the pilot interviewees were faculty or adjunct faculty at a professional-level Doctor of Physical Therapy program and were either fellows of AAOMPT and/or had completed the OCS. The pilot study was performed to test the interview procedure and for identifying and adjusting technical processes. Since the pilot interviews focused on processes involved in computer-based interviews and not necessarily on discussion of the cases, the interviews from the pilot study were not included in the data analyzed for this study. One problem surfaced during the pilot testing when one of the testers experienced problems with a pop-up blocker associated with restrictive workplace network settings. Based on that finding, the researcher advised one of the informants, a member of the military, against doing the interview on a work computer. No other technical difficulties were encountered.

Recruitment of participants was done through an email sent to all physical therapists that responded to the recruitment survey for the previous Delphi study.[134] The potential participants were invited to participate in the current study and told that one interview was required (Appendix 2: Invitation to Study). This email also explained the interview process and the technology involved. A research assistant then sent an informed consent form (Appendix 3: Informed Consent Form) to the informants that had replied and indicated willingness to participate. Once informants signed and mailed the consent form to the primary researcher, a follow up email was sent to the informant to schedule the session at a time convenient to the informant. In the email scheduling the session, the primary researcher explained the use of web conferencing for the interviews, the basic computer requirements, and included a hyperlink to the web conference.

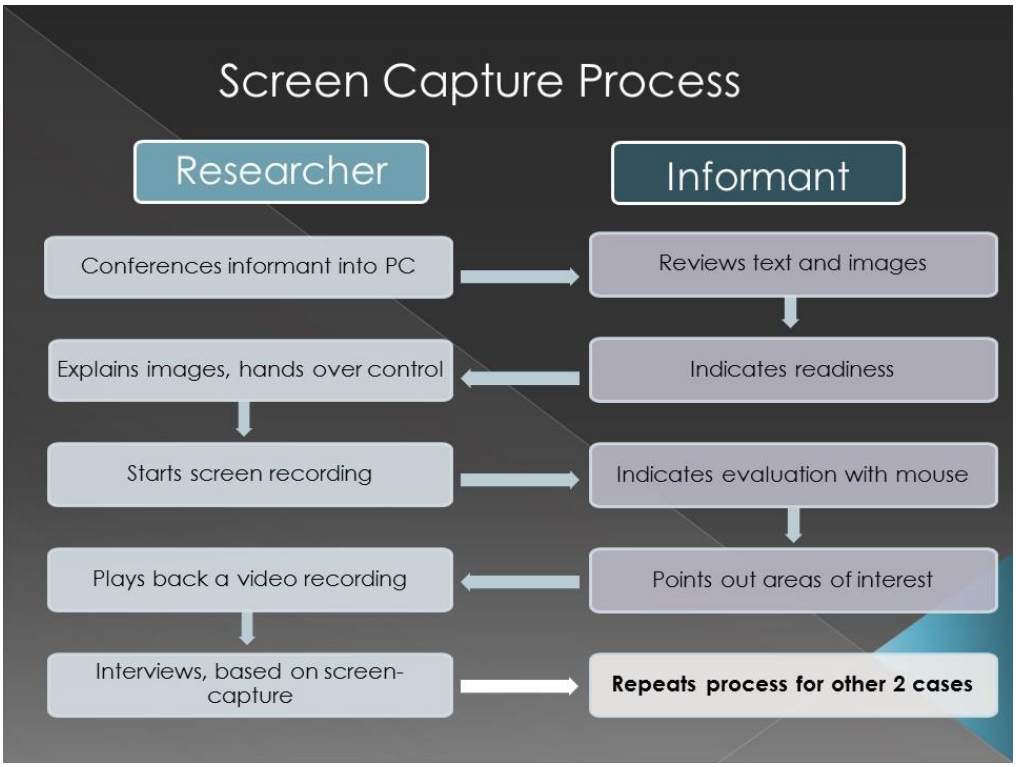
Data Collection: Screen Capture

The informants were conferenced into the researcher's computer (see Appendix 4: Screenshot during an Interview) and shown the first case. Since the informants had not previously been exposed to the cases, they were instructed to take as much time as necessary to read through the case description for the first case and to view the accompanying images on the researcher's screen. Once the informants had completed the review of the first case, they proceeded to evaluate the imaging studies on the researcher's screen, using a function of GTM that allowed them to take control of researcher's computer (Image1: Data Collection). Informants were asked to indicate when they were ready to start evaluating the imaging studies. When the informant indicated readiness, the researcher started the screen-capture video recording and the informant took control of the researcher's computer. The researcher instructed the informant to evaluate the imaging studies accompanying the first case, after explaining the radiographic projection used. In case of advanced imaging, this involved explaining the type of imaging used and the anatomical location and orthogonal planes of the slices. The informant indicated their viewing pattern and evaluation of the images on the researcher's monitor with the mouse cursor, specifically pointing out areas of interest in the images by stopping the mouse or circling around the area (see Appendix 5: Screen-Capture Playback in Expression).

The researcher recorded the informant's on-screen activity using Microsoft Expression Encoder 4 screen-capture and video-editing software (Expression).[173] The informant was advised not to speak during this screen recording. Subsequently, the researcher played the screen-capture video back to the informant in the Expression video editor and conducted the

interview based on this playback while recording it in GTM (Appendix 5: Screen-Capture Playback in Expression). The same procedure was used for each of the cases.

Figure 1: Data Collection



Data Collection: The Interviews

The primary researcher conducted all interviews. The interview process was explained to the informants and they were informed they could seek clarification of the process and/or terminate the interview at any time. The informants were also told they could pause the playback at any time and take control of the mouse to further explain areas of interest in the images or to clarify their on-screen activity.

The interviews in this study were based on three cases of musculoskeletal disorders that included patient history, complaints, and examination findings, as well as imaging studies. Both conventional radiographs and advanced imaging studies were employed (Appendix 1: Cases).

No imaging findings were reported for the cases. The cases were written by the primary researcher, using case reports from an internet education site for radiologists as a foundation.[174] The cases were reviewed for content validity by three fellows of AAOMT that taught evaluation and treatment of musculoskeletal disorders at a professional-level DPT program.

The interview format employed in this study has been referred to as the general interview guide approach.[163] This approach is more focused than a conversational interview and ensures that specific information is collected, while having a degree of adaptability based on the informant's responses.[163] The following questions were asked for each area of interest in the imaging studies, as indicated by the informant: a) What did you find interesting in the area that you indicated? b) Are there likely to be functional consequences associated with the changes you see? If so, what were those consequences? c) Do you see indications for caution or referral and, if so, what are they? The informants' replies were followed up using probing questions to encourage them to expand on their answers.

The researcher avoided moving to a new topic until the informant's views had been thoroughly explored and the discussion had reached saturation.[163] Informants' own terms were used when probing for clarification, avoiding comments or questions that might imply there was a correct factual answer. The researcher reiterated that the purpose was not to test the informants' knowledge but to understand the process by which they evaluated the images. The informants' on-screen activity during the evaluation of imaging studies was recorded using Expression. The interviews, over the screen-capture videos and the informants' additional on-screen activities, were recorded with GTM, saved as Windows Media Video recordings (WMV),[175] and backed up to a secured document website.

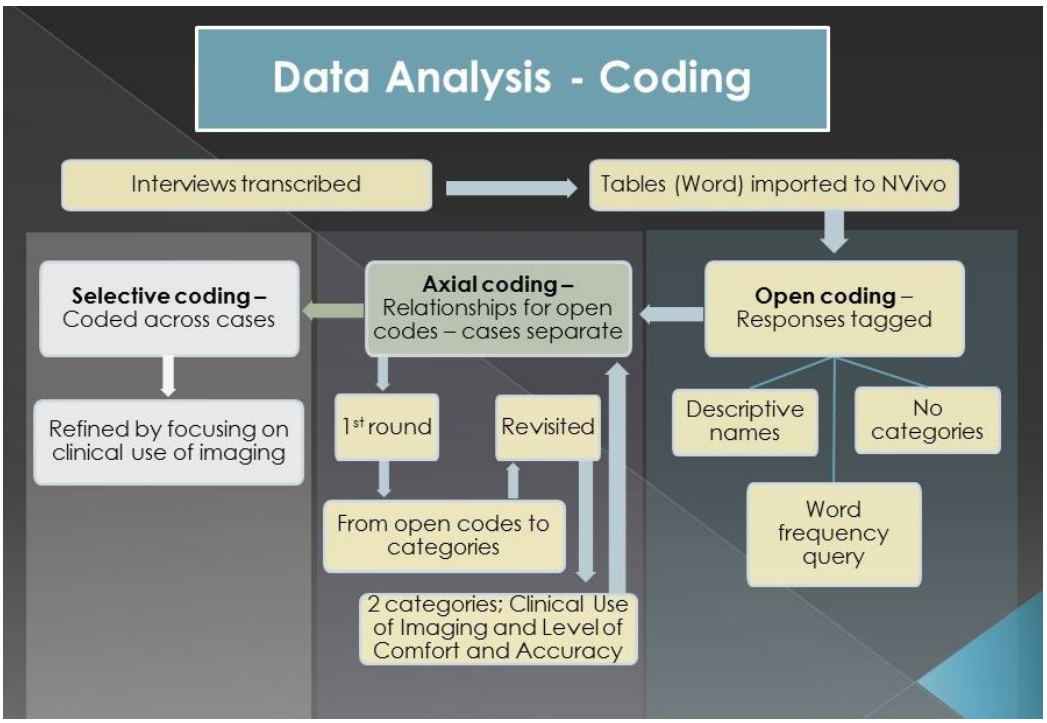
Data Analysis

Consistent with grounded theory, data were transcribed and analyzed following each interview, with the analysis used to inform subsequent interviews. The analysis was aided by using NVivo,[164] a specialized database application. Databases are commonly described as electronic filing systems based on tagging (coding) each piece of information by entering it into a specific field of a record. The databases organize information in a manner that allows data to be easily searched, retrieved, and aggregated, so specific data and their relationship to other data can readily be identified and cross-referenced.[164] NVivo does this, as well as provide a range of powerful queries that allow for visual representation of data and data relationships. One such query is the word frequency query, which provides a visual demonstration of the most frequently occurring words in textual sources and the relationship between these words. This presentation is commonly referred to as a word cloud or word frequency query (see Appendix 6: Examples of Presentations of the Results of Word Frequency Queries). The word frequency queries were used to quickly identify trends within the data and suggest codes during initial coding.[176]

The primary researcher transcribed the interviews from the WMV recordings into tables in Word. Each statement was entered into a unique cell in the tables and the tables imported into NVivo (Image2: Coding). At this stage, the primary researcher decided which responses would be included verbatim, for purposes of direct quoting, and which responses would be distilled into statements that captured their essence.[177] Responses that could be considered merely factual were distilled into shorter statements of what the informant had relayed. When Informant EF provided an assessment of the possible causes of decreased abduction seen in Case #2, the researcher transcribed this as, “Lack of downslide during abduction. Could be

consistent with a) the arthritic process, b) adhesive capsulitis, or c) a poorly functioning rotator cuff." The informant went on to explain what these different explanations for loss of motion would mean in terms of clinical decision-making, which the researcher transcribed in full, "If arthritis is a component of this, we should see rapid improvement with treatment – improved inferior glide and posterior glide in 2-3 treatments. If a rotator cuff tear is the central problem, we might make improvements as far a pain, but not so much in active motion. So, if there is no change in 6 weeks or so, I would pass the patient on to the orthopedic surgeon."

Figure 2: Coding



The use of tables during transcription of the text was chosen due to the advantages offered when importing transcribed text into NVivo. When text is imported from a document into NVivo, this is done by highlighting and copying text in the document. If the highlighted text is pasted into NVivo from a cell in a table, rather than from plain text, the selected text appears bolded in NVivo, while the remaining, non-selected text in the cell, is placed alongside it un-

bolded (see Appendix 7: Example of Table Format and Nodes). This makes it easier to identify the context and significance of the copied text.

Coding

Analysis was initiated with open coding, where responses or statements were examined one at a time, copied into "nodes," and given a descriptive label.[1(138)] In NVivo, the term "node" refers to a data record where segments of data are stored and labeled. These nodes were used exclusively for coding and will hereafter be referred to as "codes." Once the responses from an interview were coded, the codes were organized into folders and subfolders. For the first round of coding, the first main folder was created. This folder, which contained the subfolders Case 1, Case 2 and Case 3, was called "Open and Axial."

During open coding, no attempt was made to categorize codes, just to give descriptive names to the coded statements. However, when it seemed that two similar phenomena had been coded under different names, the text under one code was copied over to another, more suitable code. That code was renamed, if needed, and the "duplicate" code subsequently deleted. Where applicable, the same code names were used across all three cases. For example, when coding Case #2 (patient with a shoulder problem) the code name "image correlation to function" from Case #1 (patient with LBP) was reused.

The next step, axial coding, was done for the purpose of looking across the data for relationships.[2(182)] Categories of codes were created, loosely based on the informants' initial responses and word frequency queries. For each case, the content from the open codes was dragged into the categories (see Appendix 8: Example of First Round of Axial Coding). This way, all open codes were initially categorized for each of the three cases. The following headings or themes emerged from the data: Degenerative Changes, Image-Clinical Correlation, Level of

Comfort in Reading Images, Other Findings, Positional Changes, and Structural Deformity, although Case #3 did not have any content for the category Positional Changes. The axial coding was then refined under a new main folder named "Axial Revisited." During this process, codes from the six main headings of the first round of axial coding were dragged into two main categories, Clinical Use of Imaging and Level of Comfort and Accuracy. Thus, the initial axial coding reflected what informants saw in the images, while the latter phase (Axial Revisited) emphasized their perceptions about the significance of imaging for their clinical decision-making (see Appendix 9: Axial coding Revisited. Clinical Use of Imaging prior to Merging Cases).

Whereas in axial coding each case had been treated separately, during selective coding statements were aggregated across the three cases. The analysis initially focused on two main categories, Themes Related to Clinical Use of Imaging and Themes Related to Confidence. After all coding was completed, each selective code was opened and exported to a Word document. In Word, transcripts of statements were copied directly under the appropriate headings in the document and the Notes function from Word´s Review menu used to reflect on the significance and meaning of each statement. This was done because the researcher found Word to be more flexible than NVivo at this stage of coding. By using different levels of headings displayed in the Word Navigation Pane, it was easy to organize and view the main themes and their subthemes (see Appendix 10 – Navigation View during Selective Coding). Once this organization was complete, the final categories were utilized to develop the main themes.

Research Ethics and Trustworthiness of Study

Research ethics in qualitative studies is often discussed in terms of the biomedical ethics principles of Beauchamp and Childress that include autonomy, justice, and beneficence/ non-maleficence.[178,179] In this study, autonomy was observed by obtaining consent to participate

and respecting the wishes of informants, as well as respecting the informant's experience. An attempt was made not to 'mute' the participant by designating 'topics to be covered' and limiting the interview to those topics or, alternatively, by classifying statements as off topic during the data analysis.

Procedural justice was followed when seeking IRB approval for the study and distributive Justice was followed when all received a fair share of burdens and benefits. Over and beyond the benefit derived from having been a participant in the process of generating knowledge,[178] the fact that informants had an opportunity to share their perspectives can be viewed as a benefit of participating in the study. During the interviews, it was evident that informants had opinions about imaging in physical therapist practice and welcomed the opportunity to express those views. Beneficence and non-maleficence require that the researcher does what is good and avoids harm. Commitment to a promise made to informants when providing them with description of the study (fidelity principle) was also followed by the researcher, who strived to be cognizant of the fact that informants had given up their time to participate in the interviews. Accordingly, interview times were carefully planned, according to informants' needs, and the researcher ascertained prior to each interview that the technology used for the interviews was working properly. In one instance, it was necessary to re-tape a part of an interview due to a technical error. The interview was re-taped during the initially scheduled interview session.

The trustworthiness of this study is presented based on the terminology proposed by Lincoln and Guba, using the terms, "credibility," "transferability," "dependability," and "confirmability."[180] Credibility, which corresponds to internal validity in quantitative studies, addresses how well the data and the data analysis address the research question.[181] It also addresses selection of informants. Since, apart from meeting the inclusion criteria, informants self-selected to be in the study, care was taken to clearly describe its nature to informants in the

invitation to the study (see Appendix 2: Invitation to Study). This gave informants the opportunity to decide whether to participate in the study and give their informed consent.

In this study, the primary researcher performed all parts of the study and used memos to describe how conclusions were reached, both of which increased credibility.[182] Credibility was also strengthened by coding in a manner that precluded inadvertent exclusion of data,[182] as well as by the use of negative case analysis that challenged the data by including statements that did not agree with the thrust of the data.[2] Furthermore, the use of rich, thick narratives to support the themes generated strengthened credibility. In this study, the researcher controlled for his own preconceptions about the integration of imaging into physical therapy practice by respecting the informant's experience and by avoiding influence on the informants' perspectives. Furthermore, the researcher used probing questions to encourage informants to expand on their answers and provide as much detail as possible.

The term "transferability" is used for what is referred to in quantitative studies as external validity.[180] In qualitative studies, the burden of judging transferability resides with the person who wishes to apply the results of research to a different context. The primary researcher facilitated this by providing narratives and establishing arguments for the most plausible interpretation, but leaving it up to the reader to determine transferability. In this study, care was taken to provide clear description of settings, methods, and participants, as well as enough data[183] to allow such judgment.

The term "dependability" is used for what is known in quantitative studies as reliability, with the caveat that the idea of reliability is not a good fit for qualitative research, since it is based in the notion that there is something tangible and unchanging "out there" that can be measured.[180] General threats to dependability may arise from ambiguity in the meaning of

words, vague definition of categories, or other coding errors. The researcher may assign meaning to terms in a manner that perhaps is not understandable to the reader but may, as a result of being close to the data, seem obvious to the researcher.[184] This tendency was minimized in this research by verifying meanings of statements with follow-up questions to informants, by using consistent language when giving directions to informants, and by providing rich, thick description to give the reader an opportunity to verify meanings. Additionally, the screen-capture videos provided a separate set of data, allowing for triangulation in data analysis. While the informant discussed imaging search patterns, the screen-capture provided a separate account of the informant's evaluation of the images. These processes served to minimize researcher bias in analysis of the data.

Objectivity, as this term is used in quantitative studies, presumes an isomorphic relationship between observation and reality, which to the qualitative researcher is unrealistic.[180] To denote objectivity, Lincoln and Guba used the term "confirmability."[180] In this study, confirmability was strengthened by an audit trail, which includes a description of the research decisions made up to the development of the themes.[180,185] Confirmability was further strengthened by review of the themes, as they were being developed and finalized, by an expert in qualitative studies.

Finally, trustworthiness may be strengthened by being aware of, and avoiding, common mistakes in grounded theory research. Potential mistakes include failing to generate theory while merely sorting data, premature closure and under-analysis of data, and overly generic analysis of data, involving the use of terms that may be applicable to any experience.[186] Throughout the research process, the researcher made a conscious effort to avoid those mistakes. A review of the relevant literature may also support the trustworthiness of qualitative research by challenging the theories being generated. In this study, this was difficult since

accounts of comparable research were not found, although literature from related fields served as a framework for research design and data analysis.

Bias is a concern in qualitative research, in particular confirmation bias, which involves seeking out evidence that supports the researcher's conclusions or views while downplaying other data.[187] In this study, bias was counteracted by negative case analysis that involves searching for data that seems contrary to the patterns emerging from the data analysis, while no outliers were excluded.[1(76)] Bias may also be introduced by the selection of informants. In this study, that may not apply, since all participants in the original Delphi study received an invitation to participate in this study and all that were willing to participate were included. As an academic who has written and taught courses on imaging, the researcher came to this study with a set of ideas as to what should be the focus of physical therapist imaging. The data analysis was conducted with this potential bias in mind, and further offset via the use of an expert in qualitative studies to challenge potential bias of the primary researcher.

Summary

This qualitative study, employed one-on-one interviews with musculoskeletal experts in physical therapy for understanding their imaging-related clinical decision-making processes. A web-conferencing application was used to facilitate the interviews of the informants. This allowed their evaluation of the imaging studies to be observed and the interviews to be recorded. The interviews were conducted using a general interview guide with questions focused on what the informant found interesting in the images, what they thought would be functional consequences of what they saw in the images, and how the imaging findings could be indications for caution or referral. The analysis of the interviews was conducted in the tradition of grounded theory, using the NVivo 10 qualitative software.

Chapter 4: Findings

Introduction

The central themes that emerged from the selective coding process were: 1) Evaluation of Imaging Studies: An Intuitive and Contextual Process and 2) The Synthesis of Imaging, Clinical Findings, and Didactic Knowledge Informs Clinical Decision-Making. In this chapter, the themes are described from the informants' perspectives, supported by their narratives.

Theme 1: Evaluation of Imaging Studies: An Intuitive and Contextual Process

This primary theme describes processes by which physical therapist experts in musculoskeletal disorders evaluate imaging studies. The theme is described by the informants' unique perspectives of the evaluation processes they employed. It is further supported by observation of the on-screen activity recorded while informants viewed the images.

Many informants stated they recognized the value of systematic evaluation approaches designed to prevent radiographic findings from being missed, such as the ABCs approach taught by Greenspan and McKinnis.[26,188] Informant YZ said, "I kind-of took the ABCs approach, followed that pattern. Being a faculty member, we briefly teach the use of the ABCs approach. As a clinician, I am not sure how much I use it. I know that I should, it is a helpful, systematic way to look at plain films." However, based on a review of the screen-capture recordings and on informants' explanations, only two informants consistently followed the ABCs search-to-find approach. Most informants demonstrated an intuitive and contextual imaging evaluation, rather than a systematic approach (See Appendix 11, Illustration of Search Patterns by Informant QR). This resembles the holistic imaging evaluation used by expert radiologists, characterized by rapid evaluation of the whole image for the identification of abnormalities,

followed by a search for related findings.[65,66] Such an intuitive and contextual approach was demonstrated by Informant YZ when evaluating Case #1:

> I saw so much mal-shaping of the vertebral bodies and I just wanted to see if that was the case with the intervertebral foramen as well. The patient does not have any radiculopathy, but I just wanted to see if there was stenosis in the foramen and I also wanted to see the facet joint spacing.

Another example could be seen in Case #3 where Informant YZ discussed the bony integrity of the tibial plateau. He looked at the trabecular structure and discussed the possibility of the presence of conditions other than osteoarthritis, which was the stated diagnosis. The informant said, "I checked for the trabecular structure of the tibial plateau to see if there was really anything of metabolic nature."

Intuitive approaches were also seen when informants moved on to a second radiograph before completing the evaluation of the first. In Case #2, many informants contrasted the regular AP view to the AP view made during attempted abduction. The informants explained this back-and-forth comparison by referring to the benefit of the abducted view for evaluation of joint mechanics, seemingly searching for clinical relevance. Not only did informants frequently move on to a second image before finishing the evaluation of the first image, they did not necessarily complete evaluation of the radiographs before moving on to advanced imaging. In the screen-capture recordings for Case #1, informants were seen to move back and forth between the conventional radiographs and the MRIs. This was most evident for areas where informants said signs of disturbed alignment or neural trespasses might be expected. They seemed to use the radiograph for the general skeletal overview, while cross-referencing the MRI to view both skeletal and neural tissues.

There were examples where contextual imaging evaluation was guided by the patients' signs and symptoms. Indeed, some informants stated that this was their approach and described how they quickly singled out the lesion of interest. When evaluating the images for Case #1, Informant WX described an approach that seemed guided by the clinical presentation:

> Tapping on the spinous process causes pain and in typical musculoskeletal cases that is not the case. When associated with psoas weakness, that is a cause for concern. So, I immediately want to look at the upper lumbar spine. When I saw that the greatest amount of malformation was at the upper lumbar spine that drew my attention.

Informant YZ described a similar process for Case #2 when tracing the scapula medially to the glenohumeral joint:

> There has got to be something more going on here considering the weakness of the supraspinatus and infraspinatus. Given the isolated weakness of these two, I am concerned about suprascapular nerve entrapment. That's the reason I was looking more proximally.

For Case #3, this informant also demonstrated a search pattern guided by signs and symptoms:

> This sounded like a knee osteoarthritis case, so I first wanted to see the joint space. However, the pain on percussion of the tibia freaked me out. I start suspecting the worst. This is not typical osteoarthritis. So, I really wanted to see the bone integrity of the tibial plateau.

Here, the informant sought a radiographic sign based on palpation findings. This displays an intuitive and contextual approach, not the systematic radiographic approach proposed in imaging textbooks written by physical therapists and radiologists.[26,188] In the examples above, radiologic evaluation, according to ABCs approach,[26,188] would have included sequential evaluation of alignment, bone density, cartilage, and soft tissues, with three to five sub steps for each of the four main headings.

Some informants demonstrated innovative approaches, when evaluating imaging studies for position and alignment. When describing the evaluation approach for Case #1, Informant DC compared distances between spinous processes in the lumbar AP radiograph, explaining this was a way to gauge whether the spine was in an extended or flexed position:

> In the AP view, I start by orientation; finding T12. Then I look how the spinous processes are lining up. Are the spinous processes in the center or not and are the processes the same distance from the pedicles? On the basis of this, I can see if the vertebrae are rotated. I also look at the distance between the spinous processes. The distance between these (points to L2 and 3) is decreased compared to the ones further up. This could mean that the vertebrae are in extension – but then again it might just be individual differences.

In this instance, the informant explained how he estimated the position of individual vertebrae to understand the patient's spinal alignment. The value of the imaging study seemed to be to enable the informant to expand his perspective and inform his treatment decisions related to mobilization of the patient.

Some informants attempted to put findings immediately into clinical context. Informant YZ, when reviewing Case #2, said, "The humeral head does look high in relation to the glenoid. But when I look at the subacromial space, there is a space there. It probably should be bigger. But this (points to the tip of the acromion vs. the greater tuberosity) does look a little tight." Thus, instead of only describing the radiographic finding of a high-riding humeral head, he also sought radiographic findings to guide clinical decision-making, to see if the subacromial space was still adequate despite the elevated position of the humeral head.

Most informants seemed at ease in using imaging studies to inform clinical decision-making. This was exemplified in Case #1 where informants appeared confident in aligning certain

imaging findings, such as evidence of bone marrow edema in the anterior vertebral bodies, to clinical information of pain on low sitting and coughing. Similarly, this was seen in Case #2 where informants discussed prognosis based on imaging findings of osteophytes and bony configuration.

However, three informants expressed lack of confidence when viewing certain imaging studies. They all stated they were not used to viewing imaging studies for a given region. Informant HG said, "I don't look at radiographs of the shoulder, so I have no clue what is normal." Informant OP said of knee radiographs, "I don't really see a bunch of them." Furthermore, the informants that indicated lack of confidence also related this to advanced imaging. All stated that they did not know enough about advanced imaging to comment on the images. Informant HG said when asked to compare T1 and T2 signals on MRI, "I don't teach imaging and I don't understand MRI. I have no clue what it means." Discomfort in reading advanced imaging studies was seen among some participants. Relating to Case #1, Informant OP stated, "The anterior vertebral bodies of L2 and 3 have me concerned, but I will admit that I did not review MRI imaging prior to the interview." Informant HG said about CT images for the shoulder, "It would be a waste of time to have me look at the CTs." Informant UV concurred, "I am not particularly good at shoulder CTs."

In summary, the informants utilized a variety of approaches in the evaluation of imaging studies. The approaches seemed intuitive and contextual rather than systematic in nature, as evident by informants not necessarily completing the evaluation of one radiograph before moving on to another radiographic view. These informants were seen to move back and forth between different types of imaging studies. Commonly, while evaluating the images, the informants quickly focused on what they suspected to be the area of clinical significance within the image, letting the clinical findings guide the search. Some informants expressed insecurity

related to viewing imaging studies, which seemed to relate to lack of familiarity with imaging studies for a given body region or unease with advanced imaging.

Theme 2: The Synthesis of Imaging, Clinical Findings, and Didactic Knowledge Informs Clinical Decision-Making

This theme describes how imaging studies provided the informants with a wider perspective of patient's clinical picture and, combined with clinical findings and didactic knowledge, helped inform clinical decision-making. The imaging studies were perceived as valuable to understanding the patient's potential for benefit from physical therapy, as well as serving to inform goals, prognosis, plan of care, and ultimately, to inform discharge planning. This theme also describes how the informants' evaluation of imaging studies was guided by integration of clinical findings and foundational knowledge, such as foundational knowledge of anatomy and biomechanics, which seemed to frame the evaluation process.

There were numerous examples where imaging findings helped informants understand the patients' signs and symptoms. Several informants commented that the MRIs in Case #3 explained the significant pain the patient experienced, despite limited radiographic findings. Informant YZ said, "I see significant bone marrow edema. Now the pain makes a little more sense." Indeed, this informant stated the images accompanying Case #3 changed his view on the case; that the imaging studies were crucial to understanding the case. He explained:

> The pain on extension makes sense because he is compressing on the front here. Because of the pain on extension, I was expecting to see something in the popliteal space, but I did not see that at all. This is a great example of how the image completely changed my impression. Initially, from history, I was only thinking about knee OA with popliteal bursitis. I was looking for a Baker's cyst.

Thus, for Case #3, the MRIs helped explain symptoms that seemed too severe to fit the clinical picture for a mild osteoarthritis. Informant UV said, "I would assume the bone marrow edema explains the pain on tapping. Pain on extension could be explained by swelling in the posterior capsular area." Some informants correlated the painful loss of range of motion with imaging findings. Informant BA said of the MRIs, "The pain on full extension correlates with the changes in the anterior aspect of the joint – the loss of space."

The imaging studies accompanying the cases were used to confirm informants' clinical impression or to decrease informants' concerns about the clinical picture. In other cases, clinical findings decreased the concerns about the imaging findings. In each case, the imaging studies provided another set of data on which to base clinical reasoning.

An example of how imaging studies confirmed the clinical impression can be seen in Case #1. Some informants pointed out that pain on coughing and pain on low-sitting positions was probably associated with bone marrow edema leading to increased pressure within the anterior part of the vertebral bodies. They pointed out evidence of this bone marrow edema on the MRIs, as well as evidence of destruction of the anterior intervertebral spaces. Here the informants seemed to combine the imaging findings with biomechanical knowledge of increased diskal pressure in the flexed position.[191]

In some instances, the imaging findings decreased informants' concerns about the clinical picture presented and gave them confidence to proceed with treatment. Examples of where imaging findings were less severe than anticipated, based on the clinical presentation, were found for Case #2. Informant YZ commented on the imaging studies, "The images are less severe than I imagined. I expected more mal-alignment. When I read the case, I thought 'this shoulder is in a (sic) bad shape,' but then the images were not as severe as I had expected."

Several informants, discussing Case #3, noted when no osteophytes were seen, their initial concerns were decreased as this seemed to be a mild case of osteoarthritis.

Alternatively, there were examples where the clinical findings, coupled with didactic knowledge, such as knowledge of normal age-related degenerative changes, decreased the informants' concern about imaging findings. Informants often relied on synthesis of the clinical picture and didactic knowledge to temper concerns that arose from first impressions of the imaging studies. Informant KL talked about the area of increased signal intensity on the T2 MRI in Case #1, which he had suggested looked suspicious for malignancy, "His pain pattern is mechanical, which steers me away from pathological causes. He has full relief lying down and there is no history of cancer or infection. So, not sure why he should have bad disease in this area." The above comments seem to present the synthesis of clinical and imaging findings in the clinical decision-making process.

An example where didactic knowledge tempered concerns about imaging findings was seen when informants discussed signs of disk disease in Case #1. In this case, none of the informants considered the disk bulges evident on the MRIs to have clinical significance. Informant FE said:

> I look at the spinal canal and there are disk protrusions (pointing to the intervertebral levels L1/2 through L4/5). However, the patient does not have neurologic symptoms and I know it's common to find these changes in asymptomatic individuals, so it may not have anything to do with what is going on now.

Similarly, Informant DC said:

> I look at the posterior vertebral borders to see if there was any significant encroachment that might cause problems. I don't think this is significant. There are little bulges here and there. I don't think there is a huge encroachment going on. The man is over 60 years old. You expect these bulges there.

> We see so often in the literature that people have these kinds of images, but they are asymptomatic. His pain might go away, but the radiographs don't change because it is just age-related changes over time.

In this case, the synthesis of didactic and clinical information took precedence over imaging findings. Informant QR, noted about the same case, "There is some canal narrowing because of joint destruction. Not of clinical concern. It's just the age. He's 74 years old and has been active." In this example, knowledge of musculoskeletal disorders tempered concerns regarding what, in the images, looked like advanced destructive processes. Decreased concern based on clinical findings and knowledge and the alternative condition where imaging findings decreased informants' concerns about the clinical picture, seemed to increase the informants' confidence in their clinical decision-making.

While assessing the imaging studies, informants often focused on imaging findings that might indicate altered biomechanical function and explained how imaging could provide better understanding of the patient's functional movement. Informants often described how they looked for evidence of abnormal position or movement patterns to inform their clinical decision-making. They did not look solely at the structural changes that could indicate altered function. When talking about Case #2, Informant YZ said, when asked about if it were possible to estimate the external rotation of the scapula, "I was using the lateral border of the scapula for that. The glenoid fossa would seem like a nice place to look for that too. But what is interesting is that the patient's rib cage is angled too. It looks like that whole image is angled. The ribs are all rotated upwards like that."

Thus, the informant used this view for confirmation of decreased downward glide of the humeral head during abduction, limited clearance of the humeral head under the subacromial arch, and excessive scapular contribution to movement.

For Case #2, informants also used a comparison of the abduction view with the standard AP radiographic view, synthesized with their knowledge of biomechanics, to draw conclusions about the function of the shoulder joint. Informant MN said, "From the scapular movement, the glenohumeral joint looks like it's really stuck. You can see the scapular involvement in the high-riding clavicle and the elevated coracoid process." Informant ST assessed the abduction view, explaining, "When I look at the abduction view, he is totally compensating by hiking his shoulder; lifting his whole shoulder girdle up – like you would see in someone with rotator cuff tear." Others pointed out a compensation mechanism involving lateral flexion of the trunk or hiking of the shoulder.[192,193]

However, not only did informants seek out imaging findings that could explain altered biomechanics, they explained how altered function might have caused the structural changes seen in the imaging studies. This was evident by the observation of anterior osteophytes on the L2 and L3 vertebral bodies that most informants explained as the result of spinal instability. Informant DC said, "The osteophytes are quite big. This tells me there is constant pulling of the anterior longitudinal ligaments. There is instability going on (sic) that is causing the pull on the osteophytes." Informant FE noted, "There is instability; excessive motion going on (sic) in these segments. So, this is the body's way to gain stability. The instability puts tension on the soft tissues, which in turn puts tension on the bony attachment sites." Informant ST explained, "I think the anterior longitudinal ligament is being pulled, so they could be traction spurs. But possibly, there is just increased load on this area generally. If he is a golfer, there is going to be an increased anterior load."

There were several examples where informants interpreted their imaging findings with reference to other observations and experiences, in addition to didactic knowledge of biomechanics and clinical experience with musculoskeletal conditions. This seemed to support

their imaging findings and give them added relevance. When looking at the MRIs for Case #3, Informant BA commented on the fact that the anterior horn of the meniscus did not seem in contact with the underlying tibia, "Looking at the first MRI, it almost looks like the meniscus is off the tibial plateau…. I cannot tell what that relationship is. The meniscus seems off the plateau. But now that I see this, I remember I have seen this in the cadaver lab." In this case, the informant initially did not appear to understand what seemed like a missing meniscus, but found meaning for this imaging sign with reference to prior cadaver lab experiences.

Other examples were seen where informants commented on imaging observations not related to musculoskeletal disorders. Informant ST explained how the patient in Case #2 compensated for the lack of glenohumeral joint motion, "As he is abducting, he is bringing his whole rib cage up. This side is also blacker (informant pointing to the ipsilateral lung field), so he is obviously inhaling as he abducts." Here the informant appeared to integrate knowledge of cardiopulmonary physiology to support her observation.

In summary, imaging findings often complemented clinical findings; confirmed the informants' clinical impression, helped informants better understand the patients' signs, and sometimes altered the views they had of the cases. The imaging studies seemed to provide the informants a perspective that was different from what they could obtain from the patient history and clinical findings alone, even when this understanding did not directly lead to a change in treatment.

Access to imaging studies and integration of imaging into clinical decision-making seemed to have the potential to change treatment plans and give informants confidence in their choice of treatment options. This seemed to be the case, particularly when findings were supplemented by clinical findings and didactic knowledge. For Case #3, informants proposed alternative

treatment approaches based on the synthesis of radiographic and clinical findings, as well as their knowledge of biomechanics. Many commented that the loss of medial joint space on the AP radiographs confirmed clinical findings of a varus position at the knee and noted they would use that finding to inform their treatment. Informant EF said of the AP radiographs in Case #3, "No, the images hold no surprises. They confirm that the varus of the knee is associated with loss of medial joint space with increased compression in the medial compartment." Some informants suggested wedging insoles to decrease the medial compression. Informant OP said, "If we can unload that medial compartment with a brace or a wedge and improve extension with the mobilization, we may be able to delay a total knee replacement." Thus, the imaging findings seemed to give the informant confidence to consider treatment alternatives to change the varus position.

Findings of potential physical impediment to motion were among the imaging findings that seemed to prompt a change in the treatment plan. This was evident when informants discussed the limits of functional progress possible where bony configuration and other structural changes seemed to have the potential to interfere with movement. In Case #2, the informants used a combination of imaging finding with biomechanical knowledge to draw conclusions about the arthokinematics of the shoulder joint. Informants highlighted osteophytes at the inferior borders of the glenohumeral joint as examples of structural changes that had the potential to limit normal abduction at the shoulder joint by impeding the normal arthrokinematic glide of the joint. Informant FE, discussed the possible influence of these osteophytes, "In the abduction image, I am not seeing the inferior glide of the humeral head I would normally see during abduction. In the abduction view, the suprahumeral space looks crammed. Inferiorly, there is something significant blocking the inferior glide." Informant BA concurred, "What stood out was the spurring on the inferior aspect of the glenoid, as well as the inferior humeral head.

There would be biomechanical consequences, since the inferior glide of the humeral head would be decreased. There would be a block to that movement, not allowing the downward glide." This way, the informants explained how the glenohumeral joint osteophytes would impede normal arthrokinematic mobility at the joint.[194,195] Informants also pointed to the shape of the acromion and predicted this would limit movement. In response to follow-up questions, informants explained these configurations were likely to impede abduction and that they would place emphasis on trying to restore normal arthrokinematics, stabilize the shoulder girdle, and improve positional awareness.

Changes in treatment plans were commonly the result of the combination of imaging findings and clinical findings. However, there were examples where the imaging findings alone provided a sufficient reason to alter treatment plans. Related to Case #1, Informant BA stated she would change the treatment approach almost solely based on imaging findings. Discussing radiographic signs of instability, she explained, "My only concern would be about the posterior position of L2. It tells me a little bit more about the instability in this area. So, even if the physical examination does not point in that direction, I might still emphasize stabilization exercises because of the images." Here the informant indicated willingness to use imaging studies to override decisions primarily based on clinical findings. This is notable because most informants said they would let clinical findings take precedence over imaging findings in making treatment decisions. Still, most frequently, it was the synthesis of imaging findings with clinical findings and didactic knowledge that led informants to considering changes in treatment.

Beyond using imaging studies to aid the selection of treatment options, informants seemed to use imaging studies to inform prognosis and predict outcomes. This is a part of clinical decision-making. Informants explained that the information gathered from imaging studies assisted them in getting a better sense of the patients' prognosis. This, in turn, helped clinicians

estimate how much progress could be expected. Discussing Case #2, Informant FE stated that the imaging findings tempered expectations for the outcome of mobilization, "The shape of the acromion looks slightly curved. This would definitely limit any overhead motion." Informant JI said:

> I would not get them to full abduction. The goal of getting additional 60 degrees; I am not going to be able to reach that. I don't think I would not treat the patient, but I would have a sit-down and show the patient the radiographs and explain that due to this we will not be able to reach full range of motion – we will only get so far.

Informant AB said about Case #2, "I can improve the patient's condition, but there are definitely going to be limits to my expectations. If the structure has changed this much, structure is going to dictate how you move." Informant EF stated, "His left shoulder will always be his 'bad' shoulder. He might have to come back in six to eight months for mobilization and we could delay the need for surgical intervention for six to ten years. That would be a good outcome." This informant further predicted that the structural changes seen in the radiographs could lead to secondary damage to the rotator cuff, "Type III acromion would predispose the patient to impingement and rotator cuff pathology down the line." Thus, the images accompanying Case #2 supported the prognosis that mobility would probably continue to be limited and that further damage to the rotator cuff was likely because of the structural changes in and above the joint.

Others stated the imaging findings might inform them if current therapies were working. This appeared to give the informants confidence to change the treatment approach. When asked about the significance of the MRI findings for Case #3, Informant DC said, "The only thing is that there is more inflammation than I was able to pick up during the examination. The patient is taking anti-inflammatory medications, which are obviously not working. I would ask him to put some ice on the area and then I would continue with strengthening exercises." A

couple of informants discussed how their treatments decisions, founded partly in evaluation of the imaging studies, could involve less costly alternatives. One example was the following statement by Informant AB regarding Case #2, "In the past, I might have asked insurance for an extra number of treatments. However, after seeing the images, I arrive at that point a little earlier." Another informant noted in Case #3 that a total knee replacement might be avoided after considering load corrections for the knee, based on radiographs.

The informants in this study did not engage in radiographic diagnosis of pathology. However, they demonstrated integration of information from the imaging studies to enable them to arrive at a basic differential diagnosis that differentiated between disease categories. For Cases #2 and 3, many informants explained how they distinguished between osteoarthritis and inflammatory arthritis, based on the different radiographic presentations for these two disease categories.[26] For Case #2, Informant YZ made the following note of a radiographic sign of osteoarthritis, "There is not just a concentric decrease in joint space. There are places where there is no joint space, some places where there is. It is telling me that this is a very progressed degenerative process." This informant explained that the asymmetrical destruction of joint space was indicative of osteoarthritis. Informant WX concurred. After concluding from the CT that the condition accompanying Case #2 was inflammatory arthritis, WX looked at the radiographs again and revised that assessment saying, "The humeral head is slightly irregular, more on the superior portion. There is also increased radiodensity along the cortex of the superior part of the humeral head. Also, some lipping at the inferior border of the head, pointing to osteoarthritis." Informant BA used a similar approach to identify osteoarthritis for Case #3, "There is a loss of joint surface smoothness in the second image. The loss of joint space is not uniform – there is more loss of space anteriorly…. I would guess, early osteoarthritis, although there are no great osteophytes." This informant went on to explain that she would be

less concerned about the patient's reactivity to treatment because this was clearly osteoarthritis.

There were also attempts at distinguishing between categories of conditions in the lumbar spine. For Case #1, Informant FE compared the lower osteophyte on the anterior vertebral body of L1 to those on L2 in his manner, "The spur at L1 is directed more inferiorly, what we typically see in degenerative disk disease. Those at L2 are not so much at the vertebral border and are pointed away from the intervertebral space, what is typical for a traction spur and instability." The informant said this was how she could differentiate between degenerative disk disease and spinal instability, based on the type of osteophytes seen in the imaging studies.[196] Informant BA also stated that there seemed to be instability in the lumbar spine, based on the posterior slippage of the L2 vertebra, for which she said she would emphasize stabilization exercises. While not examples of radiographic diagnosis of pathology, these examples appear to be attempts at preliminary physical therapist differential diagnosis to inform treatment.

Thus, beyond basic differentiation between categories of disorders, the informants expressed reluctance to engage in diagnosis. Referring to the MRIs for Case #3, Informant FE said, "I am not confident that physical therapists should be making determinations about medical diagnosis. We can make determinations about treatment; how treatment is going in terms of biomechanics." For Case #1, Informant WX said regarding the T1 MRI, "I jumped right into this area here (pointing to the anterior L2/3 intervertebral joint and vertebral bodies). This could be cancerous or some other pathology. But, it's not for me to make that decision." Informant OP, suspecting pathological changes in vertebral bodies in the MRIs for Case #1, said, "I am really glad there is a radiologist that looks this over." Thus, this reluctance to engage in diagnosis seemed based in awareness of professional boundaries and the scope of physical therapist practice.

The synthesis of imaging findings and clinical findings seemed to guide the informants' decisions regarding referral of patients to other health care professionals. This was seen when they combined imaging findings and treatment response to decide whether to treat patients or refer them. Often, the MRI findings were what prompted a suggestion for referral. For Case #1, Informant BA explained, "You could take 200 people from the street and half of them might have radiographic finding similar to these. But the dark and bright areas in the MRIs look like more diffuse lesions. I would definitely want a professional opinion." When probed for further explanations, the informant voiced concerns about the possibility of a tumor. Informant YZ said, regarding Case #1, "There is obviously some kind of reactive process going on; some kind of increased activity in that tissue..... You know, without the MRI, I would be less concerned. I would probably still want to make a referral. But when I see the MRI, for sure; there is something serious going on." Informant YZ said:

> Is this just a very, very, very damaged spine or is this truly a sinister pathology? I still am unable to answer that question with what I see here, which is why I probably want to make a referral or get some consultation. I don't think my imaging skill-set can comprehensively view these images….in this case, I need more help.

The MRI findings frequently were the impetus to refer patients to other health care professionals and many informants found grounds for caution based on the MRI appearance. However, only one informant wanted to stop treatment for this individual based solely on the MRIs. Regarding Case #1, when discussing the areas of altered MRI signal intensity in the vertebral bodies, Informant GH said, "This looks like a tumor or compression fracture. I would refer, neither evaluate nor treat."

Imaging presentation was not the main reason for referring patients to other health care professionals. Many informants stated they would not use the imaging presentation as the

primary guide whether to refer to other health care professionals, rather they would rely more on the treatment response.[36] For example, Informant AB noted regarding Case #1, "After two treatments without a favorable response, I would refer on to a specialist." However, while the treatment response was the primary basis for referral, the imaging appearance also appeared to prompt informants to be cautious. One informant explained that the MRI appearance gave grounds for caution, but he would only refer if there were not a favorable response to treatment, "I would have the patient on a short leash, particularly if not getting a positive response. If there are reports of fluctuating or unpredictable pain, I would be quicker to refer." Informant DC said about Case #1, after discussing the MRIs, "If the patient has not significantly improved after four visits, I am referring. I feel that is less than an optimal outcome. I would refer."

Not many informants expressed interest in additional imaging information beyond what accompanied the three cases, nor did they show interest in having access to additional imaging studies. Still, there were a few examples of this. Pointing to a horizontal line on the T1 MRI for case#1, Informant ST said, "Anteriorly and inferiorly on the L1 vertebra, it looks like a compression fracture and there is decreased vertebral height of L1. Not sure though, I would like to get a CT scan." Relating to Case #2, some expressed a desire for more detailed soft tissue imaging of the shoulder. Informant ST noted, "There is not a lot of room superiorly, which is probably why he is impinging there. But we need an MRI to see if this is due to a rotator cuff tear." Additionally, some informants complained there were not enough slices of the advanced imaging studies accompanying the cases for purposes of evaluation. Pointing to a dark area in the coronal plane CT for Case #2, Informant JI said, "I am not clear if this is an abnormality or if there are (sic) just other structures coming in there – like the infraspinatus. Again, I would like to see several slices in succession for orientation."

Summary

The main findings of this study indicate that informants found imaging studies informed the clinical decision-making process and that being able to view images improved the clinical decision-making process through better understanding of the patient's condition. The following main themes emerged from the analysis of the interviews: 1) Evaluation of Imaging Studies: An Intuitive and Contextual Process and 2) The Synthesis of Imaging, Clinical Findings, and Didactic Knowledge Informs Clinical Decision-Making.

Although informants were aware of systematic approaches to the evaluation of imaging studies, they did not seem to employ such methods. Instead of systematically evaluating the images, most informants quickly focused on the area of suspected changes and performed additional observations from there. Another characteristic of the informants' evaluation of imaging studies was the comparison of different radiographic views; contrasting regular radiographic views to modified views. Furthermore, informants were seen comparing different imaging methods, moving back and forth between radiographs to advanced imaging. The informants did not evaluate the images for pathology. Their focus was on changes in the images that might correlate with functional disturbances. While informants avoided making a diagnosis of pathology, they demonstrated attempts at basic differential diagnosis, such as in distinguishing between inflammatory and degenerative arthritis.

Overall, the informants presented decision-making processes that synthesized clinical presentation, imaging findings, and didactic knowledge to guide their treatment plan and prognosis. Imaging findings indicative of impediments to motion seemed to trigger changes in the treatment plans when the informants interpreted these findings in light of their knowledge of biomechanics.

Thus, combined with clinical findings and didactic knowledge, imaging studies appeared to inform the clinical decision-making process. Imaging was seen by informants to improve their understanding of the patient's condition. The imaging studies frequently confirmed the informants' perception of the cases, as based on the case descriptions. Sometimes the clinical findings decreased the informants' concern about the imaging findings, but in other cases, imaging findings decreased informants' concerns about the clinical presentation. Informants stated they would base decisions regarding whether to refer or to treat patients on clinical findings or treatment response, in combination with imaging findings. The fact that no informants considered imaging diagnosis to be the task of physical therapists seemed to indicate awareness of professional boundaries.

Chapter 5: Discussion/ Conclusions

Introduction

There is increasing interest in imaging by physical therapists. This is evident in position papers from the APTA,[40] guidelines for imaging education,[39,41] imaging-related research activity,[15,18,17,19,20] and imaging textbooks by physical therapists.[8,10,12,16, 197] However, while these publications demonstrate an interest in imaging, they do not present an approach to the evaluation of imaging studies specific to physical therapist practice**.** Furthermore, little is known about how physical therapists evaluate imaging studies and use them in clinical practice. This study investigated the processes that physical therapist experts in musculoskeletal disorders use to evaluate imaging studies and how they use these to guide their clinical decisions.

The interviews conducted for this study revealed that informants considered imaging to be a valuable tool for clinical decision-making and that they used imaging studies to inform treatment decisions. This is consistent with the findings of Little and Lazaro[22] and Wilcox et al,[107] who found imaging to be important in clinical decision-making, for identifying contraindications to treatment, and for understanding the patients' disease process.[22] The participants in Wilcox's study reported that viewing the imaging studies, not just reading the radiographic reports, was important to their clinical decisions and 58% of the participants reported the images altered their treatment 26-50% of the time.[107] What follows is a discussion of the main themes to emerge from this study: 1) Evaluation of Imaging Studies: An Intuitive and Contextual Process and 2) The Synthesis of Imaging, Clinical Findings, and Didactic Knowledge Informs Clinical Decision-Making.

Discussion of Themes

Through the informants' comments and the processes utilized when viewing the images, the informants demonstrated that they evaluated imaging studies in the context of clinical findings and didactic knowledge to provide context to their visual perceptions.[142] The information gained by viewing imaging studies was framed within existing knowledge of anatomy and biomechanics and it seemed to resonate with their understanding of musculoskeletal disorders.[66,142,146] Thus, a strong foundational knowledge seemed to inform imaging-based clinical decision-making. This aligns with constructivist models of adult learning.[198]

In this study, no attempt was made by the author to assess whether the informants' findings were accurate. The focus of this study was on the processes they used for the evaluation of imaging studies and how they applied their findings clinically. The application of imaging studies to clinical decision-making has not been described, with the exception of a description of the use of radiographs and MRI to guide physical therapy treatment of the TMJ.[34] However, the relevance of those descriptions is limited in the context of this current study, since there are few similarities between TMJ disorders and the lumbar spine, shoulder, and knee disorders presented through imaging in this study.

The physical therapists in this study used an intuitive and contextual process in their evaluation of imaging studies and, for the most part, did not follow systematic search-to-find strategies such the ABCs approach.[26,188] The informants quickly identified what they expected to find, based on the clinical information, and followed up by searching for associated abnormalities and corroborating evidence. This approach was evidenced by the informants' on-screen activity and their discussion of the imaging evaluation. This approach stands in contrast

to textbooks on imaging for physical therapists,[26,188] as well as articles on imaging for radiologists[189] and other physicians[190] that promote systematic search strategies.[26,188]

Although systematic strategies are widely promoted,[26,189,190] it is of interest that expert radiologists do not employ these strategies in clinical practice, but use a holistic analysis of entire images at a glance to identify lesions.[65,58,68,149] While the ABCs approach is recommended for training purposes,[26,189,190] expert radiologists rely more on pattern recognition[54,86] and holistic perception of images.[65,58,68] The experts quickly identify findings that do not fit recognized patterns[65-68,145] and then proceed to evaluate images for associated evidence.[65] The imaging evaluation by the physical therapist experts in this study seems to parallel the holistic viewing patterns described for expert radiologists.[66,65,67] But, while it may seem similar, this does not imply that the evaluation demonstrated in this study exemplifies imaging expertise. The exemplar knowledge that characterizes expert radiologists stems from extended practice resulting in a high volume of imaging exemplars stored in memory.[86] The physical therapists in this study may not have such extended practice, although this study did not address that question.

In light of Thornquist's study,[42] as well as May and Dennis,[45] the finding of an intuitive and non-systematic approach to imaging evaluation is somewhat unexpected. The informants in this current study were orthopedic specialists and 12 out of 18 were certified manual therapists. According to Thornquist, manual therapists have a preference for systematic data gathering and information processing[41] and in the study of May and Dennis, the orthopedic physical therapists preferred to process information in a manner consistent with the hypothetico-deductive approach.[45] The equivalent of a hypothetico-deductive approach in radiographic clinical decision-making would be the use of search-to-find approaches to the evaluation, such as the ABCs.[26]

It is not clear if this intuitive and contextual approach reflects the physical therapists' academic preparation at the professional-level or post-professional level. Most professional-level physical therapist programs include courses on the evaluation of imaging studies. However, it is not clear whether these courses emphasize systematic approaches to imaging evaluation. The 2014 survey of professional-level DPT programs in the US by Boissonnault et al. did not report whether the programs participating in the study taught systematic imaging evaluation. However, 44.7% of the physical therapist programs that taught imaging required an imaging textbook.[4] The most commonly used imaging textbook was McKinnis' Fundamentals of Musculoskeletal Imaging[9] that advocates systematic approaches to imaging evaluation.

In this context, it was considered whether what is known about the current imaging education in physical therapy professional-level programs could be applied to the informants in this current study. Eleven of the 18 informants (61%) graduated as physical therapists over ten years ago and it is not known if imaging was commonly included in professional-level curricula at that time. However, eight of the eleven held a DPT degree, two a DSc degree, and one a PhD (PT) degree.[199] These informants may also, during their professional career, have become familiar with imaging through textbooks and/or continuing education programs.[200,201,202] Some may have also gained their knowledge through self-study grounded in foundational knowledge of anatomy and the musculoskeletal system. These processes fit the cognitive models of constructivist theories of adult learning[152,153] that assume new learning is subsumed into existing knowledge structures.[152,153] Basing new knowledge about imaging on prior, relevant knowledge is in agreement with findings that expert physical therapists have an inclination to be lifelong learners and take an individualized approach to evaluation, outside the boundaries of merely history and physical examination.[89,90,93]

Most informants in this study displayed confidence in using imaging studies to complement their clinical decision-making. There were numerous examples of this in the informants' imaging evaluation. However, for those informants who did express uncertainty about evaluating imaging studies, it was usually related to advanced imaging. This is consistent with the findings of Little and Lazaro who found that participants used advanced imaging findings less frequently than findings from radiographs.[22] However, three informants expressed a general lack of confidence in viewing imaging studies for a given region.

This seeming lack of confidence by some in using imaging studies for clinical decision-making was unexpected, since physical therapists with advanced orthopedic training have shown strong performance on radiographic diagnosis.[35] Furthermore, fellows of AAOMPT are expected to be able to identify radiological appearances of common musculoskeletal syndromes[171,172] and imaging is a part of the foundational knowledge underlying OCS.[172] The work settings and experience do not seem to explain the stated lack of confidence. One of these informants held an OCS certification, the other two had both OCS certification and AAOMPT fellowships. Two of the informants had 16-20 years of experience and the third six to ten years. All worked at academic institutions, but one also worked in a hospital outpatient and inpatient setting. The explanation for a lack of confidence related to certain imaging studies may be that these informants had not kept up their proficiency in imaging or that their clinical practice offered few opportunities to practice the application of imaging. In this context, it is worth considering that requirements for maintaining AAOMPT fellowship and OCS certification do not specify that physical therapists must maintain their currency in every field of their foundational knowledge.[200]

The informants rarely expressed interest in obtaining additional imaging, beyond the images presented with the cases. This appears to reflect a conservative view of referrals or

recommendations for imaging and may correspond to the low referral rates for imaging by physical therapists that do have the right to refer patients to imaging.[21,74,75] The informants in this study seemed aware of best-evidence imaging guidelines, such as the ACR appropriateness criteria and the Ottawa rules.[59,60,57,58] They also showed awareness of the limitations of imaging findings when applied in isolation from clinical findings.[197] These views correspond to views of physical therapists that have led the discussion for expanded use of imaging in physical therapy practice[6-8,10,12,25,26] and awareness by physical therapists of the limitations of MRI.[25,203] Thus, the informants generally expressed a balanced view of what imaging studies could and could not contribute to management of patients with musculoskeletal disorders.

This study sought to explain how physical therapy experts in musculoskeletal disorders employ imaging studies in clinical decision-making. The informants' narratives relayed their perception that imaging is a valuable tool for making clinical decisions, to guide treatment, to identify when caution is needed, and to provide a better sense of the patient's prognosis, as well as explain symptoms that do not fit the clinical picture.[22,23,107] When discussing Case #1, informants talked about the need for caution based on MRI findings. When discussing Case #2, informants pointed to imaging findings that put limits on the expectation for the recovery of full function and, in Case #3, informants pointed to MRI findings that could explain symptoms that did not fit the clinical picture. Furthermore, the informants used imaging studies to deepen their understanding of the patient's condition and to confirm clinical findings. Finally, there are several instances where informants described imaging findings that aided their decisions to refer patients to other health care professionals.

The informants in this study demonstrated decision-making processes that integrated imaging findings with the clinical picture and didactic knowledge. This agrees with Jensen et al. that found experts tend to merge clinical decision-making and didactic knowledge.[89] In this

current study, the informants perceived the imaging studies widened their perspectives, improved their understanding of the patients' conditions and, subsequently, their clinical decision-making process.

However, the informants primarily used clinical findings and treatment response for decisions on whether to treat patients or to refer to other health care professionals. This preference for using clinical findings and treatment response corresponds to the finding of Boissonnault and Ross.[36] In a study of the reasons physical therapists refer patients to consultation or imaging,[36] the authors found that in 65 cases, of 78 reviewed, the physical therapists' decisions to refer patients was based on clinical findings.[36] This reliance on clinical findings over imaging findings, despite imaging evidence of potentially serious injuries, was demonstrated in a case report by Ross and Cheeks.[204] The authors described the management of a patient who suffered a hangman's fracture of the second cervical vertebra in a motor vehicle accident, a potentially life-threatening condition. The physical therapist treating the patient demonstrated full trust in the clinical examination, despite noting concerning radiographic findings, and recommended continued conservative treatment since the clinical findings were not severe. In this case, it appeared the physical therapist's confidence in value of the physical examination led them to place higher value on clinical findings than on their radiographic findings.[204] This is consistent with the findings of this current study. Some informants stated that clinical findings of uncomplicated musculoskeletal disorders would override sinister-looking imaging findings when considering referrals to other health care professionals. This approach to referral-related clinical decision-makings reflect the confidence in clinical examination. According to Moore et al., the capability for clinical examination enables physical therapists to accurately identify musculoskeletal conditions in need of imaging

studies.[82] In the Moore et al. study, this ability was demonstrated through the strong correlation found between clinical diagnostic findings and MRI findings.[82]

Based on Thornquist's study, manual therapists might have been expected to place more emphasis on imaging findings. Thornquist found that manual therapists tended to embrace the biomedical model[46,47] and, according to this model, the value of diagnostic information grows with its perceived reliability.[41] This is a perspective that should favor diagnostic technology such as imaging. However, this perspective was not evident during the interviews with these informants, although imaging studies are perceived as somewhat of a gold standard in the diagnosis of musculoskeletal disorders.[82] One potential explanation for this seeming discrepancy is that while physical therapists have not demonstrated competence in radiographic diagnosis,[35] physical therapist experts in musculoskeletal disorders excel at clinical diagnosis,[82,77] as well as management of musculoskeletal conditions and knowledge of musculoskeletal disorders.[74,83] This may lead them to place more value on the clinical examination than on imaging.

The informants did not engage in radiographic diagnosis of pathology, beyond the basic differential diagnosis, and generally preferred to refer to other health care professionals when imaging findings raised suspicion of pathology. This aligns with the literature on physical therapists' use of imaging that does not advocate radiographic diagnosis by physical therapists.[10,12,26,197] The fact that the physical therapists did not focus on evidence of pathology differentiates their imaging evaluation from that of radiologists and other physicians. Informants rarely discussed disease as an explanation for the imaging findings. Although this contrasts with the core of the biomedical model,[47] the avoidance of diagnosis of pathology echoes the sentiment expressed by some physical therapy leaders who have stated that diagnosis of pathology is the domain of physicians and that physical therapists should limit

themselves to identifying and treating dysfunction.[205] Furthermore, not making a diagnosis of pathology is in accordance with physical therapy practice acts.[95]

The informants' approach to evaluation of imaging studies focused on local causes for the patients' signs and symptoms with an emphasis on the body from a biomechanical perspective. These emphases, which align with Thornquist's description of manual therapists,[45,46,49] were displayed in the informants' focus on identifying structures that could account for functional disturbances. The physical therapists in this study frequently identified altered alignment and structural impediments to motion and used these to guide treatment. This is exemplified in the findings for Case #2 where informants explained how changes in the alignment of the acromion might impede abduction and how the increased scapular contribution to abduction was an indication of loss of motion at the glenohumeral joint. While this approach to imaging studies may seem aligned with chiropractors' biomechanical approach, there are differences.[206,207] In Case #1 none of the participants interpreted the position of one vertebrae relative to another as subluxation, in the chiropractic sense of the term of minute changes in position or angulation of one vertebra relative to another.[27,207] The informants in this study were generally more interested in evidence of altered function.

The informants' emphasis on imaging evidence of structural impediments to motion differs from that of radiologists and other physicians. The source of this difference is not clear. The study by Boissonnault et al. that looks at imaging in professional-level DPT programs, does not report an approach to imaging education that reflects an emphasis on functional disturbances or movement limitations.[4] Furthermore, the emphasis on the findings of functional significance is only partly reflected in physical therapists' publications about imaging. [8-12,24] Physical therapists have written several textbooks[8-12] that are not fundamentally different from books on medical imaging.[188] Only with rare exceptions,[34] do they describe a physical therapist approach to

evaluation of imaging studies for the purpose of guiding treatment interventions. But, even if they do not offer an approach to imaging that is unique to physical therapists, the books most commonly used in physical therapist professional-level imaging curricula offer case studies and critical thinking points specifically for the physical therapist[9] and discuss the clinical relevance of imaging for the physical therapist for each area of the body.[8-12] Furthermore, post-professional imaging seminars emphasize application of imaging to clinical problems and require attendants to predict functional consequences associated with changes seen in imaging studies, in order to aid the selection of appropriate intervention strategies.[105,106,201,202]

The informants in this study demonstrated approaches to the evaluation of imaging studies and their use in clinical decision-making that align with suggestions by Boyles, Deyle, and Barr for integrating imaging into physical therapists' practice.[6,14,23,25] These authors emphasize that physical therapists should be able to determine when imaging studies could complement the patient examination for the best treatment outcomes and underline the value of being able to synthesize imaging information with clinical findings for optimal treatment planning.[6,23,24] This was evident through informant's discussions about whether or not to refer patients, as well as their discussion of the significance, for function and mobility, of structural changes seen in the imaging studies.[194,195,208]

A few authors have emphasized that physical therapists should independently evaluate imaging studies from the physical therapist perspective since imaging findings that may not be included in the radiology report may be important to physical therapist's clinical decision-making.[23,25] This includes identifying indications for caution in performing treatment interventions.[23] For these reasons, having the opportunity to see the images is seen as valuable.[22-23,25] Two studies have confirmed that physical therapists consider it important for

decision-making to be able view imaging studies and not be limited to reading radiographic reports.[22,107]

Summary of Discussion

The first research question for this study was "what processes do physical therapist experts in musculoskeletal disorders use to evaluate and interpret imaging studies?" Most informants in this study employed some form of innovative and contextual imaging evaluation and rarely demonstrated a systematic approach to evaluation (see Figure 3: Theoretical Framework). They did not use search-to-find approaches, typical for hypothetico-deductive clinical decision-making, but rather engaged in a holistic analysis of the images that is characteristic of pattern recognition. They tended to go directly to the areas of interest, guided by the clinical picture and didactic knowledge.

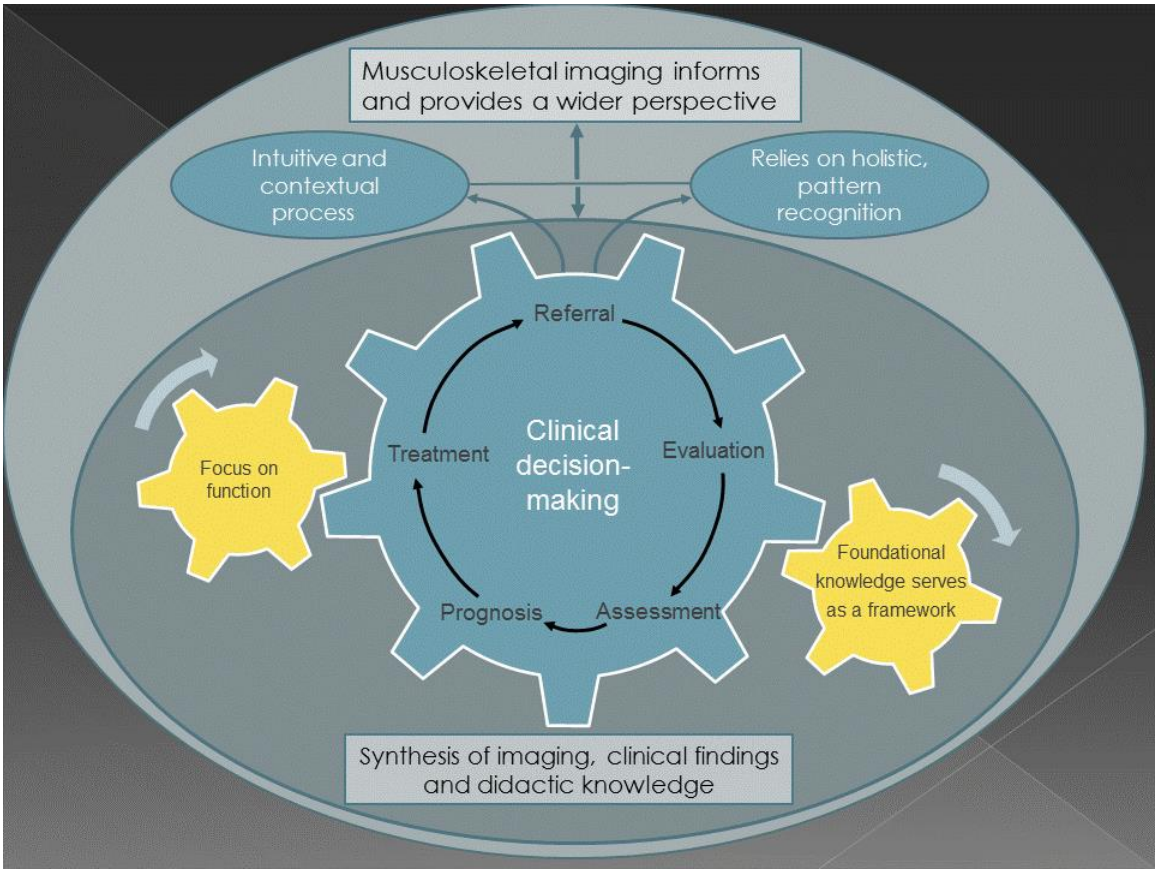
The second research question was "how do physical therapist experts in musculoskeletal disorders utilize imaging studies to guide clinical decision-making?" This study found that imaging-related clinical decision-making by these informants was focused on function. They engaged in basic differential diagnosis, but avoided making imaging diagnoses of pathology and rarely discussed disease as an explanation for the imaging findings. However, they frequently pointed out imaging findings that could explain functional disturbances and used them to guide treatment decisions.

The informants found imaging to be a valuable tool for complementing clinical decisions, to widen their perspective of clinical findings, to guide treatment, and to identify when caution was needed for examination or treatment. To do this, they seemed to synthesize imaging with clinical findings and relevant background knowledge of anatomy, biomechanics, and musculoskeletal disorders. The imaging studies seemed to offer the informants deeper

understanding of the patient's condition as well as to confirm informant's clinical findings. Informants discussed their decisions on whether to continue to treat patients or refer them to other health care professionals, primarily basing their decisions on clinical findings and treatment response and using imaging to inform, rather than dictate, decisions made.

The picture that emerged in this study was that of physical therapists, confident in the evaluation and management of musculoskeletal disorders, but also willing to admit the limits of their abilities and refer to other health care professionals as needed.[84] In this respect, the informants positioned themselves as responsible players in the field of health care, confident in their unique contributions.

Figure 3: Theoretical Framework



Implication and Significance for the Field of Physical Therapy

There are only a few studies on physical therapists' use of musculoskeletal imaging in clinical settings. Thus, it is important to describe how physical therapy experts currently evaluate and interpret imaging studies and how they use them to guide clinical decisions. This study may support further research of how various groups of physical therapists use imaging in clinical decision-making.

Physical therapist professional bodies are placing increased emphasis on the use of imaging[40] and, in view of increasing physical therapist autonomy,[209] it is possible that the scope of physical therapy practice in the US may need to be expanded.[23,73] Furthermore, the more common use of imaging by physical therapists in other countries[76,122,210] may also support the expansion of the scope of physical therapy practice in the US to include the right to refer to imaging. To support such developments, this study may promote discussions about the role of imaging in physical therapy practice and assist in establishing criteria for the scope of practice.

An expanded scope of practice may call for increased imaging education in professional-level physical therapist programs, as well as through continuing education. The findings of this study may help inform curricular development and assist educators in setting objectives for imaging instruction for physical therapists.

Delimitations

The following can be considered delimitations:

1) The technology used during the interview process was novel to most informants, although the primary researcher has over 15 years of experience in multimedia and technology to facilitate this process. In this study, the problems associated with this method were

ameliorated by clearly explaining the use of videoconferencing tools in the recruitment letter for the study. That allowed informants who felt unable or unwilling to interact with this technology a chance to decline participation.

2) The use of internet-mediated research presented challenges not encountered in other forms of interviews. Interviews conducted at a distance, while they offer much flexibility and save on travel time and money, have disadvantages. Non-verbal cues are lost, and it may be difficult to establish trust and rapport. The use of webcams for two-way communication, instead of relying solely on computer audio, could have minimized this problem. However, webcams were not utilized since some informants might not have a webcam installed and the researcher felt informants might find it intrusive to be interviewed via a webcam. While non-verbal clues were lost by not using webcams, there were also benefits to using only computer audio since the webcams can be a distraction. Three informants chose to use a combined microphone and webcam. The researcher found it a distraction to be able to see the informant's face while they evaluated the imaging studies, as this shifted the attention to the informant's eye movements and impeded the researcher's ability to focus on the movements of the mouse cursor. Therefore, during the interviews with these three informants, the researcher minimized their webcam window. In retrospect, even if informants were not required to use webcams, the researcher could have used a webcam. This might have improved the sense of personal interaction.

3) The decision to record the informants' screen activity prior to the interview also created challenges and in retrospect, it might have been better not to employ the two-stage process described above, but to conduct the interview while recording the participant's viewing of the images. Using video recordings as a basis for the interviews proved complicated to manage. The screen-capture playback during the interview created an extra layer of complexity for the

informants and the researcher. It was difficult to keep informants on track and to synchronize the playback and the interview. Some informants tended to digress and move ahead of the playback, forcing the researcher to move the playback forward and skip over 'scenes' the informant had not yet addressed. This tended to break up the interview and interrupt the normal conversational flow. With a one-stage approach, the participant could have discussed the images accompanying the cases on the screen. This would make it unnecessary to search for them in the replay of the video and would have allowed the informant to demonstrate and explain the viewing process simultaneously. Discussions about the clinical decision-making processes could have followed. This problem should have been caught during the pilot interviews. However, the pilot interviews were focused on the interview procedure and on identifying technical processes, and were not long enough and detailed enough to identify this problem.

4) Certain difficulties are associated with qualitative interviews.[211] They are time-consuming and difficult to master,[212,159] partly due to the interview skills required[213] and partly due to challenges related to the analysis of the interviews and the generation of theory from the data.[186] Qualitative interview studies present difficulties for novice researchers and the choice of a qualitative design could be considered a delimitation due to the primary researcher's limited experience with qualitative research. This lack of experience resulted in some use of closed-ended questions, most evident in discussions of the imaging studies for case #2. The impact of this was somewhat minimized by having the trustworthiness of the themes reviewed by an expert in qualitative research.

5) Finally, it is difficult to maintain and demonstrate rigor in qualitative studies. For that reason, as well as for perceived lack of objectivity, qualitative research may not be fully

appreciated in the scientific community. The trustworthiness of this study has been previously presented in Chapter 3.

Limitations

Several limitations apply to this study:

1) The successful selection of experts assumes that it is possible to identify suitable participants.[214] However, the selection of experts for this study presented a challenge. No imaging certifications are available for physical therapists and it is not possible to identify with certainty physical therapist experts in imaging. For this reason, it was decided to select, as informants, experts in musculoskeletal physical therapy including physical therapists with OCS certification and fellows of AAOMPT. These therapists were assumed most likely to have clinical experience with imaging. However, since three informants expressed lack of confidence when viewing advanced imaging studies as well as certain areas of the body, this assumption may be considered a limitation.

2) The researcher chose, as informants, physical therapist experts in evaluation and treatment of musculoskeletal disorders; fellows of AAOMPT and physical therapists with OCS certification. Because of this selection of informants, the patient cases used in this study were limited to musculoskeletal disorders. Thus, the results of this study primarily apply to evaluation of musculoskeletal imaging studies and to physical therapists with expertise in musculoskeletal evaluation and treatment. The results may not be generalizable to other physical therapists.

3) This study was limited to investigating the processes physical therapists use to evaluate and interpret imaging studies and how they employ them in clinical decision-making. The study

was not intended to address the accuracy of the physical therapists' evaluation or to compare their imaging evaluation to that of other health care professionals

4) There is the potential for bias on the behalf of the primary researcher who has promoted independent evaluation of imaging studies by physical therapists.[34,215] This researcher is also on record advocating that physical therapists use ultrasound imaging for diagnosis of musculoskeletal conditions, not just for the purpose of biofeedback.[216] An external reviewer was used to challenge the primary researcher's potential bias.

5) The variety in current practice experience of informants may also be a limitation. The data analysis was conducted with the above-mentioned limitations in mind.

Future Inquiry

This study attempted to address a gap in the knowledge of how physical therapist experts in musculoskeletal disorders evaluate and interpret imaging studies and how they employ imaging studies to guide clinical decisions. The study offers preliminary answers to these questions. Further research is needed to support initiatives to strengthen and expand imaging education. Additional research is needed to understand what characterizes the evaluation of musculoskeletal imaging studies by other groups of physical therapists, such as recently-graduated physical therapists that do not have an orthopedic specialization but have recently received imaging training as a part of their professional-level DPT curriculum. Furthermore, the use of musculoskeletal imaging for clinical decision-making by physical therapists without the right to refer for imaging could be contrasted to that of physical therapists with the right to refer, such as physical therapists in the military. Considering the intuitive approach to evaluation of imaging studies demonstrated by informants in this study, further exploration of

the processes used in musculoskeletal imaging evaluation by physical therapists might be a relevant topic for further study.

Conclusion

The research questions asked in this study are: 1) What processes do physical therapist experts in musculoskeletal disorders use to evaluate and interpret imaging studies? 2) How do physical therapist experts in musculoskeletal disorders utilize imaging studies to guide clinical decision-making?

This study demonstrates how physical therapist musculoskeletal experts utilize imaging studies in the clinical decision-making process, described from the physical therapists' perspective. The informants were found to use intuitive, contextual, and holistic approaches that are characteristic of pattern recognition. This contrasts with the systematic search-to-find strategies that characterize hypothetico-deductive processes for gathering information; strategies that are taught in textbooks on imaging. The informants tended to focus initially on the area of suspected findings, based on clinical information. However, some informants followed up with a search for additional abnormalities; a process resembling that used by expert radiologists. In this study, the therapists' focus was on imaging findings that might indicate impediments to normal function rather than on pathology.

The therapists in this study expressed a clear sense of the limitations of their knowledge related to imaging, while demonstrating good use of what they did know. Their perspective of the images viewed was grounded in their confidence in didactic knowledge of the musculoskeletal system and their clinical experience, which ultimately guided their clinical decisions regarding the patient's plan of care. They noted a readiness to collaborate with others and be team players in the field of health care, as evident by a willingness to refer to medical

specialists when uncertain of imaging findings or in cases where the patient was not making progress as expected. They generally took a conservative view towards referrals for imaging studies and appeared to be aware of imaging recommendations according to best-evidence guidelines.

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Appendices

Appendix 1 - Cases

A) Case One

HISTORY

The patient, a 74 year old male, a retired accountant, complains of activity-related mid-lumbar pain. He is a physically active and plays golf three times a week, although he has been forced to decrease his activity levels the last 6 months due to pain. The onset of pain was insidious, but it is mainly associated with tasks that involve rotation, although there may be sharp pain on coughing and prolonged weight-bearing; especially if stooped. The patient is pain free in the recumbent position and sleeps well. Sitting in the erect position is rarely painful, but low sitting positions, as when driving his convertible, are poorly tolerated. There is no radiating pain and no reports of weakness or of loss of bowel or bladder control. There is no history of cancer and no laboratory evidence of inflammatory processes. His Oswestry score is 28%; denoting moderate disability. On the 0–10 Numeric Pain Rating Scale (NPRS), he rates his pain during the last 24 hours as 8 at worst, but as 0 at best.

PHYSICAL EXAMINATION

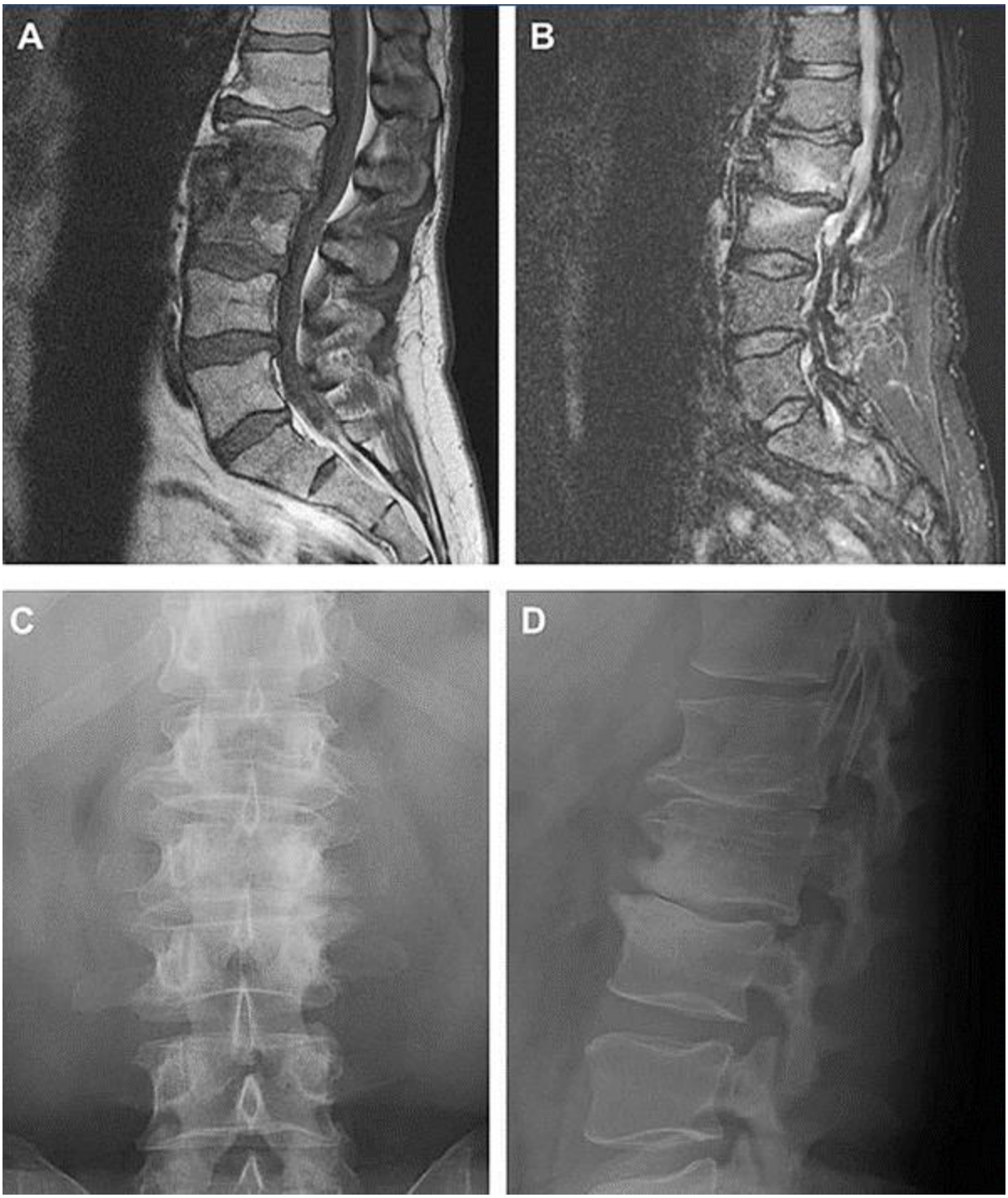
The patient is of ectomorphic build and seems in good physical condition for his age. He is symmetrical and his spinal curves appear normal. Active range of flexion (using a fingertip-to-floor method) is 20cm; limited by lumbar pain. Extension is within normal limits (WNL). On visual estimation, lateral flexion is slightly limited to the right. Rotation is painful bilaterally at end of range. Reflexes are WNL and no areas of decreased sensation are found. Lumbar extensor strength is WNL and pain free, but testing of lumbar flexor strength is terminated due to increase in pain. Lower extremity strength, as measured with manual muscle testing, is WNL, except for the right iliopsoas which measures 3+. The straight leg raise test is WNL and so are other tests for neurotension.

On passive intervertebral motion testing (PIVM), lateral flexion is limited bilaterally at L1/2 and 2/3. Postero-anterior pressure in the upper and mid lumbar spine provokes mid-lumbar pain, but extension is WNL at all lumbar levels. Rotation is slightly limited at L1/2 and L2/3.

On palpation, lumbar spine extensors are hypertonic. Pain is provoked with moderately heavy tapping on the L2 and 3 spinous processes

Goals

The aim is to lower the patient's rating for worst pain to no more than 3 and the Oswestry to $\leq$10% (minimal disability). At the end of treatment, it is hoped that the patient will be able to play golf three times a week and sit pain free.



B) Case Two

HISTORY

Your patient is a 55 year old auto mechanic complaining of pain and stiffness in the left shoulder. He reports that this shoulder always been less mobile than the right, but only in the last couple of years have movements been painful to the point of affecting at work. The patient's work frequently involves holding his hands overhead for extended periods and he says he has learned to adjust to these working conditions. Outside of work, he is not physically active.

PHYSICAL EXAMINATION

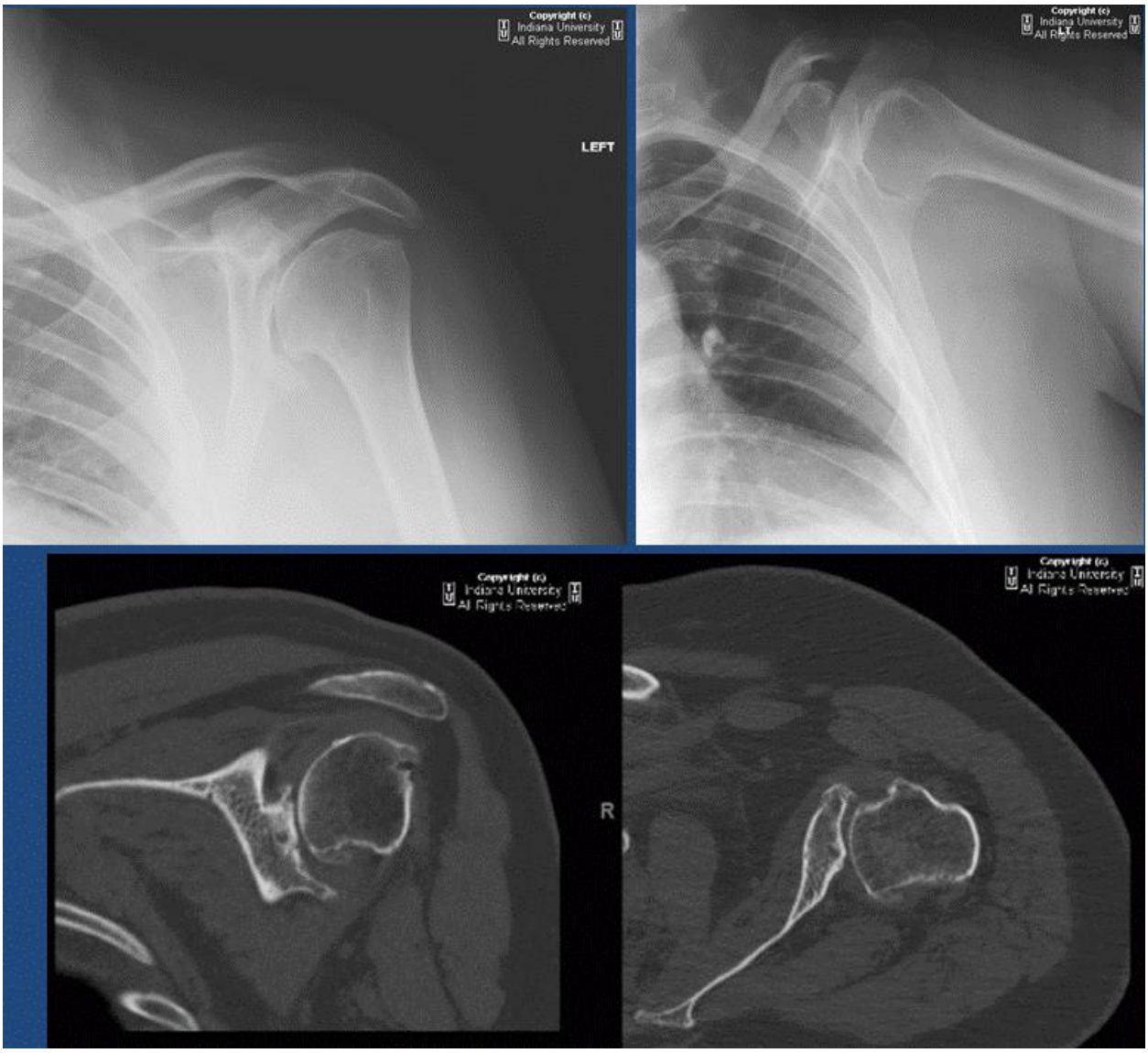
The patient is a mesomorphic male who seems in fairly good physical condition for his age. On inspection, a forward shoulder position is noted bilaterally. There is considerable atrophy of infraspinatus and supraspinatus muscles of the left shoulder. There is considerable limitation of active flexion, abduction, and external rotation of the left shoulder: Flexion: R= 160^0; L= 130^0; abduction: R= 160^0; L= 110^0; external rotation: R= 80^0; L= 50^0. Manual muscle testing reveals a strength deficit of infraspinatus and supraspinatus; both muscles measure 3. Strength of other muscles is WNL. Motions of the right shoulder are WNL and pain free.

Neer's impingement sign is painful and the crank/ apprehension test is positive; indicative of anterior instability. The sulcus sign for inferior instability is positive both at 0 and 90 degrees.

The patient brings AP radiographs of the left shoulder (in resting position and on attempted abduction), as well as coronal plane and axial CT scans. There is no accompanying radiographic report and the patient cannot recall if a definitive radiographic diagnosis was made.

GOALS

The aim to obtain 130 degrees of abduction, full external rotation, and muscle strength of 4 in both infraspinatus and supraspinatus.



C) Case Three

HISTORY

A 68 year old fairly sedentary retired policeman with diagnosis of osteoarthritis of the right knee, confirmed with radiographs and MR imaging six months ago. Pain has increased since the time of diagnosis and the patient now complains of pain on weight bearing that interferes considerably with daily activities and interrupts sleep at night. High doses of non-steroidal anti-inflammatory drugs have not changed his symptoms. His Lower Extremity Functional Scale (LEFS) score is 39. On the NPRS, he rates his pain during the last 24 hours as 8 at worst but 2 at best.

PHYSICAL EXAMINATION

The patient is slightly overweight and displays mild varus of both knees. He walks with a considerable limp and does not fully extend the right knee in standing. The knee extension gradually returns to

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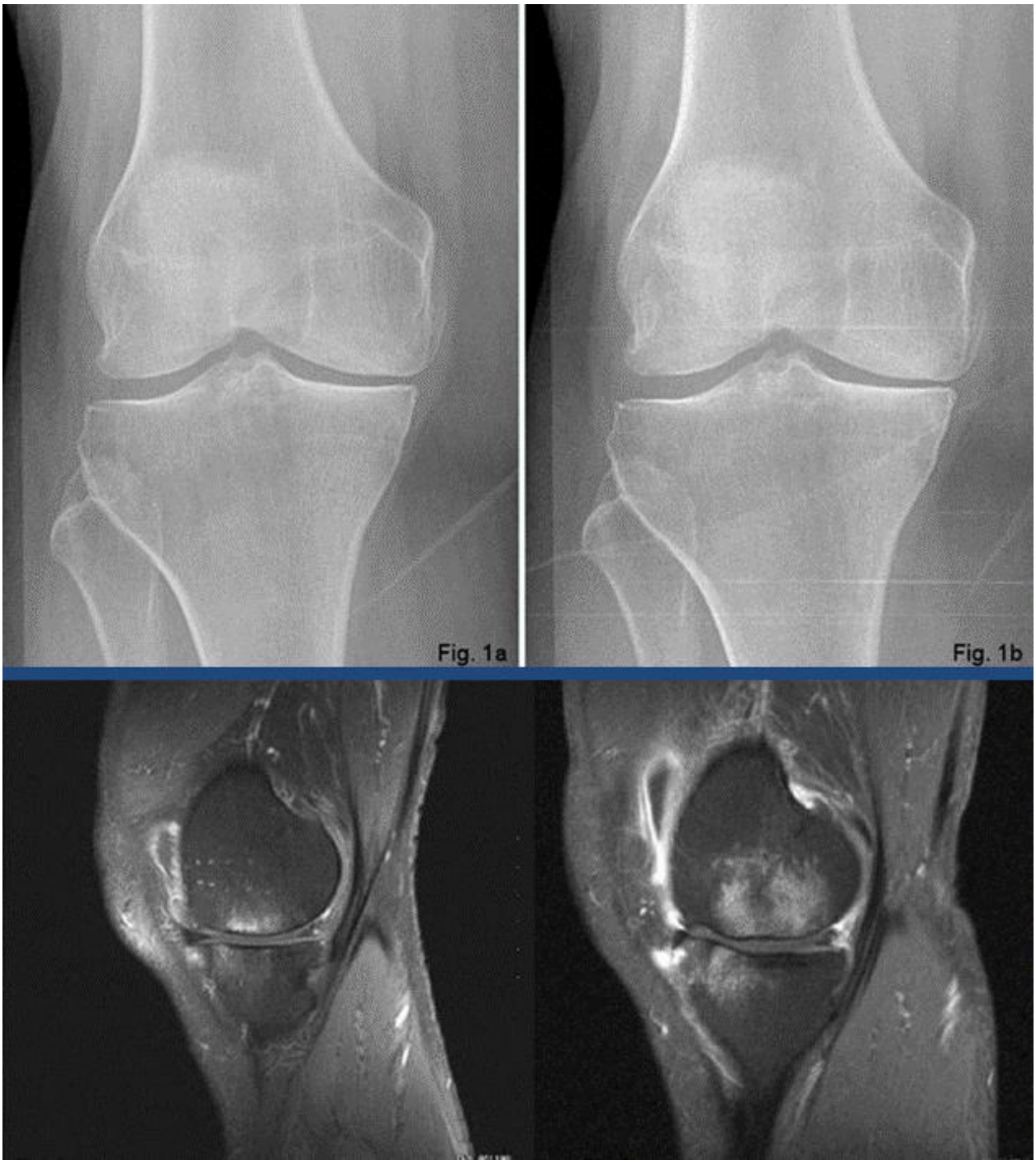
normal after a few minutes of standing and walking around. He can ascend stairs with a reciprocal gait; but all the weight bearing in flexion while descending stair is done on the left leg. The patient can squat, bearing equal weight on both legs, to 60^0 of knee flexion - but can go no further due to pain. In the supine position, the patient has full extension and 125^0 of flexion bilaterally. The gap test (a valgus stress test) for the medial collateral ligaments reveals laxity with minimal discomfort bilaterally.

On palpation, there is tenderness along the medial joint line. Light tapping on the medial femoral condyle and the medial tibial plateau provokes sharp pain.

GOALS

The aim is for a worst pain score of no more than 2 and a LEFS score of 50-60. At the end of treatment, he hopes to be able to regular household chores and walk a couple of blocks without difficulty.



Appendix 2: Invitation to Study

Dear Colleague

As I thank you again for your participation in the Delphi study Diagnostic Musculoskeletal Imaging in Physical Therapy, I would like to invite you to participate in a web-conference based interview; a part of my PhD project investigating the use of musculoskeletal imaging by physical therapists.

Only one Interview is required. It will be conducted online and will be scheduled at a time convenient for you. I feel this is exciting research, conducted with a truly novel method.

The interview process is as follows: Once we have scheduled the interview time, you will receive three cases with history, examination findings and imaging studies - similar to the cases we used in our Delphi study.

1. You will view the imaging studies on my computer monitor via web-conferencing, indicating with a click of the mouse areas of interest in the images. Your clicks will be recorded by a screen-capture program.
2. Subsequently, the screen-capture video will be played back to you and will give a foundation to the interview that focuses on:
    1. What you found interesting in each area of the images.
    2. Your evaluation of functional consequences of the radiographic changes seen in the images.
    3. Indications for caution or referral.

If you are interested in this study, I will send you a consent form that explains this process in more detail.

Appendix 3: Informed Consent Form

Consent Form for Participation in the Research Study Entitled "Diagnostic Musculoskeletal Imaging in Physical Therapy: Its Scope and Role in Clinical decision-making."

Funding Source: University of St Augustine, Institutional Research Fund.

IRB protocol #: 01261126Exp

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For questions/concerns about your research rights, contact:
Human Research Oversight Board (Institutional Review Board or IRB)
Nova Southeastern University
Ph: (954) 262-5369/Toll Free: 866-499-0790
IRB@nsu.nova.edu

What is the study about?
This interview study aims to describe how physical therapists use imaging studies (conventional radiography and advanced imaging) to aid examination and clinical decision-making in the treatment of musculoskeletal disorders.

Why are you asking me?
This study attempts to establish baseline knowledge as to the current use of imaging by physical therapists treating musculoskeletal disorders. There are, apart from specially credentialed physical therapists in the military, no groups of physical therapists that can be considered specially trained in the use of imaging for clinical decision-making in the management of musculoskeletal disorders. However, physical therapists with OCS certification and fellows of AAOMPT have been shown to have superior clinical decision-making ability related to musculoskeletal disorders and basic knowledge of imaging is one of the foundations underlying OCS certification and fellowship in AAOMPT. This makes physical therapists with OCS certification and fellows of AAOMPT ideal candidates for this study. Ten to fifteen participants will be recruited for the study.

What will I be doing if I agree to be in the study?

A meeting for the interview will be scheduled at a time and place convenient to you. Only one interview is required. During the interview, you will first be presented with three cases of musculoskeletal conditions, including history, examination findings and imaging studies. Before viewing the associated imaging studies, you will be asked for a preliminary assessment of the cases and the potential need for further examination. Then you will privately view the accompanying imaging studies on a computer monitor, indicating with a click of the mouse areas of interest in the images. A screen-capture program will record this viewing activity, which will subsequently be played back to you. The interview will then focus on your impression of the imaging studies and what you indicated as interesting in each area. This process should take less than two hours.

In the event of a research-related injury, or if you have questions or concerns about the study, please contact the principal investigator, Hilmir Agustsson, via telephone (904)826-0084.

Is there any audio or video recording?
The interviews will be recorded and these audio recordings synchronized with a sequence of images recorded by the screen capture program, as described above. However, no video recording will be involved.

What are the dangers to me?
There are only minimal risks involved. Your views and comments will be anonymous except to the principal investigator and co- investigator. However, a publication of the study may involve direct quotes where you may still be identifiable through comments you make – even if your name is not mentioned.

If you have questions or concerns about the study, or in the event of a research-related injury, please contact the principal investigator, Hilmir Agustsson, via email (agustsso@nova.edu) or telephone (904)826-0084. You may also contact the IRB. (See contact information above.)

Are there any benefits for taking part in this research study?
There will be no direct benefits associated with participation in this study.

Will I get paid for being in the study?
There will be no costs to you or payments made for participating in this study.

How will you keep my information private?
All information obtained in this study will be strictly confidential unless disclosure is required by law. Only the principal investigator and co-investigator will have access to this information. No files, audio recordings, interview transcripts, notes, or files relating to the analysis of the interviews will contain your name – only a pseudonym. However, members of the IRB and regulatory agencies may review research records. All of these individuals are bound by confidentiality

The interview data will be analyzed using specialized software on a password-protected personal computer and backed up on a daily basis to a secure password-protected website. Handwritten notes will be scanned will be kept in a locked cabinet. Research data will be retained for 36 months from the conclusion of the study, after which the data will be destroyed. At 36 months, data on the principal investigator's the personal computer will be deleted and the

computer's recycle bin emptied. Data backed up to the Web site will be deleted and the Web site account subsequently closed.

What if I do not want to participate or I want to leave the study?
You have the right to leave this study at any time or refuse to participate. If you do decide to leave or you decide not to participate, you will not experience any penalty. If you choose to withdraw, only information collected about you up to the point you leave the study will be kept in the research records, however, you may request that the data not be used. These will, similarly, be kept on record for 36 months from the conclusion of the study.

Other Considerations:
If significant new information relating to the study becomes available, which may relate to your willingness to continue to participate, this information will be provided to you by the investigators.

By signing below, you indicate that:
1. This study has been explained to you
2. You have read this document or it has been read to you
3. Your questions about this research study have been answered
4. You have been told that you may ask the researchers any study related questions in the future or contact them in the event of a research-related injury
5. You have been told that you may ask institutional review board (IRB) personnel questions about your study rights
6. You are entitled to a copy of this form after you have read and signed it
7. You voluntarily agree to participate in the study entitled "Diagnostic Musculoskeletal Imaging in Physical Therapy: Its Scope and Role in Clinical decision-making."

Once you have signed the consent form, please fax it or mail to the address above. The principal investigator will then sign it, scan the completed form, and send to you as an email attachment.

Participant's Signature: _____ Date: _____

Participant's Name: _____ Date: _____

Signature of Person Obtaining Consent: _____

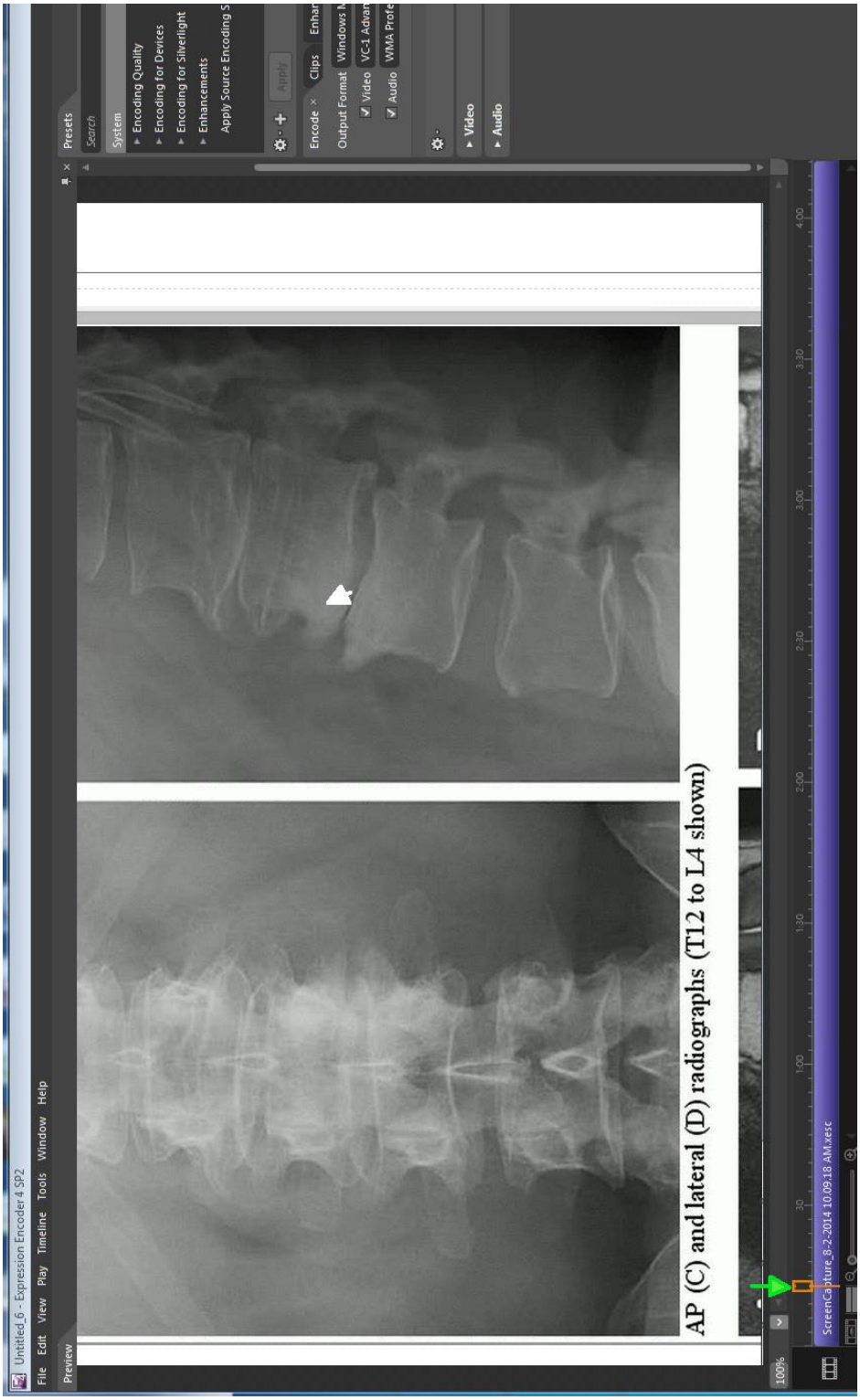
Date: _____

Appendix 4: Screenshot during an Interview

A screenshot of the computer screens during an interview. The yellow frame indicates area being recorded with screen-capture. The area outside the capture shows the GTM controls. The green arrow indicates computer control; the red arrow screen sharing; the blue arrow the recording feature in GTM.

Appendix 5: Screen-Capture Playback in Expression

Green arrow indicates video playback control; white arrow the area indicated by informant.



Appendix 6: Examples of Presentations of the Results of Word Frequency Queries

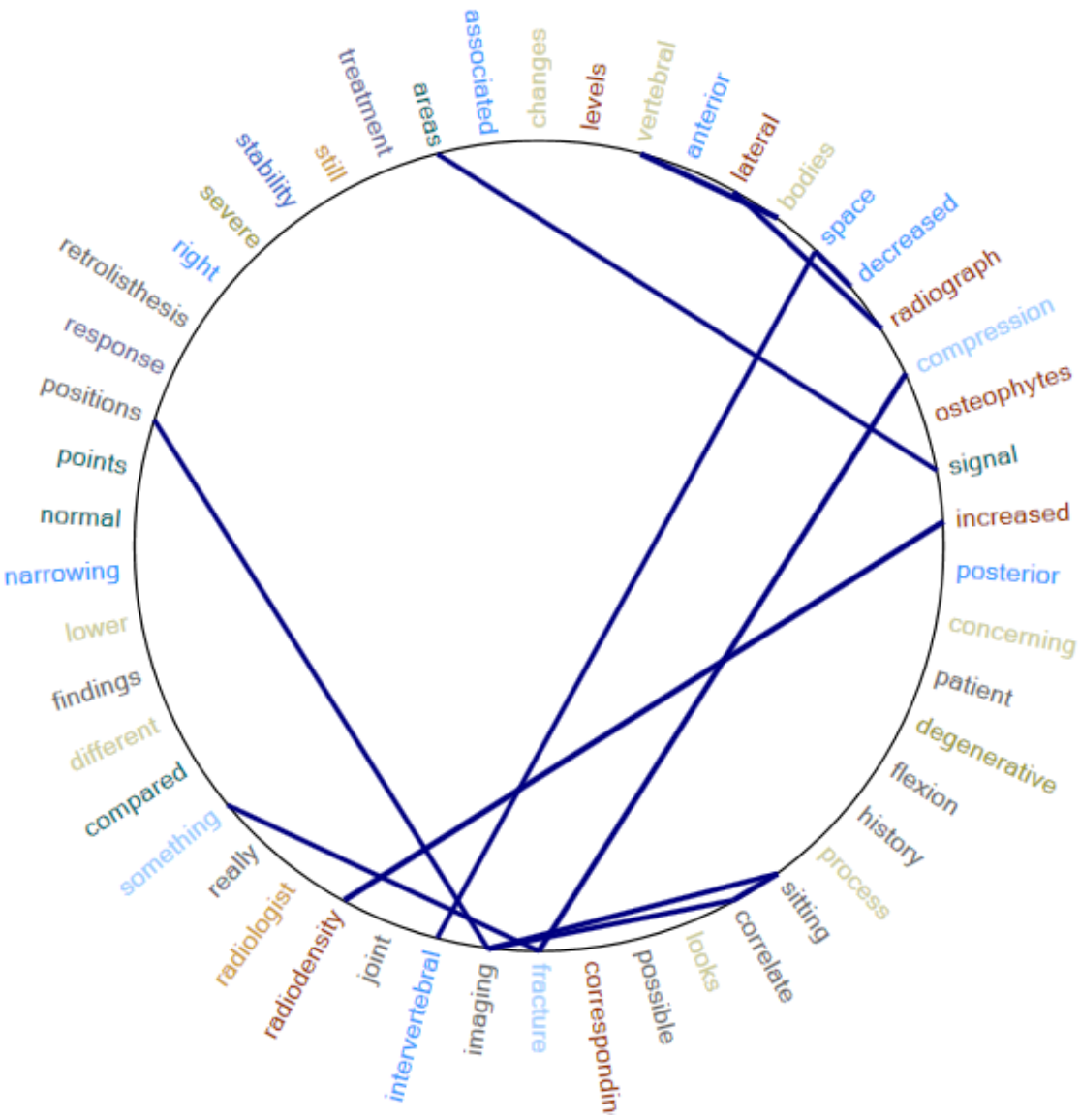
Query related to Case 1

Word Frequency Query Result

Word	Length	Count	Weight	Similar Words
changes	7	23	1.87	change, changes
levels	6	20	1.62	level, levels
vertebral	9	19	1.54	vertebral
anterior	8	17	1.38	anterior, anteriorly
lateral	7	16	1.30	lateral
bodies	6	15	1.22	bodies
space	5	14	1.14	space, spaces
decreased	9	12	0.97	decrease, decreased
radiograph	10	12	0.97	radiograph, radiographs
compression	11	11	0.89	compression
osteophytes	11	11	0.89	osteophytes
signal	6	11	0.89	signal, signals

Summary

Word cloud



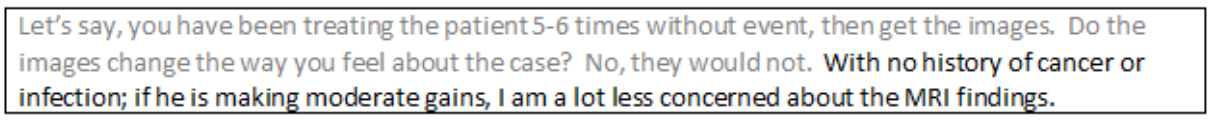
Relationships

Appendix 7: Example of Table Format and Nodes

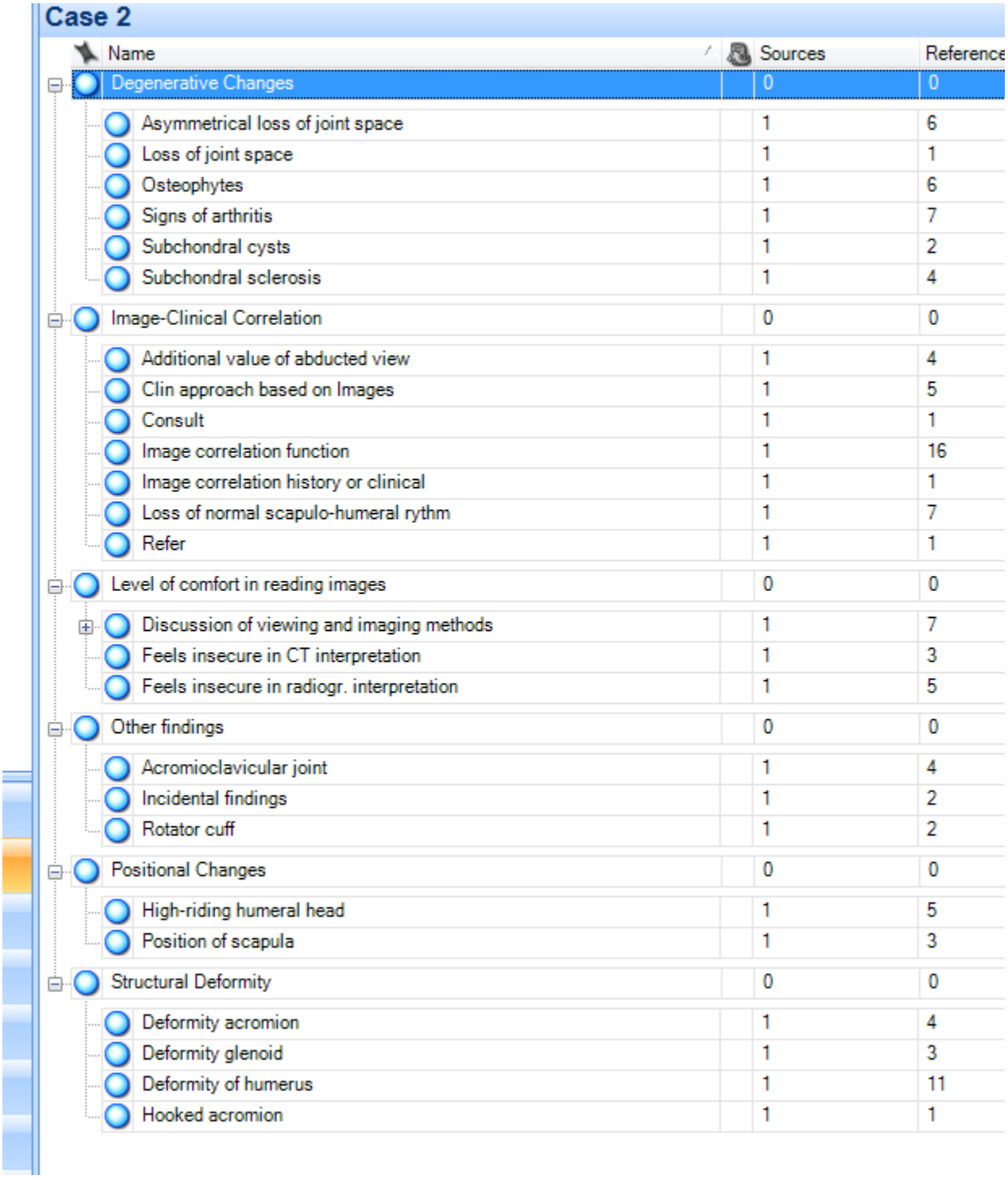
Example of comments made by one informant for Case #1;

AP radiograph: left pedicle of L2 and 3: sclerotic changes, blurring facet joint lines at this level. If this is facet joint involvement (combined with limited rotation L/R) – I would have expected limited extension.
AP: no lateral curvature.
AP: disk space narrowing; better seen in the lateral view. Pretty advanced, probably longstanding.
Lateral: L1/2 and 2/3 levels; the L1/2 disk space is pretty much gone.
Lateral: Large osteophytes at the L1/2 and 2/3 levels.
Lateral: Retrolisthesis with foraminal narrowing.
Lateral: sclerotic changes
Lateral: Osteophyte at L1/2 and 2/3 levels, are they of the same nature – what are they telling us? The condition is long-standing. There is no history of injury, but with such changes at these levels, there must have been significant injury at some point.
MRIs: T1 is concerning in terms of loss of definition at L2/3. These could be really severe Modic changes. The levels about look more like your standard degeneration disk disease. The T2 has increased signal intensity at the same level.
MRIs: You talk of loss of definition at L2/3 on T1. Comparing this to T2, does that change your mind about the seriousness of the condition? Concerned with the increased signal intensity. But, his pain pattern is mechanical – which steers me away from pathological causes (full relief lying down) and no history of cancer or infection. So, not sure why he should have bad disease in this area. More concerned with what I see in the MRI than in the conventional radiographs. He is 74; compression fractures do happen in older men. He has pain with flexion; I don't know if this area represents recent compression fracture. Still there is nothing indicating compression – no history of sneezing or fall.
MRIs: Pain on low-sitting position and coughing – does that correlate with what you see in the images? Again, due to possible facet joint involvement and retrolisthesis, I would have expected extension to be painful. Pain on low-sitting positions, I am not sure this this corresponds to the imaging findings. With history of cancer or infection and no laboratory evidence cancer very unlikely – so I am not sure I can explain the MRI findings. However, the psoas muscle weakness and pain with tapping on the spinous processes has me concerned about a possible destructive process.
Let's say, you have been treating the patient 5-6 times without event, then get the images. Do the images change the way you feel about the case? No, they would not. With history of cancer or infection; if he is making moderate gains, I am a lot less concerned about the MRI findings.

Below is an example of coding of the last statement under the open code "Less concern about image findings due to history" showing selected and accompanying (grayed-out text).



Appendix 8: Example of First Round of Axial Coding



Case 2

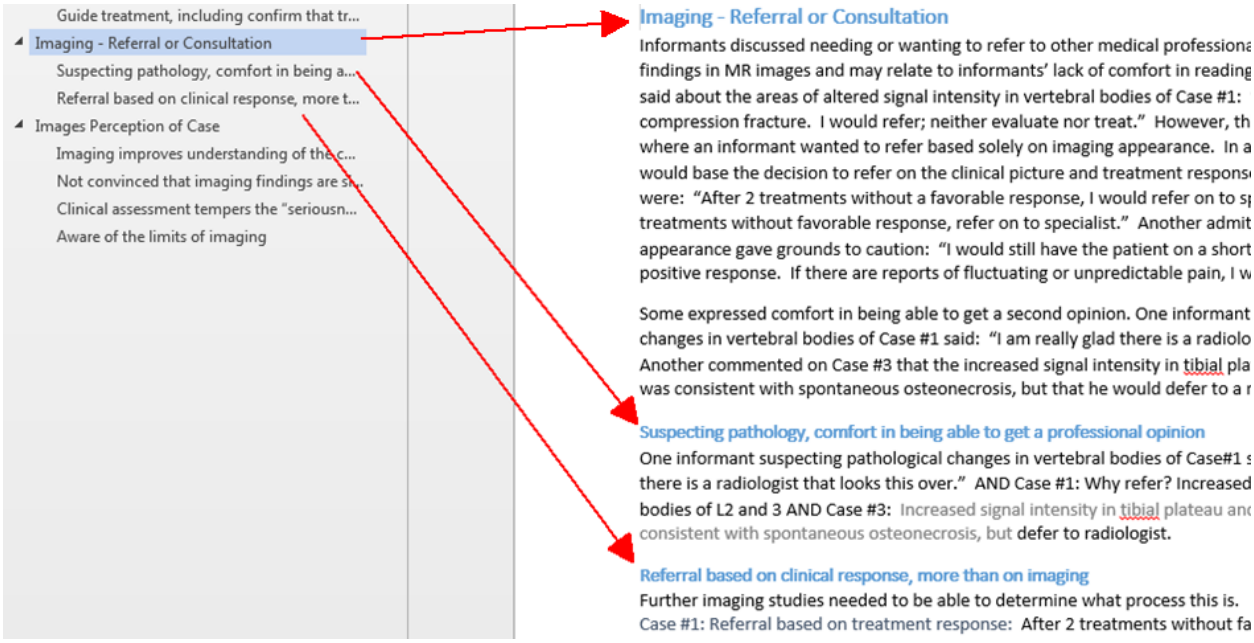
Name	Sources	Reference
Degenerative Changes	0	0
Asymmetrical loss of joint space	1	6
Loss of joint space	1	1
Osteophytes	1	6
Signs of arthritis	1	7
Subchondral cysts	1	2
Subchondral sclerosis	1	4
Image-Clinical Correlation	0	0
Additional value of abducted view	1	4
Clin approach based on Images	1	5
Consult	1	1
Image correlation function	1	16
Image correlation history or clinical	1	1
Loss of normal scapulo-humeral rythm	1	7
Refer	1	1
Level of comfort in reading images	0	0
Discussion of viewing and imaging methods	1	7
Feels insecure in CT interpretation	1	3
Feels insecure in radiogr. interpretation	1	5
Other findings	0	0
Acromioclavicular joint	1	4
Incidental findings	1	2
Rotator cuff	1	2
Positional Changes	0	0
High-riding humeral head	1	5
Position of scapula	1	3
Structural Deformity	0	0
Deformity acromion	1	4
Deformity glenoid	1	3
Deformity of humerus	1	11
Hooked acromion	1	1

Appendix 9: Axial coding Revisited. Clinical Use of Imaging prior to Merging Cases

Clinical Use of Imaging

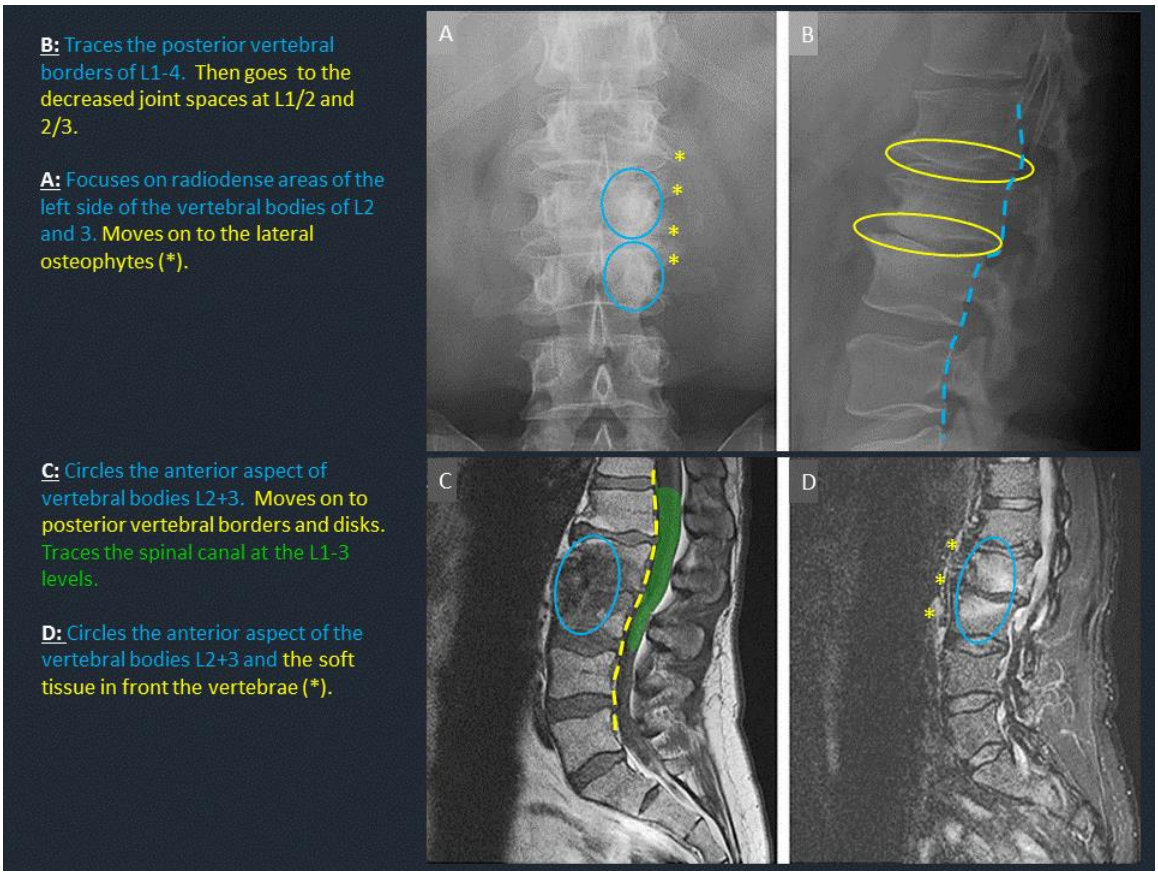
Name	Sources	Reference
Image-Clinical Correlation (1)	0	0
Decision-Direction	0	0
Image Correlation- Function	0	0
Image correlation History	1	2
Image correlation pain	1	5
Image correlation Palpation	1	1
Image correlation_Other clin	1	2
Images not that alarming	0	0
Osteophytes clinical correlation	1	3
Patient presentation - reactive	1	1
Treatment response	1	1
Would images inform treatment	1	1
Image-Clinical Correlation (2)	0	0
Additional value of abducted view	1	4
Clin approach based on Images	1	5
Consult	1	1
Image correlation function	1	16
Image correlation history or clinical	1	1
Loss of normal scapulo-humeral ryth	1	7
Refer	1	1
Image-Clinical Correlation (3)	0	0
Clin approach based on Images	1	5
Comparing images 6 months apart	1	13
Consult	1	1
Image correlation function	1	8
Image correlation history or clinical	1	6

Appendix 10 – Navigation View during Selective Coding

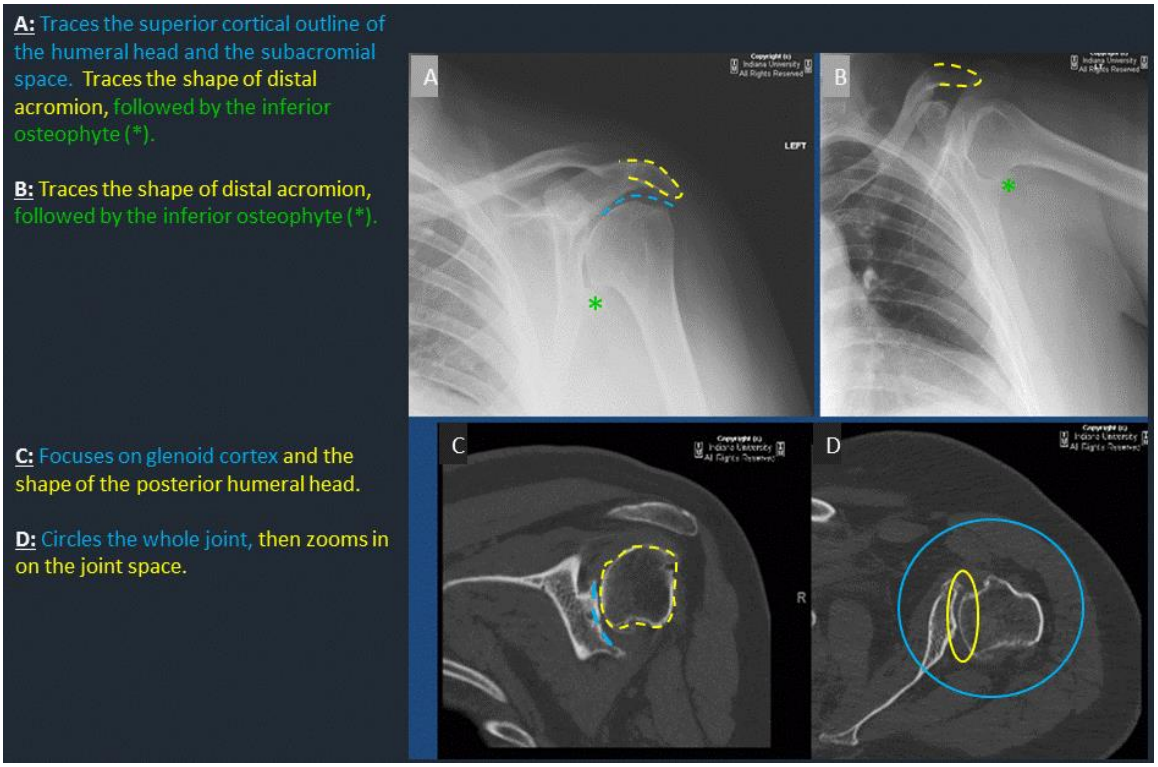


Appendix 11 – Illustration of Search Patterns by Informant QR.

Case 1



Case 2



Case 3