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A graphical clinical decision aid for managing imaging report information

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Objective: The purpose of this article is to propose a graphical decision aid for managing radiology report information to assist learners in developing clinical decision-making skills through a structured approach.
Methods: A graphical decision aid informed by learning theories was constructed to manage radiology report information by identifying an overall strategy, specific decision-making steps, and decision goals. A review of radiology reports was performed to demonstrate the rich source of complex information requiring clinical decision making. Radiology report data were descriptively analyzed, and findings were described as definite or indefinite, while recommendations were reported as required or optional.
Results: The graphical decision aid involves 4 stages. The 1st 2 stages interpret report information and consider data obtained during the clinical encounter. The following 2 stages guide decisions by answering questions to ensure patient safety and/or to confirm diagnosis and to address broader case management questions. The mean (SD) age of participants whose imaging reports were reviewed was 73.4 (7.0) years. Of 170 reports, common findings included degenerative disc disease (98%), soft tissue or vascular calcification (94%), bone demineralization (92%), and zygapophyseal joint degeneration (86%). Common indefinite findings were spinal stenosis (15%), compression fracture (12%), bony abnormality (12%), radiodensity (12%), and disc degeneration (10%). One hundred twenty-one recommendations suggested follow-up actions.
Conclusions: Information within imaging reports requires identification and interpretation to inform complex clinical decisions. The graphical decision aid proposed in this article is designed to facilitate the development of decision-making skills by providing a structured and evidence-based information management process.

Key Indexing Terms: Clinical Decision Making; Low Back Pain; Radiography; Spine

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INTRODUCTION

The fundamental purpose of diagnostic imaging is to inform clinical decision making.[1] However, imaging reports can contain large amounts of data, which can overwhelm cognitive processes resulting in poor decision making. Research has shown that humans have a limited capacity to mentally process simultaneously occurring novel data, typically limited to 7 ± 2 bits of information, stored within working memory for only a few seconds.[2,3] Because of this limited capacity, cognitive processing can be overwhelmed.[4] Rather than developing an increased cognitive capacity, expert clinicians manage large volumes of clinical information by developing the ability to efficiently identify new data as either relevant or irrelevant in sequential decision-making steps.[5,6]

The fact that expert clinicians demonstrate efficient mental processing of complex information is contrasted with the fact that students and inexperienced counterparts do not.[5] This contrast leads to questions about how one moves from student to novice to expert. For educators, pertinent questions are the following: Can learning complex decision making be facilitated? If so, what strategies are most beneficial? What strategies help students develop how information is sequenced, connected, or synthesized and used to solve problems or inform actions.[7–9]

The Need for a Staged Approach to Manage Radiology Report Information

Chiropractic students are tasked with learning to identify a wide variety of radiographic features. In the United States, the National Board of Chiropractic Examiners Part IV examination is required for licensure in most regions. This examination tests the ability to identify radiographic features that (1) are consistent with cases commonly encountered in practice, (2) exhibit contraindications to chiropractic care, and (3) require other evaluation or management to preserve life or health.[10]

The ability to identify radiographic features is of no benefit without the capacity to adequately process information and generate consistent and appropriate clinical decisions. Thus, educators are tasked not only with helping students learn to identify normal and abnormal findings but also with learning to properly integrate imaging report information with other clinical data to guide rational decision making. This challenge is significant. Learning to identify imaging findings requires memory development, whereas learning to integrate a broad range of clinical information to inform rational decision making demands other cognitive processes.

Evidence-Based Learning Strategies

Cognitive learning theories variously describe and focus on how learners mentally structure and process information to solve problems and inform future actions.[4,7–9] Rather than relying on memory or automated responses, complex clinical decision making involves information sequencing and combining to solve problems or inform actions.[7–9] Concept maps, algorithms, and staged process models are academic tools used to facilitate complex cognition because they provide a framework for mentally organizing information through visual representations and by guiding multistage decision-making processes.[8,11–13] A stepped approach may provide a structured framework for engaging the challenge of helping students move from memory-based learning to the cognitive processes required for assimilating clinical and imaging report information to inform clinical actions.

To the authors' knowledge, there is currently no published decision-making process model or tool available to assist learners in organizing and integrating radiology report information to inform efficient clinical management decisions. Such a structured approach can potentially benefit students and educators by providing a framework for decision making using distinct steps.[5,14–17] The purpose of this article is to propose a systematic, stepped decision process for managing radiology report information.

METHODS

Radiology Report Data

To provide direct evidence for the concept that diagnostic imaging reports contain a large volume of disparate information requiring complex decision making, the authors undertook an analysis of lumbar spine X-ray imaging reports. Reports were obtained from records generated from a previous randomized controlled trial during which participants aged 65 years or older with subacute or chronic low back pain underwent digital X-ray imaging.[18] All participants were ambulatory. A complete list of inclusion/exclusion criteria can be found in the published study protocol.[18] This secondary analysis was deemed exempt by the institutional review board Human Protections Office of Palmer College of Chiropractic. Radiology reports were generated by board-certified medical or chiropractic radiologists from either a regional health care facility or the radiology department within the Palmer College of Chiropractic clinic system. Other types of imaging (e.g., magnetic resonance imaging [MRI]) reports were not included.

Two study team members independently recorded definite and indefinite findings by category per report. Likewise, individual recommendations (those deemed required and optional) were counted by category per report. "Definite" findings were those identified with unequivocal text or terms indicating high confidence, whereas "indefinite" findings were defined as those with text signifying that additional clarification was needed, often prefaced with terms such as "probable," "suspected," or "possible." In some instances, a finding classified as definite also contained an indefinite etiology, such as "spondylolisthesis of indeterminate origin." Because this represents 2 distinct bits of information, when this occurred, definite (spondylolisthesis) and indefinite (indeterminate origin) findings were recorded. Completed data collection forms were entered into an electronic database using a double-key entry process. Discordant findings were resolved using a consensus discussion process between study team members. Descriptive statistics report demographics for the population studied and study findings using mean and standard deviation for continuous variables and counts and percentages for categorical variables. The purpose of reporting descriptive-level prevalence data from X-ray imaging reports was to demonstrate evidence of the large volume of disparate information contained within them and the need for a structured decision process to manage such information. Thus, a comparative analysis was not performed with any clinical outcome, such as pain level or disability.

Graphical Decision Aid Development

The decision aid was developed and informed by analytic theory, which achieves rational decisions by preselected alternatives and visually demonstrated by algorithms involving mutually exclusive choices.[19] However, an algorithmic model represents neither an information synthesis process, the mutable hierarchy of radiology report data contributing to multiple case-based management options, nor multiple potential decisions that can be made at each step. Therefore, the authors constructed a conceptual process using a graphical design incorporating a stepped approach consistent with cognitive research focused on tools that facilitate the development of decision-making abilities.[2,4,7–9] The decision process outlines 4 stages similar to a semantic network representation and a situated clinical decision-making framework that identifies an overall strategy, specific decision-making steps, directionality of the process, and goals.[17,20] Answers to questions contained within stages 3 and 4 focus on information management. Answering stage questions for each finding or recommendation promotes a sequential decision-making process. The proposed model shares characteristics with the diagnosis-based clinical decision guide developed by Murphy and Hurwitz in that it organizes decision making into distinct steps navigated by answering key clinical questions.[21–23]

Table 1 - Demographic Characteristics of Patients Imaged ($n = 170$)

Categories	*n* (%)
Age (y) and mean (SD)	73.4 (7.0)
Male	105 (62)
Non-Hispanic or Latino	167 (98)
Race	
Asian	1 (1)
Black or African American	3 (2)
White	162 (95)
Other	2 (1)
Multiracial	2 (1)
BMI mean (SD)	31.2 (6.4)
Average LBP over past week (0–10 points) – mean (SD)	5.7 (2.0)
1st LBP episode (y) and mean (SD)	28.1 (20.2)
RMDQ mean (SD)	7.6 (5.0)
LBP categories	
Pain without radiation	119 (70)
Pain with radiation to extremity	48 (28)
Lumbar spinal stenosis	2 (1)
Symptomatic > 6 mo postsurgery	1 (1)
1-y all fracture risk and mean (SD)	12.1 (8.8)
1-y hip fracture risk and mean (SD)	4.2 (5.5)
Timed up and go (seconds) and mean (SD)	11.9 (4.5)

BMI = body mass index; LBP = low back pain; RMDQ = Roland Morris Disability Questionnaire.

RESULTS

Our team obtained data from 170 radiology reports. The mean age (SD) of the sample was 73.4 (7.0). Radiology reports were written primarily by a single radiological team (96%). Demographic characteristics are listed in Table 1.

We identified 4 basic types of clinical information within 2 broad categories within reports. Categories included findings and recommendations. Findings were partitioned into those that were definite or indefinite, while recommendations were divided into those that are required or optional. Individual findings are listed in Table 2 as "definite" (identified with text indicating high confidence in the finding) and "indefinite" (indicated with equivocal text or requiring more information).

Common findings classified as definite included degenerative disc disease (98%), soft tissue and vascular calcification (94%), bone demineralization (92%), zygapophyseal degenerative joint disease (86%), and spinal curvature/list (75%). Spondylolisthesis was another common finding with 76 (45%) reports including at least 1 subcategory: degenerative 53 (31%), unspecified 11 (6%), retrolisthesis 5 (3%), lateral listhesis 4 (2%), and isthmic 3 (2%). Table 3 reports recommendations by category for the 121 identified. In some reports (12), recommendations were described as a required activity (e.g., "follow-up with MRI is needed") though later rephrased as "will likely be needed" or "if needed," suggesting that the action was optional.

Table 2 - Prevalence of Definite and Indefinite Findings (Described as Possible, Probable, or Otherwise With Uncertainty) on Lumbar Spine Conventional Radiography Reports ($n = 170$)

Findings	Definite: *n* (%)	Indefinite: *n* (%)
Disc degeneration	166 (98)	17 (10)
Calcification[a]	160 (94)	5 (3)
Bone demineralization	157 (92)	1 (1)
Facet degeneration	147 (86)	0 (0)
Curvature or list	127 (75)	1 (1)
Surgical findings	66 (39)	2 (1)
Anterolisthesis, degenerative	53 (31)	0 (0)
Scoliosis	22 (13)	1 (1)
Pelvic unleveling	21 (12)	0 (0)
Sacroiliac joint arthrosis	19 (11)	5 (3)
Hip osteoarthritis	19 (11)	5 (3)
Radiodensity[b]	12 (7)	21 (12)
Anterolisthesis, unspecified	11 (6)	11 (6)
Congenital anomaly[c]	11 (6)	0 (0)
Transitional segment	10 (6)	4 (2)
Condrocalcinosis	10 (6)	1 (1)
Bony abnormality[d]	9 (5)	20 (12)
Bowel gas accumulation	8 (5)	0 (0)
Hyper- or hypolordosis	8 (5)	0 (0)
Compression fracture	6 (4)	20 (12)
Alignment abnormalities[e]	6 (4)	0 (0)
Retrolisthesis	5 (3)	0 (0)
Rib variant[f]	5 (3)	1 (1)
Lateral listhesis	4 (2)	0 (0)
Aortic aneurysm	4 (2)	3 (2)
Diffuse idiopathic skeletal hyperostosis	4 (2)	4 (2)
Anterolisthesis, isthmic	3 (2)	2 (1)
Visceral abnormalities[g]	3 (2)	2 (1)
Rib fracture	1 (1)	2 (1)
Spinal stenosis	0 (0)	25 (15)

[a] Calcification: includes soft tissues and vascular structures.
[b] Radiodensity: opacity.
[c] Congenital anomaly: e.g., spina bifida, Oppenheimer's ossicle, and trapezoidal-shaped vertebral body.
[d] Bony abnormalities: e.g., subchondral sclerosis, physiologic vertebral body wedging, dysplastic acetabulum, and heterotopic bone.
[e] Alignment abnormalities: e.g., thoracic hypokyphosis, accentuated lumbosacral angle, and pelvic rotation.
[f] Rib variant: e.g., hypoplasia, lumbar rib, or rib deformity.
[g] Visceral abnormalities: e.g., bladder effacement and liver projected over iliac crest.

Graphical Decision Aid

Figure 1 displays the proposed graphical decision aid, which includes 4 distinct stages. The first 2 stages require interpreting and viewing report information through the figurative lens of the clinical presentation. Stage 3 requires answers to ensure patient safety and/or to confirm a diagnosis, while stage 4 requires answers to broader case management questions. The final 2 decision-making stages are consistent with clinical guidelines and best practice recommendations.[22–25]

Table 3 - Recommendations by Category Contained Within Lumbar Spine X-Ray Imaging Reports

Recommendation Categories[a]	*n* (%) Recommendations
Required: necessary to obtain vital information	15 (12)
Optional: may be necessary to obtain vital information	50 (41)
Additional imaging necessary to improve image quality	13 (11)
Additional information needed to inform management	43 (36)

[a] Some reports may contain more than 1 category.

Stage 1: Identify and Interpret

In the 1st stage, individual findings and recommendations are identified from radiology reports. Findings are reported either conclusively (categorized in this study as definite) or indefinitely (Table 1). Likewise, clinical recommendations are considered either required or optional. Required recommendations necessitate action as exemplified by "Initial evaluation with ultrasonography is needed." Optional recommendations are written less definitively, such as "Comparison [with] the previous diagnostic imaging studies . . . would be beneficial, if available; however, MRI would provide greatest diagnostic imaging sensitivity for further characterization of noted compression fractures."

Stage 2: View Findings/Recommendations Through a Clinical Presentation Lens

The 2nd stage represents an information synthesis. Individual findings and recommendations are viewed through a figurative lens represented by the clinical history, current health status, working diagnosis, cultural context, lifestyle habits, and other factors. Only after synthesizing information obtained from both the clinical presentation and the report can informed clinical decisions be made. Although represented as stage 2, most clinical information is likely obtained before rather than after the radiology report.

Stage 3: What Actions Should I Take to Ensure Safety, Confirm Diagnosis, and Communicate to This Patient?

Management decisions may be different in the short and long term. Initial (short-term) management decisions regarding individual bits of information contained within radiology reports require answering the following questions: What actions should I take to ensure patient safety,

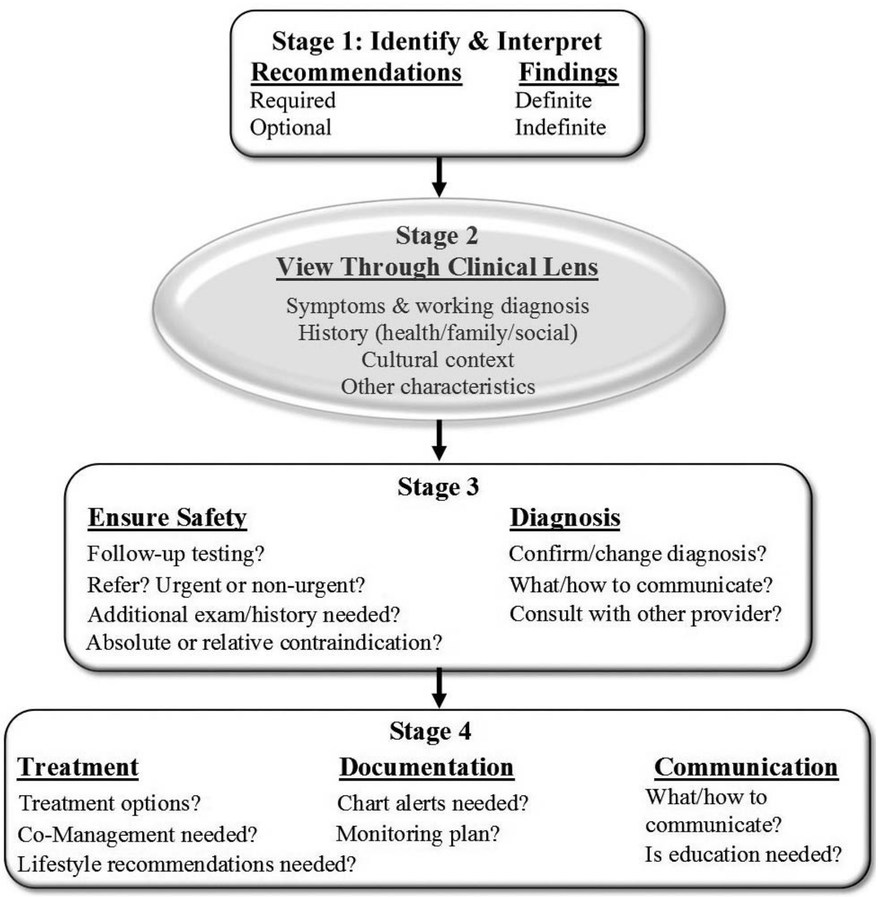

Figure 1 - Four-stage clinical decision aid for managing imaging report information.

confirm diagnosis, and communicate appropriately to this patient? Thus, decisions occurring in this stage inform immediate actions. Identifying findings representing contraindications to potential treatment strategies also occurs during this stage. When no additional actions are required to further define/refine a diagnosis, ensure safety, or initiate referral, decision making proceeds to the next stage, where longer-term management questions are answered.

Stage 4: Given This Finding or Recommendation, What Management Options Exist? What Should Be Communicated to the Patient and How? What Should Be Monitored and How?

Longer-term management decisions are again informed by viewing each bit of information contained within a radiology report through the lens of the clinical presentation. Identical findings may be addressed differently in patients with differing presentations. For example, it may be appropriate to schedule early reevaluation after a trial of care due to a high-risk clinical history. The same management plan may be different for a patient without elevated risk. Answering questions about management options, treatment strategies, and patient preferences also inform key aspects of evidence-based clinical management.

DISCUSSION

This article proposes a graphical decision aid to help guide and develop complex decision-making skills involving imaging report information. Because clinical management decisions may be dissimilar for patients with essentially identical findings, the proposed decision aid is adaptable to many potential clinical presentations. For example, the likelihood of bone demineralization in older adults is high, so noting this finding may not be surprising for an older patient.[26,27] However, the finding of demineralization may suggest the need for follow-up bone densitometry, dietary evaluation, exercise recommendations, and/or other therapies, such as those focused on reducing fall risk.[28,29] Likewise, a best practice action following a finding of abdominal aortic aneurysm on X-ray imaging includes ordering follow-up diagnostic ultrasound or other imaging. However, if these actions have already occurred, follow-up testing may not be necessary unless the image indicates substantially new information compared with prior knowledge.[30,31] Decisions regarding these example scenarios can occur in an organized manner by filtering each bit of information through the clinical presentation and then answering the questions in steps 3 and 4 of the graphical decision aid (Fig. 1).

Questions about what and how to communicate diagnostic information with patients are included in stages 3 and 4. Communicating test results can inadvertently label patients with an inert condition (e.g., mild disc degeneration) and cause concomitant morbidity.[32] Insufficient or poor communication can lead to disease labeling, patient anxiety, disempowerment, poor understanding, and therapeutic failure.[33,34] Because of the potential negative outcomes of poorly communicated diagnostic information, the decision aid includes questions to increase student awareness of the need to communicate with patients and that decisions should be made regarding how to relay such information. The question of how to communicate findings or recommendations acknowledges that patients may not understand medical terminology or may interpret information based on psychosocial and cultural factors, which should be considered prior to communicating.[38]

Radiology reports may contain numerous findings and recommendations requiring complex clinical decision making. Many findings considered definite require interpretation with respect to clinical importance. For example, intervertebral disc and zygapophyseal joint degeneration is common in older patients.[35] Therefore, the high prevalence of these findings in our sample is not surprising. However, clinical interpretation is needed to appropriately understand what role degenerative change may play in a given clinical situation. Compared with mild degeneration, moderate to severe lumbar spine degeneration results in anatomical and physiological changes contributing to altered loading mechanics and foraminal/intervertebral canal narrowing.[36,37] Knowing the severity of degeneration is often clinically important to inform appropriate exercise frequency, intensity, or joint loading recommendations. Understanding the severity of spinal degeneration may also be important when considering a diagnosis for patients with signs of neurogenic claudication.[35,36]

Adding to decision-making challenges are the alternate terminology interpretations occurring between radiologists and ordering providers. Terms such as "suspicious for . . . ," "consistent with . . . ," and "compatible with . . ." are not always interpreted by providers in the same manner they were implied by radiologists.[38] This interpretative challenge, alongside the common occurrence of indefinite findings and recommendations included in imaging reports, requires comparison with other clinical information to effectively render clinically appropriate decisions.

Limitations

We observed several instances of the word "advise" preceding a formal recommendation, raising the question of whether the recommendation was required or optional. When preceded by the word "advise," recommendations were classified as optional. However, this may not have been the implied meaning, nor is it necessarily true that recommendations without the word "advise" were intended to be required.

Some findings may have been misclassified. However, independent reviewers and a consensus process minimize potential misclassifications. Radiology reports studied were written predominantly by a single radiological team. Specific language used primarily by this team could have influenced results. Reports used for this study were obtained from a randomized controlled clinical trial consisting of primarily white older adults. Thus, the prevalence of specific findings and recommendations may not be generalizable to other samples. However, reporting prevalence data was not the primary purpose of the retrospective analysis. Rather, the purpose was to provide quantitative evidence that radiology reports contain a rich source information that requires complex decision making. Finally, the graphical decision aid proposed in this article is informed by learning theories and designed as a tool to facilitate cognitive decision-making processes. Because this publication merely proposes the tool, it has not been assessed for validity or its ability to support efficient, consistent, and rational decision-making development in students.

CONCLUSIONS

Imaging reports contain much information that must be considered within the context of the clinical presentation of individual patients. The graphical decision aid proposed in this article is designed to support the development of clinical management skills by providing a structured conceptual framework for managing information to inform clinical decisions.

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The authors declare no conflicts of interest.

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REFERENCES

1. Larson DB, Froehle CM, Johnson ND, Towbin AJ. Communication in diagnostic radiology: meeting the challenges of complexity. *AJR Am J Roentgenol*. 2014; 203:957–964.
2. Kay D, Kibble J. Learning theories 101: application to everyday teaching and scholarship. *Adv Physiol Educ*. 2016;40:17–25.
3. Young JQ, Van Merrienboer J, Durning S, Ten Cate O. Cognitive load theory: implications for medical education: AMEE guide no. 86. *Med Teach*. 2014;36:371–384.
4. Khalil MK, Elkhider IA. Applying learning theories and instructional design models for effective instruction. *Adv Physiol Educ*. 2016;40:147–156.
5. Kushniruk AW. Analysis of complex decision-making processes in health care: cognitive approaches to health informatics. *J Biomed Inform*. 2001;34:365–376.
6. Patterson F, Cousans F, Coyne I, Jones J, Macleod S, Zibarras L. A preliminary investigation to explore the cognitive resources of physicians experiencing difficulty in training. *BMC Med Educ*. 2017;17:87.
7. Nalliah S, Idris N. Applying the learning theories to medical education: A commentary. *Educ Psychol*. 2014;1:3.
8. Ertmer PA, Newby TJ. Behaviorism, cognitivism, constructivism: comparing critical features from an instructional design perspective. *Perform Improvement Q* 2013;26:43–71.
9. Taylor DC, Hamdy H. Adult learning theories: implications for learning and teaching in medical education: AMEE Guide No. 83. *Med Teach*. 2013; 35:e1561–e1572.
10. National Board of Chiropractic Examiners. *National Board of Chiropractic Examiners Part IV Test Plan*. Greeley, CO; National Board of Chiropractic Examiners; 2015.
11. Baig M, Tariq S, Rehman R, Ali S, Gazzaz ZJ. Concept mapping improves academic performance in problem solving questions in biochemistry subject. *Pakistan J Med Sci*. 2016;32:801.
12. Cutrer WB, Castro D, Roy KM, Turner TL. Use of an expert concept map as an advance organizer to

improve understanding of respiratory failure. *Med Teach*. 2011;33:1018–1026.
13. Kassab SE, Hussain S. Concept mapping assessment in a problem-based medical curriculum. *Med Teach*. 2010;32:926–931.
14. Banning M. A review of clinical decision making: models and current research. *J Clin Nurs*. 2008;17:187–195.
15. Patel VL, Kaufman DR, Arocha JF. Emerging paradigms of cognition in medical decision-making. *J Biomed Inform*. 2002;35:52–75.
16. Moskowitz AJ, Kuipers BJ, Kassirer JP. Dealing with uncertainty, risks, and tradeoffs in clinical decisions. A cognitive science approach. *Ann Intern Med*. 1988;108: 435–449.
17. Gillespie M, Peterson BL. Helping novice nurses make effective clinical decisions: the situated clinical decision-making framework. *Nurs Educ Perspect*. 2009;30: 164–170.
18. Goertz CM, Salsbury SA, Vining RD, et al. Collaborative care for older adults with low back pain by family medicine physicians and doctors of chiropractic (COCOA): study protocol for a randomized controlled trial. *Trials*. 2013;14:18.
19. O'Neill ES, Dluhy NM, Chin E. Modelling novice clinical reasoning for a computerized decision support system. *J Adv Nurs*. 2005;49:68–77.
20. Arocha JF, Wang D, Patel VL. Identifying reasoning strategies in medical decision making: a methodological guide. *J Biomed Inform*. 2005;38:154–171.
21. Murphy DR, Hurwitz EL, Nelson CF. A diagnosis-based clinical decision rule for spinal pain part 2: review of the literature. *Chiropr Osteopat*. 2008;16:7.
22. Murphy DR, Hurwitz EL. A theoretical model for the development of a diagnosis-based clinical decision rule for the management of patients with spinal pain. *BMC Musculoskelet Disord*. 2007;8:75.
23. Murphy DR, Hurwitz EL. Application of a diagnosis-based clinical decision guide in patients with low back pain. *Chiropr Man Therap*. 2011;19:26.
24. Globe GA, Morris CE, Whalen WM, Farabaugh RJ, Hawk C. Chiropractic management of low back disorders: report from a consensus process. *J Manipulative Physiol Ther*. 2008;31:651–658.
25. Hawk C, Schneider M, Dougherty P, Gleberzon BJ, Killinger LZ. Best practices recommendations for chiropractic care for older adults: results of a consensus process. *J Manipulative Physiol Ther*. 2010;33:464–473.
26. Tarride JE, Hopkins RB, Leslie WD, et al. The burden of illness of osteoporosis in Canada. *Osteoporos Int*. 2012;23:2591–2600.
27. Cauley JA. Public health impact of osteoporosis. *J Gerontol A Biol Sci Med Sci*. 2013;68:1243–1251.
28. Hernlund E, Svedbom A, Ivergard M, et al. Osteoporosis in the European Union: medical management, epidemiology and economic burden. A report prepared in collaboration with the International Osteoporosis Foundation (IOF) and the European Federation of Pharmaceutical Industry Associations (EFPIA). *Arch Osteoporos*. 2013;8:136.
29. Jarvinen TL, Michaelsson K, Aspenberg P, Sievanen H. Osteoporosis: the emperor has no clothes. *J Intern Med*. 2015;277:662–673.
30. Desjardins B, Dill KE, Flamm SD, et al. ACR Appropriateness Criteria(R) pulsatile abdominal mass, suspected abdominal aortic aneurysm. *Int J Cardiovasc Imaging,* 2013;29:177–183.
31. Keisler B, Carter C. Abdominal aortic aneurysm. *Am Fam Physician*. 2015;91:538–543.
32. Hom J, Smith CD, Ahuja N, Wintermark M. Radiology support, communication, and alignment network: imaging for low back pain. *J Am Coll Radiol*. 2016;13(11):1385–1386.e1.
33. Ha JF, Longnecker N. Doctor-patient communication: a review. *Ochsner J*. 2010;10:38–43.
34. Wallner LP, Hawley ST. Communicating disease-specific knowledge to patients: an overlooked aspect of personalized medicine. *J Oncol Pract*. 2016;12:497–498.
35. Vining R, Potocki E, McLean I, Seidman M, Morgenthal AP, Goertz C. Prevalence of radiographic findings in individuals with chronic low back pain screened for a randomized clinical trial: secondary analysis. *J Manipulative Physiol Ther*. 2014;37(9):678–687.
36. Beattie PF. Current understanding of lumbar intervertebral disc degeneration: a review with emphasis upon etiology, pathophysiology, and lumbar magnetic resonance imaging findings. *J Orthop Sports Phys Ther*. 2008;38:329–340.
37. Modic MT, Ross JS. Lumbar degenerative disk disease. *Radiology*. 2007;245:43–61.
38. Gunn AJ, Tuttle MC, Flores EJ, et al. Differing interpretations of report terminology between primary care physicians and radiologists. *J Am Coll Radiol*. 2016;13(12 Pt A):1525–1529.e1.