

Using Digital Health to Support Best Practices: Impact of MRI Ordering Guidelines Embedded Within an Electronic Referral Solution

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Abstract. *Background:* Between 2003 and 2012, the number of MRIs performed in Canada more than doubled to 1.7 million [1]. According to a 2010 Health Council of Canada report nearly 30% of MRIs were inappropriately ordered [2]. The use of diagnostic imaging referral guidelines has been shown to improve the appropriateness of imaging orders [3, 4].

Objectives: To identify the number of unnecessary pre-consult MRIs ordered for patients with knee pain. As well, the impact that new evidence-based clinical decision support (DS) guidelines embedded within the referral form has had on the number of unnecessary MRIs was investigated.

Methods: This study employed a retrospective design approach. Charts of all knee pain patients over the age of 55 who were referred for consultation to the 5 participating orthopedic surgeons during the study period were reviewed by three medical students.

Results: 270 patient charts were included in this study. MRI was ordered for 60 patients with only 56.7% having had a prior X-ray. Of the 60 ordered MRIs, 50 (84%) were considered inappropriate, while only 10 (16%) were appropriate. Our results were compared to previous results of a quality improvement study implemented at the same clinic. A substantial reduction of 12% in the number of pre-consult MRIs and a 5% increase in the number of ordered X-rays before consultation was demonstrated.

Conclusion: This work highlights the impact of including DS tools within an electronic referral form to support clinical best practices.

Keywords. Electronic referral (eReferral), enabling technology, decision support, diagnostic imaging, clinical value, benefits realization, best practices, digital health

1. Introduction

Between 2003 and 2012, the number of magnetic resonance images (MRI) performed in Canada doubled to 1.4 million per year [1, 5], and will continue to increase as the population ages [6]. According to a Health Council of Canada report, as many as 30% of MRIs were ordered unnecessarily in 2010 [7]. Research suggests that the percentage of

inappropriate imaging referrals ranges extensively from 1% to 88% [4, 8-13], however, there is a lack of research within the Canadian context to fully understand the prevalence locally. An orthopedic surgeon in Kitchener, Ontario, together with some colleagues, recently completed a quality improvement project by conducting a retrospective chart review on patients who were over 55 years of age and presented with knee pain. Many of these patients were referred by their family physician to have a knee MRI prior to seeing the orthopedic surgeon for a consultation. When reviewing the charts for those patients who had a pre-consult MRI prior to the orthopedic consult, the surgeons determined that 78% of the MRIs were unnecessary, and in 73% of the cases a diagnosis would have been possible with only an x-ray (results not published).

Supporting clinical best practices through the implementation of a clinical decision support (DS) tool is sought to reduce the escalating orders of unnecessary diagnostic imaging [14]. The implementation of a DS tool at the point of order has been shown to reduce the total number of MRI and computed tomography (CT) imaging examinations by as much as 36% [3, 15-17]. One study that measured the proportion of inappropriate examinations before and after implementation of the DS by using a chart review found that in addition to a reduction in the total number of MRI and CTs ordered, there was a 50% reduction in the proportion that was deemed inappropriate [13]. This research substantiates the assumption that DS not only impacts the number of imaging orders, but also the level of inappropriate orders.

The System Coordinated Access program (SCA), funded by the Ministry of Health and Long-Term Care and housed at the eHealth Centre of Excellence (eCE) in Waterloo, Ontario, is supporting the development and deployment of an electronic referral (eReferral) solution across five Local Health Integrated Networks (LHINs) in Ontario. Waterloo Wellington LHIN (WWLHIN) was the first to go live with the eReferral solution for orthopedic referrals in August 2017. At the same time, the Joint Department of Medical Imaging (JDMI) at the University Hospital Network in Toronto, Ontario, were pursuing the development of clinically validated guidelines for diagnostic imaging requests. These guidelines are based on the area of injury and provide clear direction on the imaging that should and should not be requested, as well as non-imaging options for care.

The SCA and JDMI teams have worked collaboratively to leverage the eReferral solution as a tool for knowledge translation of the newly developed imaging guidelines. These guidelines have been used to establish appropriate phrasing that is integrated into the eReferral form to support referring physicians with diagnostic imaging decision making (Figure 1). The main objective of this retrospective chart review was to assess the impact of the DS language embedded within the orthopedic form on the number of pre-consult MRIs ordered for knee pain patients 55 years of age and older referred to a local orthopedic clinic, and the proportion of those MRIs that are deemed as clinically unnecessary. Results were also compared to those of the previous QI study conducted through the same Orthopedic Clinic. The results of this study are highly relevant to the provincial efforts to address the problem of unnecessary ordering of MRI that when controlled will impact the wait times for imaging services and reduce costs associated with performing unnecessary tests.

DIAGNOSIS: <input type="checkbox"/> Hip Right / Left <input type="checkbox"/> Knee Right / Left <input type="checkbox"/> Osteoarthritis <input type="checkbox"/> Inflammatory arthritis <input type="checkbox"/> Fracture <input type="checkbox"/> Post-traumatic arthritis <input type="checkbox"/> Failed hip or knee replacement <input type="checkbox"/> Joint derangement not yet diagnosed <input type="checkbox"/> Other:	REASON FOR REFERRAL: <input type="checkbox"/> Primary Replacement: <input type="checkbox"/> Hip <input type="checkbox"/> Knee <input type="checkbox"/> Opinion on <u>prior</u> replacement: <input type="checkbox"/> Hip <input type="checkbox"/> Knee <input type="checkbox"/> Opinion/management advice: <input type="checkbox"/> Hip <input type="checkbox"/> Knee URGENCY: <input type="checkbox"/> Routine <input type="checkbox"/> Urgent
X-RAY REPORTS OF THE AFFECTED JOINT MUST ACCOMPANY REFERRAL If no X-ray report is available from within the last 6 months, we recommend the following views: Knee: AP weight bearing, lateral of knee flexed at 30°, skyline Hip: AP pelvis, AP and lateral of affected hip Patients are required to bring their X-Rays to their appointment. In the setting of osteoarthritis, MRI is not usually further contributory and is not recommended.	

Figure 1. eReferral form with embedded DS language for DI ordering at point of referral.

2. Methodology

A convenience sample of 5 orthopedic surgeons was recruited for this study. All orthopedic surgeons were accepting faxed referrals directly from providers, and referrals (electronic and fax) processed through an Orthopedic Central Intake. The surgeons provided a list of all patients who attended an orthopedic consult with them between October 2017 and May 2018. The electronic medical charts for this patient list were reviewed by three medical students, and only those who met the inclusion criteria (>55-year-old patient referred for knee pain) were included in the study. Data was extracted from the referral letters that PCPs sent to specialists as well as from the clinic’s electronic medical records database. Data collected included the date of referral, date of consult, age, gender, diagnosis, intensity of pain, duration of adherence to pain management, X-ray ordered, number of MRIs requested pre or post consult, and post-consult disposition. A sample of 10 reviewed charts were assessed prior to the data collection to measure the inter-rater level of agreement among the trained medical students regarding the decision on the appropriateness of the MRI ordered. The trained medical students provided the final decision on the necessity of MRI ordering for patients prior to the consultation under the supervision of the orthopedic resident and with the consultation of one of the participating orthopedic surgeons when needed. The medical students followed a decision algorithm previously developed by the orthopedic specialists involved in the QI study.

3. Analysis

To maintain confidentiality, participants were de-identified and assigned unique numbers. Data was analyzed using the Statistical Package for Social Sciences (SPSS) (SPSS; IBM Corp, Armonk, NY. Version 24; 2018). Descriptive analyses were conducted. Summary statistics including means and standard deviations for continuous variables and frequency distributions for categorical variables, were used to describe the sample. Fleiss Kappa test was used to determine if there was agreement between the reviewers’ decision on whether the MRI ordered prior to consultation with orthopedic surgeon was appropriate. Fischer Exact and Chi-square tests were used to examine the association between categorical variables based on MRI ordering and appropriateness. Independent student t-Test was used to determine if a difference exists between the means of two MRI groups (appropriate vs inappropriate and MRI vs. no MRI) on a continuous dependent variable. A p-value <0.05 was considered statistically significant.

4. Results

4.1. Patient Characteristics

Table 1. Patient characteristics. Different letters between groups = Significant difference ($P < 0.05$); same letters between group means = Non-significant difference ($P \geq 0.05$). *P-value < 0.05 was considered statistically significant

Characteristics of patients	Overall (N=270)	MRI appropriate (N=10)	MRI Inappropriate (N=50)	Total MRI (n=60)	No MRI (n=210)	P value (MRI vs. No MRI)
Age years Mean (SD)	68.4 (\pm 9.2)	59.7 (\pm 4.4)	64.1 (\pm 8.0)	63.4 (\pm 7.7)	68.8 (\pm 9.1)	P=0.000*
Gender n (%) Females	165 (61.1)	4 (40)	24 (48)	28 (46.7)	137 (65.2)	P=0.009*
Severity of Pain n (%) Mild Moderate Severe N/A	7 (2.5) 38 (14.1) 32 (11.9) 193 (71.5)	- 2 (20) - 8 (80)	1 (2) 6 (12) 4 (8) 39 (78)	1 (1.7) 8 (13.3) 4 (6.7) 47 (78.3)	4 (1.9) 32 (15.4) 28 (13.4) 145 (69.3)	P=0.387
Duration of adherence to management n (%) Acute None 3-6 months 6-12 months 12+ months Unknown N/A	6 (2.2) 1 (0.4) 7 (2.6) 8 (3.0) 22 (8.1) 23 (8.5) 203 (75.2)	1 (10) 1 (10) - 1 (10) - - 7 (70)	1 (2) - 2 (4) 2 (4) 3 (6) 1 (2) 41 (82)	2 (3.3) 1 (1.7) 2 (3.3) 3 (5.0) 3 (5.0) 1 (1.7) 48 (80)	4 (1.9) - 5 (2.4) 5 (2.4) 19 (9.0) 22 (10.5) 155 (73.8)	
X-ray ordered n (%) No Yes Yes-prior to MRI Yes- Post MRI Yes- At consult Unknown	22 (8.1) 204 (75.5) 34 (12.6) 7 (2.6) 1 (0.4) 2 (0.8)	3 (30.0) - 6 (60.0) 1 (10.0) - -	15 (30.0) 1 (2.0) 28 (56.0) 6 (12.0) - -	18 (30.0) 1 (1.7) 34 (56.6) 7 (11.7) - -	4 (1.9) 203 (96.7) - - 1 (0.5) 2 (1.0)	
Post-consult disposition Conservative treatment Arthroplasty Arthroscopy	142 (53.0) 118 (44.0) 8 (3.0)	6 (60) - 4 (40)	35 (70) 14 (28) 35 (70)	41 (68.3) 14 (23.3) ^a 5 (8.3) ^a	101 (48.5) ^b 104 (50.0) ^b 3 (1.5) ^b	P=0.000*
Wait time Mean (SD) days	181.9 (\pm 143.5)	251.5 (\pm 143.5)	175.4 (\pm 110.8)	185.61 (\pm 114.5)	181.08 (\pm 151.1)	P=0.852

Charts of 437 patients with knee pain were retrospectively reviewed, and 167 were excluded as they did not meet the inclusion criteria. A total of 270 patient charts were included in the analysis. Table 1 presents the demographic and clinical characteristics of the sample and the appropriateness of MRI ordering. The mean age of patients was 68.5 (\pm 9.26) years. There were 165 (61.1%) females and 105 (38.9%) males. The severity of

pain was only reported for 77 knee patients in the charts, and of those, patients reported pain severity as follows: 41.6% severe pain, 49.4% moderate pain, and 9% mild pain. The most common diagnosis of the knee pain was osteoarthritis (82.8%). Other diagnoses included tears, injuries, degenerative changes, baker’s cyst, fractures, or a combination of these. The post- consult disposition for most patients was conservative treatment (53.0%), followed by arthroplasty (44.0%).

A total of 60 (22%) knee pain patients were ordered a pre-consult MRI. Mean age of patients with ordered MRI was 63.4 (\pm 7.70) years, while the mean age for those with no ordered MRI was 68.8 (\pm 9.19) years. A statistical significant difference was detected between both groups ($p=0.000$). In the pre-consult MRI group, 53.3% were male while in the non-ordered MRI group 34.1% were males. A statistically significant difference related to gender was detected between both groups ($p=0.009$). Regarding the post consultation disposition, 68.3% of patients who received MRI prior to consultation were considered for conservative treatment (non-surgical), while 50% of patients who were not ordered MRI prior to consultation were considered for arthroplasty (surgical). Significant differences were detected between both groups regarding each post-consult disposition ($p<0.001$). Of the 270 charts, 140 patients were referred to the orthopedic clinic after the eReferral system went live. Of those, 52 were referred using the new form which included the imaging DS guidelines, either through the electronic referral form or fax.

4.2. Incidence and appropriateness of MRI ordering

Pre-consult MRIs were ordered for 60 of the patients included in this study. Of those, 56.7% had X-ray ordered prior to the MRI, 11.7% had X-ray following the MRI, and 30% did not have any X-ray requested prior to consultation. Fleiss Kappa test results showed a moderate agreement between reviewers on the decision of appropriateness of MRI ordering prior to consultation, $K=0.583$, (95% CI, 0.225 to 0.941), $p=0.001$. Of the 60 ordered MRIs, 50 (84%) were considered inappropriate, while only 10 (16%) were appropriate.

4.3. Comparison with quality improvement study

Table 2. Comparison of results of DI study and Quality Control study

	DI appropriateness study (October 2017 -May 2018)	Quality study (Oct 2015-Oct 2016)
	270 charts	650 charts
Demographics		
Mean age	68.5 y	67.8 y
Gender		
Females	61%	57%
Males	39%	43%
Pre-consult MRI	60 (22%)	221 (34%)
X-ray ordered pre-MRI	57%	52%
Inappropriate MRI	84%	77%

This study builds on the QI study conducted by the orthopedic clinic to assess the number and appropriateness of pre-consult MRIs ordered for knee pain patients \geq 55 years referred to the same clinic during the study period Oct 2015- Oct 2016. Table 2 summarizes the comparison of results between both studies.

5. Discussion

This current study was one of the first to explore the effect of DS embedded within an orthopedic referral form on the number of pre-consult MRI scans ordered for knee pain patients > 55 years of age. It also assessed the proportion of those MRIs that are considered clinically inappropriate. Moreover, this study compared its findings to an earlier QI retrospective chart review study (unpublished data) conducted at the same clinic.

The proportion of cases diagnosed with osteoarthritis in the older patients presented with knee pain in this study (84%) is consistent with the estimated prevalence of OA (60-80%) reported in other studies [18]. Similar to the literature,[19] more than half of patients in our sample (61%) who suffered the burden of knee pain were females.

A pre-consult MRI was ordered for 22% of the patients in this study; of those, the majority were deemed clinically unnecessary (84%). Of the patients who were ordered knee MRI before consultation, only about half of the patients had an x-ray ordered prior to the MRI. This finding is in concurrence with Petron and colleagues who reported that only 44% of patients in their case-control study received a radiograph prior to the pre-consult MRI [12]. This is expected given the shift in the PCPs recent approach of overusing MRI and underusing X-ray when assessing knee pain patients. Evidence shows that PCPs tend to order a high number of MRIs [12]. This is common practice even though MRI findings in older patients with knee pain are more sensitive to detect knee pathology rather than clinical knee lesions [12], which does not necessarily explain the cause of pain [20], and can confound the diagnosis, the surgical decision, and the treatment plan [12, 21]. This low diagnostic efficacy of MRIs ordered for knee pain patients > 55 years of age further emphasizes the importance of embedding the guideline tool within the referral form to assist PCPs with their imaging order decisions. The DS guidelines from the JDAMI group and embedded in the orthopedic referral form are reflective of evidence and do not recommend MRIs where degenerative changes are known or suspected. In these patients, radiographs are not required to make a diagnosis.

Interestingly, a significant variation in the post-consult disposition was detected among patients with pre-consult MRI vs. those with no MRI. The proportion of conservative treatment as post-consult disposition was higher among patients with a pre-consult MRI (68%). Conversely, the surgical decision (arthroplasty or arthroscopy) was lower for patients with pre-consult MRI (32%). These findings are mostly consistent with previous research that concluded MRIs ordered by PCPs before consultation were significantly less likely to result in a subsequent surgical decision compared to the MRI ordered by orthopedic surgeon [22]. This variation in the surgical decision even with the presence of the MRI findings could be related to the number of radiographs ordered for patients. In our study population, the lack of radiological evidence of the severity and extent of arthritis in 30% of patients who were ordered MRI prior to the orthopedic consultation may have influenced the surgical decision, consistent with other research that found MRI of degenerative changes of the knee in older patients would do little to influence orthopedic surgeons to modify or change their surgical management decisions [12] compared to the radiographic evidence [23].

This study demonstrated a trend favoring a higher probability that the embedded diagnostic imaging guidelines in the referral form positively impact the ordering of pre-consult MRIs. Overall 25% of patients in our study had been referred for an MRI scan; 4% were deemed necessary, while 21% were considered unnecessary MRI scans performed before their orthopedic consultation, and 30% of these scans were not

preceded by an x-ray. The study didn't demonstrate a statistical significance though between the clinically necessary vs unnecessary MRI scans ordered pre-consultation. However, when compared to the existing QI study results, our findings showed a reduction of 12% in the proportion of overall pre-consult MRIs ordered as well as an increase of approximately 5% of x-rays requested prior to MRIs. The lack of detection of any significance difference regarding the appropriateness of MRI scans in relation to the use of the DS language could partly be due to the moderate exposure of PCPs to the DS language embedded in the referral form. PCPs may require a longer time of exposure to the DS language to become accustomed to applying the guidelines within their daily practice. Approximately half of the sample (52%) were initially referred to the orthopedic surgeons after the electronic system went live and of those only 37% were introduced to the DS language embedded in the referral form. Also, the limited sample of pre-consult MRI might have affected the statistical power and the ability to detect a significant difference related to the appropriateness of the MRI scans. However, this finding highlights the potential benefits of applying the guidelines in practice, especially if circulated at a larger scale.

It is important to note the other factors that might contribute to the unnecessary diagnostic imaging, which could also affect the adoption of the DS tool. For many primary healthcare providers, MRI is considered as the customary path to referring patients for orthopedic consultation [23]. Patients' expectations, long wait-time for an orthopedic consult together with the general perception of diagnostic imaging as a method to rule out diseases are all important indicators [14]. Therefore, it is valuable to consider these factors while assessing the adoption of the DS tools in practice. Further studies are required to thoroughly investigate the impact of these factors on applying DS in practice.

6. Limitations

This study is retrospective in nature; thus, its findings are exploratory and preliminary. Moreover, the study was limited to patients referred to only one orthopedic clinic within southwest Ontario, making it difficult to generalize findings to different settings and contexts. The strengths of this study lie in its relatively large sample of patients within this setting and that the characteristics of the sample was broadly comparable to the literature. Our results demonstrate positive tendencies but failed to show statistically significant differences. The study results are supported by findings of previously published studies.

Pre-consult MRIs were the focus of this study. It would be useful to investigate the level of appropriateness of post-consult MRI scans in relation to the new embedded DI guidelines in future studies. Also, the study did not assess other factors that might affect the integration of the DS language into practice, such as the effect of patients' expectation, and long-wait times. However, our findings can serve as a baseline for future studies that address these points.

7. Conclusion

DS language embedded within the electronic referral form has the potential to reduce the number of unnecessary MRIs ordered for orthopedic patients. We demonstrated that the

number of MRI scans ordered prior to consultation has decreased and the number of x-rays has increased compared to patients referred to the same clinic prior the integration of the DS language in the referral form. This impact could be increased with wider adoption of the guidelines. Larger-scale studies are needed to explore this potential further.

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