Appropriateness of Spinal Imaging Use in Canada

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EXECUTIVE SUMMARY

Overview

Diagnostic imaging is an essential component of Canadian healthcare which contributes enormously to patient management. Common forms of imaging currently include magnetic resonance imaging (MRI), computed tomography (CT), and plain x-rays. Costs of diagnostic imaging in Canada have increased rapidly in the last 2 decades, and given fiscal pressures facing the Canadian government there is a pressing need to find efficiencies in the use of diagnostic imaging technology. It is estimated that 50–80% of the adult population will experience spine related complaints (e.g., low back pain) in their lifetime, and imaging of the lumbar spine accounts for approximately one-third of all MRI procedures in some Canadian provinces.

Key Findings

Systematic Review of the Literature

There are 22 studies that have explored appropriateness of spine-related imaging, and all have found some inappropriate use. The rate of inappropriate imaging varies considerably according to which criteria are used, and there appears to be little consensus on a common definition of appropriateness. 18 studies have explored interventions to improve appropriateness of spine-related imaging, and active decision aids appear more promising than passive dissemination of educational material. Patient-important outcomes are rarely considered in studies exploring appropriateness of imaging.

Survey of Canadian Spine Surgeons

Most Canadian spine surgeons (84%) require imaging studies to accompany all spine-related referrals. MRI is the most common form of imaging required, but there is tremendous variability in this area. Furthermore, even with imaging studies, 53% of surgeons refuse more than 20% of all referrals without a consultation, and less than 20% of patients who are assessed are surgical candidates. The current system of referring patients with spine-related complaints for surgical assessment in Canada appears to generate a substantial amount of unnecessary imaging.

Provincial Utilization Data

From 2001-2011, MRI spine utilization has increased markedly, but this has not reduced the use of spine x-ray or CT spine, and spine x-rays still currently account for nearly half (40%) of all spine imaging costs. Compared to Ontario, the increase in spine imaging expenditures in Manitoba has been disproportionate to the increase in the number of procedures performed because of increases in unit cost over the 10 year study period in Manitoba (i.e., fee schedule increases). Disparities in access to spinal imaging according to socioeconomic status were documented in both provinces. Improved health system coordination for patients with spinal complaints may help to improve efficiency of spine imaging use (e.g., diagnostic imaging pathways to reduce need for “lead up” testing with x-ray or CT spine before MRI; alternative and innovative models of care which provide standardized assessment of patients with low back pain could streamline referral of appropriate patients for advanced spine imaging and surgical consultation).

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Background

Diagnostic imaging is an essential component of Canadian healthcare which contributes enormously to patient management. Common forms of imaging currently include magnetic resonance imaging (MRI), computed tomography (CT), and plain x-rays. Advances in technology have allowed for earlier, less invasive and more accurate diagnosis of disease and have improved patient health outcomes in many cases. At the same time, the proliferation of advanced technology has led to substantial perceived need for these technologies, thereby increasing the utilization of imaging services. Increases in utilization of diagnostic imaging in Canada have far exceeded population growth; between 1993/1994 and 2003/2004 there was a 300% increase in the number of CT scans and a 600% increase in the number of MRI scans - more rapid growth than almost any other type of Canadian health service.[1] Imaging of the lumbar spine accounts for approximately one-third of all MRI procedures in some provinces, such as Alberta where 25,000 lumbar spine MRIs were done in the fiscal year 2009/2010.[2] It is not clear to what degree the increase in diagnostic imaging reflects optimal technology utilization.[1,3-6] It is possible that financial interests,[6,7] defensive medicine,[6] or consumer demand [8] may result in overutilization of imaging. A recent study led by one of us (YRR) studying Ontario patients with degenerative spine disease referred for surgical consultation found that 100% of CT scans and 60% of MRIs were unnecessary, resulting in an additional cost estimated at 24-million dollars/year.[9] Another recent study by another applicant (TEF) found that over half of lumbar spine MRIs in Edmonton and Ottawa were either inappropriate or of uncertain value.[10] International and intranational comparisons provide further evidence of possible overutilization. In 2004/05, Canada performed nearly four times the number of CT exams per capita and two times the number of MRI exams per capita than Sweden or the United Kingdom performed in 2002.[11,12] Furthermore, there is considerable regional variation in the use of diagnostic imaging in Ontario.[11]

Canada currently spends 10% of total outpatient expenditure on diagnostic imaging; the Ontario government's spending on operating costs for diagnostic services represented approximately 5% of total operating costs of the Ministry of Health and Long-Term Care (MOHLTC) in 2003/04.[13] The actual costs are higher if one also considers the capital costs of equipment and the costs of downstream tests and interventions due to imaging results.

To date, efforts to improve access to medical imaging have focused on increasing supply and the number of MRI scanners in Canada increased 14-fold from 19 in 1990 to 266 in 2009.[14] Simply increasing the number of scanners in Ontario, without instituting methods to encourage the appropriate use of imaging technology, has not resulted in proportionate reduction in wait-times [15] and may not be associated with improved health outcomes. Medicare enrollees in higher-spending regions in America receive more care than those in lower-spending regions, but do not have better health outcomes. [16,17] A subsequent analysis focusing specifically on Medicare expenditures for diagnostic imaging, controlling for differences in patient characteristics, found that greater spending for diagnostic imaging was not associated with improved survival.[18] Costs of diagnostic imaging in Canada have increased rapidly, and given fiscal pressures facing

the Canadian government there is a pressing need to find efficiencies in the use of diagnostic imaging technology.[19]

Limitations of Current Evidence

Regulatory guidelines for medical device manufacturers focus on safety, rather than on clinical effectiveness. Decisions to fund or adopt imaging devices are made by those paying for the technologies. Health technology assessment (HTA) attempts to provide analyses of costs and benefits of technology; [20] however, these assessments do not always follow an explicit, transparent or evidence-based process [13].

The Canadian Association of Radiologists (CAR) recently published its first edition of clinical practice guidelines for diagnostic imaging. This document stresses physician autonomy, stating that the guidelines are not intended as a means of restricting the physician's role in the process of decision-making for imaging study requests.[21] A 1-year pilot project was recently completed at the Children's Hospital in Winnipeg which implemented an order entry tool based on the CAR Guidelines in an effort to reduce inappropriate ordering of diagnostic imaging. The investigators reported "minimal changes in order practices". Specifically, only 2% of 8700 orders for medical imaging followed decision support advice (i.e., ordering physicians chose to override and ignore the advice for 98% of their imaging requests), and 11% of all imaging orders were clearly inappropriate according to the CAR Guidelines (Dr. Markus Faulhaber, personal communication). Feedback from physicians indicated that the CAR Guidelines were largely based on expert opinion and were overly generic, and that recommendations should be based on the best available evidence.

Filling the Knowledge Gap

We propose to systematically review the research literature to inform the appropriateness of diagnostic imaging utilization, with a specific focus on spinal imaging. Our systematic review will also capture all studies that have explored the appropriateness of Canadian utilization of spine-related imaging. We will conduct a descriptive analysis of the utilization of spine-related diagnostic services in Canada (specifically in Ontario and Manitoba) in order to quantify current use, explore factors that may be associated with different rates of utilization, and estimate associated costs of inappropriate utilization. After the grant was awarded, and in consultation with Manitoba Health, we also decided to conduct surveys of Canadian spine surgeons to explore the current efficiency of surgical assessment of LBP patients and patterns of imaging use.

Objectives

This Knowledge Synthesis project, funded by the Canadian Institutes of Health Research (CIHR), addressed the following questions:

1. What research is available to identify rates of non appropriate imaging ordering and utilization in the area of spine-related complaints?

   Areas of interest include understanding the extent of imaging prior to, or as a condition to being seen by specialists versus ordering after examination to determine a diagnoses or to confirm/plan interventions such as surgery (i.e. pre-op care).

   Specific imaging to be investigated includes MRI, CT, and X-rays.

2. Are there effective interventions to decrease the rate of inappropriate spine-related imaging?

Of particular interest to Manitoba Health:

* Identification of breadth of inappropriate imaging (focused on CT, MRI and X-ray interventions)

* Cost and impact of the issue

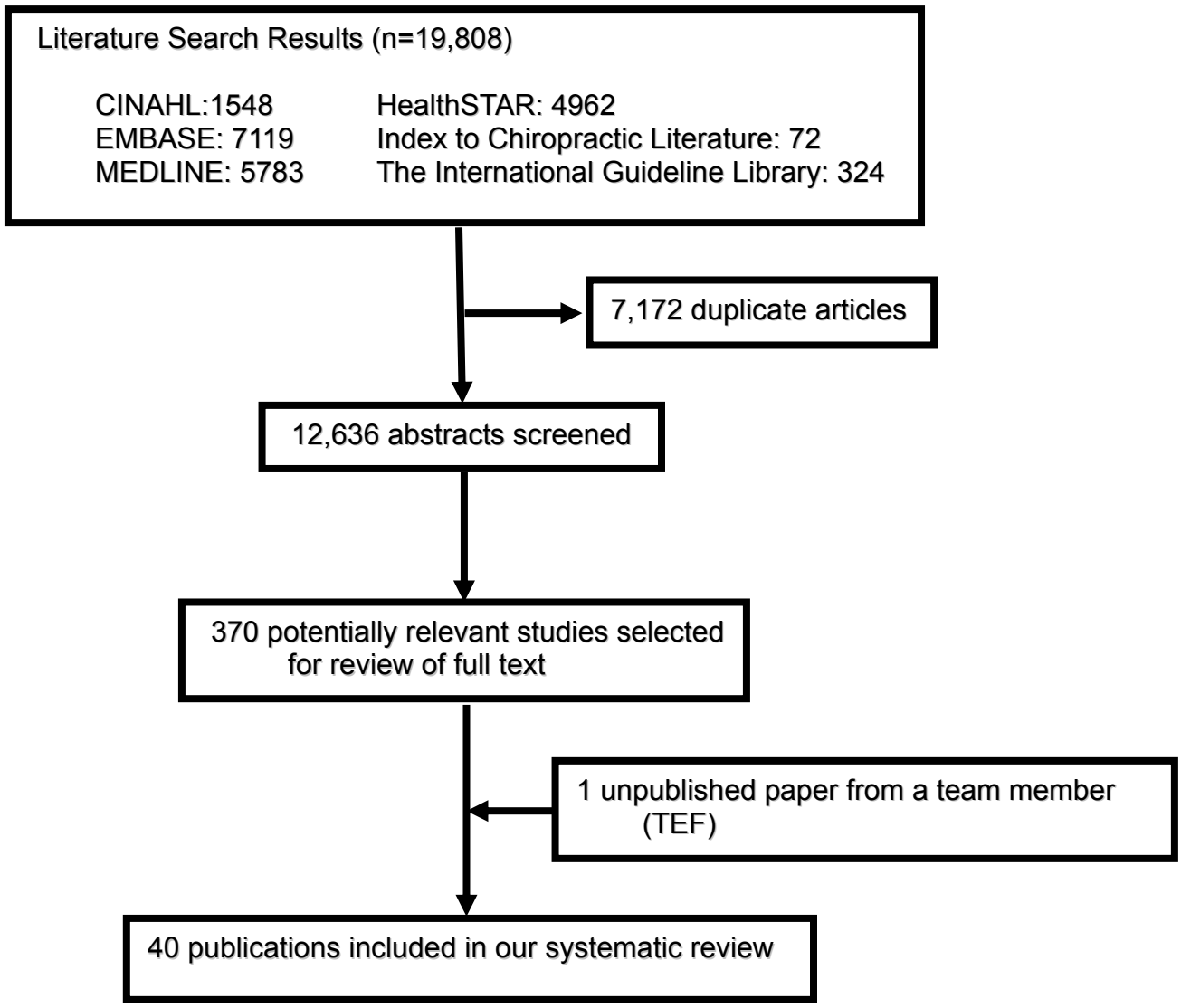
1. Literature review on spine imaging appropriateness

We used a highly sensitive search strategy to identify all publications on the topic of appropriateness of spine-related imaging indexed on any of 6 electronic databases (MEDLINE, HealthStar, EMBASE, CINAHL, Index to Chiropractic Literature, and The International Guideline Library). We searched all databases from inception to May 29, 2012.

Eligible studies met any 1 of the following criteria: (1) reports data on the proportion of spine-related imaging that was inappropriate; or (2) tests a strategy to improve the appropriateness of spine-related imaging

Of 12,636 unique citations, we reviewed 370 in full text and 39 provide eligible for our review. We located 1 unpublished study, resulting in 40 eligible studies for our systematic review (**Figure 1**).

Figure 1: Flow diagram of study selection



22 unique cohorts from 21 studies reported on the proportion of inappropriate spine-related imaging, involving populations from 7 different countries: [22-42]

- USA - 12 studies
- Canada - 2 studies
- Norway - 2 studies
- Australia - 2 studies
- UK - 1 study
- France - 1 study
- Finland - 1 study (reporting 2 cohorts)

The literature on appropriateness of spine-related imaging is challenging due to the application of multiple standards. There were 22 different appropriateness criteria reported in 21 studies, only 4 of which were reported in more than 1 study (see **Tables 1-3**). All studies agree that inappropriate imaging occurs, but the size of the problem depends on the criteria applied. For example, the study by Ammendolia et al. applied 3 different criteria to their patient population and concluded that the rate of inappropriate imaging could be as low as 13% to as high as 47% depending on the criteria that was applied.[42]

There is little consensus on a comprehensive definition for appropriateness of spine-related imaging. Existing guidelines and decision rules are based on ensuring close to 100% sensitivity for all and any “clinically significant lesions”. This permits ‘rules’ with very low specificity. In most cases, the association with measures of direct patient-importance is unknown.

There does appear to be broad consensus that imaging is inappropriate for uncomplicated LBP, of any duration, and this may be an important target for reduction of inappropriate imaging.

Table 1: Studies exploring the appropriateness of cervical spine imaging

Study	Country of Study	Population	Appropriateness criteria	Findings
Hoffman et al., 2000 [22]	USA	X-rays for acute, blunt neck trauma (n=34,069)	The National Emergency X-Radiography Utilization Study (NEXUS) criteria	12.7% of X-rays were inappropriate
Oikarinen et al., 2009[23]	Finland	CT scans of the neck (n=30)	Guidelines for imaging recommended by the European Commission	3% of CT scans were inappropriate
Moak et al., 2011 [24]	USA	Acute, blunt neck trauma patients (n=124)	NEXUS + dangerous mechanism of injury	7.4% of CT scans were inappropriate (9 of 122)
Griffith et al., 2011 [25]	USA	CT scans for acute, blunt neck trauma (n=1589)	The National Emergency X-Radiography Utilization Study (NEXUS) criteria	20% of CT scans were inappropriate
Kokabi et al., 2011 [26]	Australia	CT scans for acute, blunt neck trauma (n=106)	Goergen's criteria	53.8% of CT scans were inappropriate
Sheikh et al., 2012 [27]	USA	Acute, blunt neck trauma patients (n=1245)	American College of Radiology (ACR) Appropriateness criteria	100% of X-rays were inappropriate (433 of 433)

Table 2: Studies exploring the appropriateness of imaging for mixed axial complaints

Study	Country of Study	Population	Appropriateness criteria	Findings
Vosburgh & Kopta, 1994 [28]	USA	71 patients that underwent 90 MRI of the spine	Author-derived criteria	22% of MRIs were judged as inappropriate
Lehnert & Bree, 2010 [29]	USA	72 outpatients referred for MRI or CT of the spine by their PCP	Proprietary evidence-based appropriateness criteria used by a national RBM program (HealthHelp, Inc, Houston, Texas)	53% (9 of 17) CT scans, and 35% (19 of 55) MRIs were judged as inappropriate

RBM program – Radiology benefits management program

Table 3: Studies exploring the appropriateness of imaging for low back complaints

Study	Country of Study	Population	Appropriateness criteria	Findings
Tacci et al., 1999[30]	USA	Workers with acute, uncomplicated LBP (n=98)	The AHCPR Guidelines, and the American College of Occupational and Environmental Medicine Guidelines	All imaging was inappropriate: 64 x-rays 22 MRIs
Hush, 2008 [31]	Australia	Workers with non-specific low back pain (LBP) (n=401)	"Numerous clinical guidelines for LBP state that X-rays and other diagnostic scans are not indicated for injured workers presenting with non-specific LBP."	All imaging was inappropriate: 261 x-rays 285 CT scans 160 MRIs
Hourcade & Treves, 2002 [32]	France	LBP patients who underwent a CT scan (red flags, n=5; non-specific acute/subacute, n=24; non-specific CLBP, n=23; sciatica, n=80)	The guidelines of the National Agency for Accreditation and Health Evaluation (ANAES) and the Consensus Conference on the use of medical imagery in low back pain and sciatica	Proportion inappropriate: Red flags – 0% Acute/Sub – 96% CLBP – 100% Sciatica – 65%
Weiner et al., 2006[33]	USA	Chronic low back pain (LBP) (n=111; age≥65)	"Official guidelines that address when imaging studies should be ordered in patients with CLBP have not been established...Advanced imaging is typically not necessary"	61% of patients had undergone MRI, all of which were deemed inappropriate

Table 3 con't: Studies exploring the appropriateness of imaging for low back complaints

Study	Country of Study	Population	Appropriateness criteria	Findings
Boden & Swanson, 1998 [34]	USA	Low back pain (LBP) patients (n=110); 77 underwent a CT or MRI	Author-derived criteria (strict, moderate and lax)	Proportion inappropriate: Strict – 99% Moderate – 95% Lax – 73%
Schroth et al., 1992 [35]	USA	Acute LBP patients (n=183)	Informed by 2 prior publications	26% of plain films were inappropriate (10 of 38) 66% of CT and MRIs were inappropriate (12 of 18)
Rao et al., 2002[36]	USA	LBP patients presenting to PCPs (n=279); 141 were referred for MRI	The U.S. Agency for Health Care Policy and Research (AHCPR) guidelines	28% of MRIs were inappropriate
Oikarinen et al., 2009 [23]	Finland	CT scans of the low back (n=30)	Guidelines for imaging recommended by the European Commission	77% of CT scans were inappropriate
Emery et al., 2013[37]*	Canada	Patients referred for a low back MRI (n=500)	The RAND-UCLA appropriateness method, including a literature review, expert assessment and a chart review	56% of MRIs were inappropriate, and 29% were of uncertain value

* This study was unpublished at the time our search was conducted

Table 3 con't: Studies exploring the appropriateness of imaging for low back complaints

Study	Country of Study	Population	Appropriateness criteria	Findings
Deyo & Diehl, 1986[38]	USA	621 walk-in patients with low back pain (LBP); 311 had an x-ray	"A list of 11 clinical findings and other indications, any one of which should prompt early radiography, was developed from criteria proposed by others"	27% of x-rays were inappropriate
Halpin et al., 1991 [39]	United Kingdom	100 patients attending for plain films of their low back	The guidelines of the Royal College of Radiologists	52% of x-rays were inappropriate
Espeland et al., 1999 [40]	Norway	Low back pain (LBP) patients referred for plain films (n=323)	Norwegian and British recommendations for the use of radiography	Proportion inappropriate: Norwegian – 34% (42% uncertain) British – 46% (18% uncertain)
Espeland et al., 2001 [41]	Norway	LBP patients referred for plain films (n=99)	Norwegian and British recommendations for the use of radiography	Proportion inappropriate:* Norwegian – 71% British – 60%
Ammendolia et al., 2007[42]	Canada	Acute LBP (n=1241); 481 were referred for x-ray	The U.S. Agency for Health Care Policy and Research (AHCPR) guidelines A modified version of the AHCPR guidelines The radiography guidelines by Simmons et al	Proportion of Inappropriate x-rays: 22% - AHCPR 47% - mAHCPR 13% - Simmons

* Patients who received inappropriate plain films rated imaging as more important than those who received appropriate imaging

We identified 18 studies that have explored interventions to improve the appropriateness of imaging for spine-related complaints, involving populations from 6 different countries:[36, 43-59]

- USA - 8 studies
- UK - 6 studies
- Canadian - 1 study
- Australia - 1 study
- Ireland - 1 study
- Norway - 1 study

Passive interventions to modify imaging rates (distribution of educational materials, media campaigns), have shown inconsistent results. Interventions focussing on active decision aids appear more promising (see **Table 4**).

In general there is very little focus on patient-important outcomes, and as such the impact of reduced imaging on patients is uncertain. Both patient-factors (e.g. the desire for imaging) and clinician-factors (e.g. defensive medicine) may have to be considered to optimally reduce inappropriate spine-related imaging.

Table 4: Studies exploring interventions to improve the appropriateness of spine-related imaging

Study	Population	Intervention	Control	Findings
Baker, et al., 1987[43]*	ED patients referred for lumbosacral x-ray (US)	Standardized referral form	General requisition form	47% reduction in number of lumbosacral x-rays performed
Deyo, et al., 1987[44]	101 patients presenting to walk-in clinic with "low risk" low back pain (US)	Educational intervention + x-ray in 3 weeks if no improvement	Immediate x-ray	88% reduction in number of lumbosacral x-rays performed
Garala, et al., 1999 [45]	5 primary care practices (UK)	Primary care physician initiated quality improvement initiative + laminated guidelines sheet	Usual care	39% reduction in number of lumbosacral x-rays performed
Oakeshott, et al., 1994[46]	62 primary care practices including 170 primary care physicians (UK)	Passive dissemination of guidelines (mail)	Usual care	31% reduction in number of spine imaging tests
Solberg, et al., 2010 [47]	MRI spine requests from primary care physicians within a 600 physician multi-specialty medical group (US)	Computerized order entry and decision support (based on American College of Radiology guidelines)	Usual care	20% reduction in spine MRI use
Stevenson & Hay, 2004[48]	Patients with acute low back pain seen in primary care (UK)	Integrated care pathway for patients with acute low back pain in primary care	Usual care	29% reduction in lumbosacral x-ray use; 67% reduction in wait times (36 to 12 weeks) for spinal specialist consultation

* Baker et al. introduced their standardized forms in 1982. A 10-year follow-up study found a 28% reduction in lumbosacral x- rays from 1982 to 1992 (Gallagher & Trotsky, 1998)

Table 4 con't: Studies exploring interventions to improve the appropriateness of spine-related imaging

Study	Population	Intervention	Control	Findings
Werner, et al., 2009[49]	General public (2 intervention counties + 1 control county, Norway)	Media campaign	No media campaign	Inconclusive: major increase in MRI capacity in the control county during study period
Maurice, et al., 1996 [50]	Cervical spine x-ray referrals from ER (UK)	Introduction of guidelines	Usual care	47% reduction in number of cervical spine x-rays performed
Blackmore et al., 2011[51]	An integrated, multidisciplinary healthcare network (US)	Mandatory series of questions at the point of care in the imaging order system. Failure to document compliance with approved indications would prevent the online order from being activated.	Usual care	33% decrease in the utilization rate of lumbar MRI for low back pain (risk ratio, 0.77; 95% confidence interval, 0.87-0.67)
Adams & Adams, 2010 [52]	A University medical center (US)	Distribution of an algorithm for radiographic evaluation of post-CT cervical spines	Usual care	16% reduction in inappropriate plain films
Stiell et al., 2009[53]	11 824 patients with blunt trauma to the head or neck at one of 12 hospitals (Canada)	Active strategies to implement the Canadian C-Spine Rule, including education, policy, and real time reminders on radiology requisitions	Usual care	25% reduction in cervical spine x-rays

Table 4 con't: Studies exploring interventions to improve the appropriateness of spine-related imaging

Study	Population	Intervention	Control	Findings
Goergen et al., 2006 [54]	Patients with blunt cervical trauma presenting to 1 hospital (Australia)	Guideline dissemination and implementation with decision-support software	Usual care	7% reduction in cervical CT & x-rays; 4% increase in brain CT scans
Rao et al., 2002 [36]	Patients with LBP presenting to a university-affiliated Veterans Affairs medical center (US)	Dissemination of the 1994 Agency for Healthcare Policy and Research (AHCPR) LBP guidelines	Usual care prior to guideline release	No change in the proportion of patients who received an MRI
Klein et al., 2000[55]	LBP patients attending a multispecialty group practice (US)	Dissemination and education regarding LBP guidelines, and access to a rheumatologist for questions	Usual care	81% reduction in low back CT scans, 28% reduction in low back MRIs
Kerry et al., 2000[56]	69 primary care practices (UK)	Dissemination of the 1993 Royal College of Radiologists guidelines, and feedback on spine imaging referral rate	Usual care	20% reduction in requests for spinal examinations compared with control practices
Freeborn et al., 1997 [57]	67 general internal medicine physicians and 28 family practice physicians (US)	Dissemination of the 1994 AHCPR LBP guidelines, and feedback on referral practices for x-ray, CT scan and MRI of the lumbar spine	Usual care	No reduction in lumbar spine imaging referrals

Table 4 con't: Studies exploring interventions to improve the appropriateness of spine-related imaging

Study	Population	Intervention	Control	Findings
McNally et al., 1995[58]	15 875 patients attending the accident department over two years (UK)	Use of posters to display guidelines encouraging the more effective use of radiology in patients with neck injuries	No posters	No change in cervical spine x-ray referrals
Tracey et al., 1994[59]	322 patients with acute LBP presenting to a teaching hospital (Ireland)	Dissemination of guidelines, clinician education, and imaging referral forms that required endorsement that guideline criterion were met	Usual care	21% reduction in lumbar spine x-rays

CONCLUSIONS

All studies that have explored appropriateness of spine-related imaging have found some inappropriate use. The rate of inappropriate imaging varies considerably according to which criteria are used, and there appears to be little consensus on a common definition of appropriateness. Studies exploring interventions to improve appropriateness of spine-related imaging have generally shown a positive effect, but active decision aids appear more promising than passive dissemination of educational material. Patient-important outcomes are rarely considered in studies exploring appropriateness of imaging.

2. Surveys of Canadian Spine Surgeons

Survey 1

On January 6, 2012, we administered a 28-item survey to all 100 surgeon members of the Canadian Spine Society (CSS), with active surgical practices, to examine current practices for spine surgeons' assessment and management of low back or low back-related leg pain patients, and their attitudes towards the involvement of LBP clinicians (chiropractors & physical therapists) to screen such patients referred for surgical assessment.

Eighty-five surgeons provided a completed survey for a response rate of 85% (85 of 100). Most respondents were male (97.6%) and approximately half (48.2%) had been in practice for more than 20 years. The majority of respondents (69.4%) dedicated over half their practice to elective spine surgery, and reports of inefficiency were common (Table 1). Approximately a third of spine surgeons turned away more than 20% of low back or low back-related leg pain patients that were referred to their practice, wait times for patients to be seen that were accepted typically exceeded 6 months, and 89.4% (76 of 85) acknowledged that their outpatient waiting time was not optimal. Only 29.5% of respondents (25 of 85) reported that their screening efficiency for low back or low back-related leg pain patients was optimal, with 41.6% screening more than 10 patients to identify a single surgical candidate. Once a patient's complaint was identified as amenable to surgery, many respondents (43.5%) reported that patients waited >6 months for their procedure and only 16.5% of surgeons (14 of 85) characterized their surgical wait times as optimal.

Willingness to have LBP clinicians screen patients

Most spine surgeons (77.6%; 66 of 85) were either willing to work with LBP clinicians to screen their low back or low back-related leg pain patients (n=54) or were already doing so (n=12). Only 7 respondents (8.2%) were opposed to considering this arrangement, with 14.1% undecided.

Table 1: Practice characteristics (n=85)

Proportion of patients with a primary complaint of low back or low back-related leg pain, n (%)	
<20%	4 (4.7%)
21% to 40%	6 (7.1%)
41% to 60%	22 (25.9%)
61% to 80%	35 (41.2%)
>80%	18 (21.2%)
Proportion of practice spent on elective spine surgery	
<25%	6 (7.1%)
25% to 50%	20 (23.5%)
51% to 75%	29 (34.1%)
>75%	30 (35.3%)
Proportion of LBP patients referred to your practice, but not accepted	
0%	20 (23.5%)
1% to 5%	12 (14.1%)
6% to 10%	7 (8.2%)
11% to 15%	10 (11.8%)
16% to 20%	10 (11.8%)
>20%	26 (30.6%)
Outpatient wait time	
1 week to 1 month	2 (2.4%)
1 to 3 months	5 (5.9%)
3 to 6 months	31 (36.5%)
>6 months	47 (55.3%)
Number of LBP or low back-related leg pain patients screened to identify a surgical candidate †	
<5	15 (17.9%)
5 to 10	34 (40.5%)
11 to 20	27 (32.1%)
>20	8 (9.5%)
Surgical wait time	
1 week to 1 month	2 (2.4%)
1 to 3 months	21 (24.7%)
3 to 6 months	25 (29.4%)
>6 months	37 (43.5%)

† = one respondent did not provide an answer for this question

History and exam findings requiring surgical assessment

Our respondents largely endorsed four findings that would necessitate surgical assessment: signs or symptoms associated with a 'red flag' condition, leg dominant pain, and low back or low back-related leg pain that was consistent with either neurological findings or imaging results (**Table 2**). Each of these items were endorsed by greater than 85% of surgeons, and only 5 respondents suggested criteria other than what we provided for consideration.

A clear majority of surgeons advised they would want to confirm an indication for surgery themselves, whether the indication was clearly identified or suspected by a LBP clinician (88.2% and 89.4% respectively). However, a majority of respondents (75.3%, 64 of 85) also agreed they would be comfortable not assessing a low back or low back-related leg pain patient referred to their practice if clear indications for surgery were ruled out by a LBP clinician; 17.6% were unsure and 7.1% would still want to assess the patient themselves. Spine surgeons were divided as to whether their patients would expect to be seen by them after an assessment by a LBP clinician, with 40.0% (30 of 85) endorsing they would, 25.9% being undecided, and 34.1% disagreeing.

Table 2: History and exam findings requiring surgical assessment (n=85)

History or Exam Finding	Level of Endorsement, n (%)
Signs or symptoms associated with a 'red flag' condition †	80 (95.2%)
Leg dominant pain	77 (91.7%)
Low back or low back-related leg pain with correlating neurological findings	74 (88.1%)
Low back or low back-related leg pain with correlating findings on imaging	73 (86.9%)
The absence of 'yellow flags' ǂ	31 (36.9%)
Severe low back pain that is unresponsive to conservative care	26 (30.1%)

† Red flag conditions were defined as cauda equina syndrome, fracture, infection, or cancer

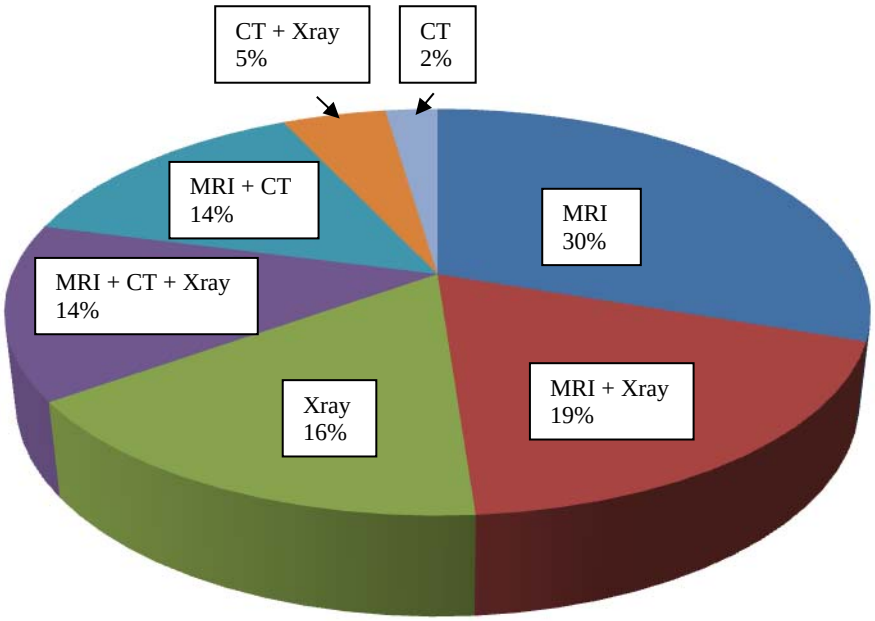
ǂ Yellow flags were defined as receipt of disability benefits, ongoing litigation, current smoker, or high emotional stress

Survey 2

On August 27, 2012, we administered an 8-item survey to all 100 surgeon members of the Canadian Spine Society (CSS), with active surgical practices, that inquired about demographic variables and imaging practices related to patients referred for spine-related complaints.

Fifty-five spine surgeons completed our survey, for a response rate of 55%. Most respondents were male (98.2%) and approximately half (45.5%) had been in practice for more than 20 years. Most respondents (65.4%) dedicated over half their practice to elective spine surgery. The majority of respondents (78.2%; 43 of 55) required imaging studies to accompany all spine-related referrals; the types of imaging studies required were highly variable, with respondents endorsing 7 different types of imaging or imaging combinations (**Figure 1**). Of the 11 surgeons that did not require imaging to accompany spine-related referrals, 4 indicated a preference for MRIs with referrals.

Figure 1: Combinations of imaging required for accepting a spine-related referral among respondents who indicated that they require imaging to accompany a new referral (n=43)



Written comments were provided by 23 respondents and the most common themes were contradictory: (1) imaging is an essential part of spine-related referrals, (2) better triaging of referrals can reduce unnecessary imaging, and (3) most spine-related referrals do not require imaging. For example:

"*MRI is the gold-standard for imaging of the spine. We went through this same debate for CT scans about 15 years ago. It is useless to resist. Patients want them. Referring physicians want them. Spine surgeons want them. It is only a matter of time before MRI will become the key to spine referrals anywhere it already hasn't. Regulating or restricting it only makes the system less efficient*"

"*We have a triage clinic now which doesn't require an MRI. Patients get a phone call from a spine nurse, and if potentially surgical, get an MRI… We phoned about 700 patients last year, and less than 10% were surgical*"

"*The vast majority of investigations are not indicated, or if indicated do not change management, resulting in inordinately long waiting times to obtain scan in those where they are indicated for management*"

CONCLUSIONS

Most Canadian spine surgeons (84%) require imaging studies to accompany all spine-related referrals. MRI is the most common form of imaging required, but there is tremendous variability in this area. Furthermore, even with imaging studies, 53% of surgeons refuse more than 20% of all referrals without a consultation, and less than 20% of patients who are assessed are surgical candidates. The current system of referring patients with spine-related complaints for surgical assessment in Canada appears to generate a substantial amount of unnecessary imaging. There may be an opportunity to engage LBP clinicians to provide standardized screening and triaging of LBP patients referred for surgical assessment to improve efficiency and reduce use of advanced imaging.

3. Provincial Spine Imaging Utilization Data

We conducted a retrospective study using health administrative databases to examine patterns of spinal imaging utilization in 2 Canadian provinces (Manitoba and Ontario) between April 1, 2001 to March 31, 2011.

The analyses were of 2 types: (i) population-based analyses of all claims for spinal imaging procedures of interest amongst adults (age 18 years or older) residing in these 2 provinces; and (ii) cohort-based analyses focused on patterns of health services use amongst specific subpopulations of individuals, e.g., examination of health services use amongst patients who receive an MRI spine procedure in a given fiscal year.
In Manitoba, we used physician claims data available through Manitoba Health to identify spinal imaging procedures, the fees paid for these procedures, and other related health services (e.g., spine surgery or spine surgery consultation). We used national census data to obtain data regarding patients' place of residence (e.g., urban vs rural) at the time a given spinal imaging procedure was performed and their neighbourhood income quintile.

In Ontario, we used health administrative database holdings at the Institute for Clinical Evaluative Sciences. Specifically, we used the Ontario Health Insurance Plan (OHIP) database to identify spinal imaging procedures, the fees paid for these procedures, and other related health services (e.g., spine surgery, spine surgery consultation). We used the Registered Persons Database (RPDB) and Statistics Canada census data to obtain data regarding patients' place of residence at the time a given spinal imaging procedure was performed and their neighbourhood income quintile.

Using the above data sources, we conducted the following population-based analyses in each province (Manitoba and Ontario) from fiscal years 2001/02 to 2010/11:

1. Annual number of spine imaging procedures (spine x-ray, CT spine, MRI spine)
2. Annual rates of spine imaging utilization per 100,000 individuals
3. Annual costs (fees paid) of spine imaging procedures
4. Regional variation in population rates of spine imaging procedures
5. Variation in population rates of spine imaging procedures by socioeconomic status (neighbourhood income quintile)
6. Annual rates of repeated testing (using 7 day, 30 day, 6 month, and 1 year observation periods)

Using the above data sources, we conducted the following cohort-based analyses:

1. Patterns of lead up testing prior to MRI spine
2. Patterns of lead up testing prior to CT spine
3. Patterns of lead up testing prior to spine surgery consultation
4. Frequency of spine surgery after advanced spinal imaging (CT or MRI)
5. Frequency of spinal imaging after spine surgery

Key Findings

- **Rates of MRI spine use increased markedly from 2001 to 2011**

In Manitoba, population rates (age- and sex-adjusted) of MRI spine scanning increased by 350% from 2001 to 2011 (233 vs. 1,040 MRI spine scans per 100,000 individuals in 2001 vs 2011). Changes in population rates of spine x-ray (3.0% increase) and CT spine (30% increase) were much less dramatic over the same 10 year study period (**Figure 1**).

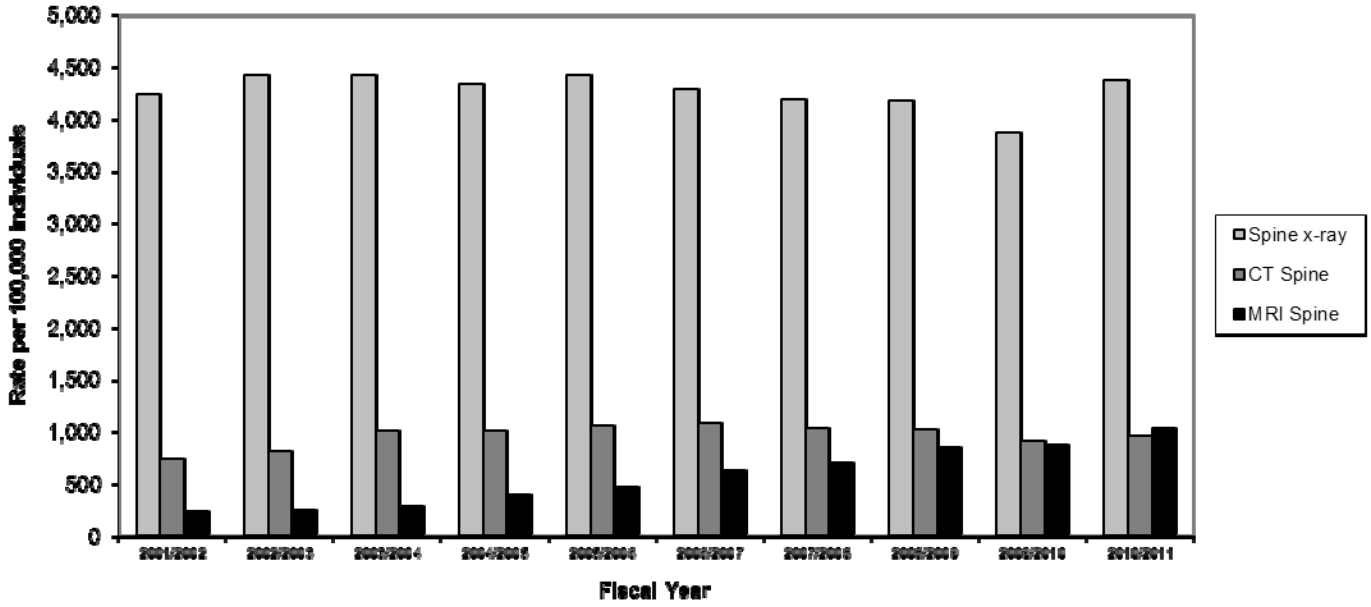


Figure 1. Spine Imaging Rates (age-, sex-adjusted), Manitoba, 2001-2011.

In Ontario, time trends were very similar, although in Ontario x-ray and CT rates saw a small decrease, rather than the small increase seen in Manitoba (**Figure 2**). Overall population rates of MRI spine use were similar in both provinces in 2010/2011 (approximately 1,000 per 100,000 individuals), but population rates of CT scanning were 61% higher in Manitoba compared to Ontario.

It is not possible to determine the appropriateness of testing at the individual patient level because physician claims data used for these analyses do not contain the clinical reason for the imaging request.

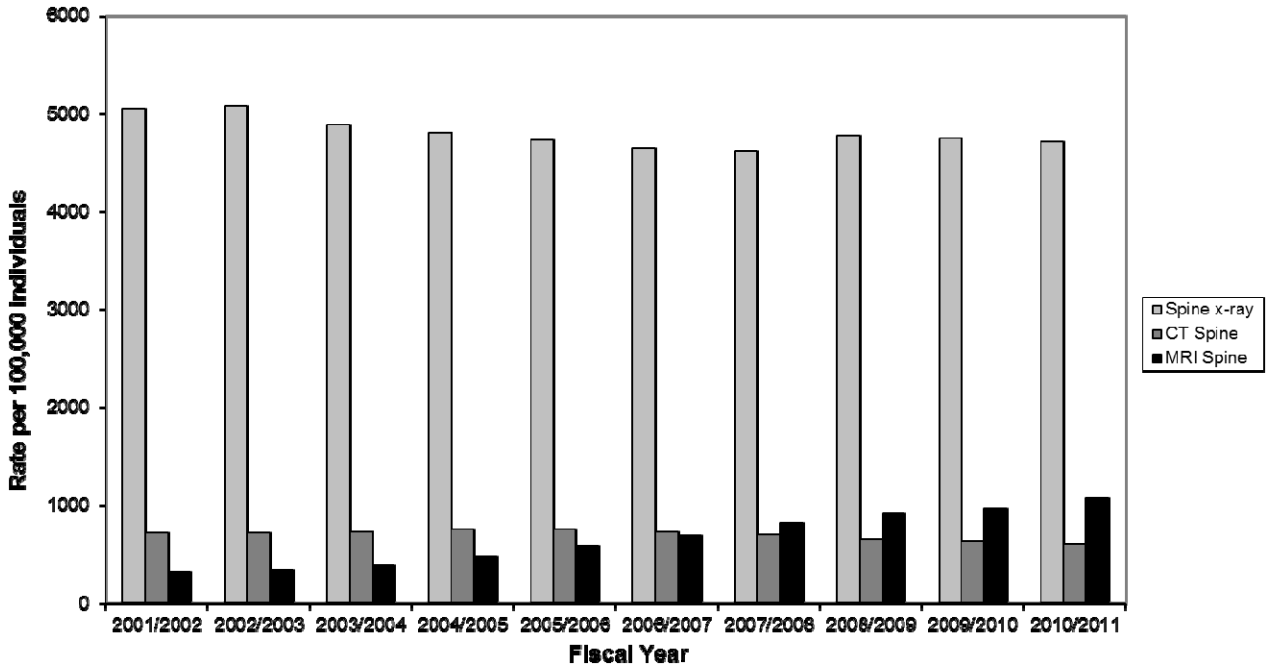


Figure 2. Spine Imaging Rates (age-, sex-adjusted), Ontario, 2001-2011.

- **Spine x-ray accounts for approximately half of spine-related imaging costs**

In Manitoba, the total cost of spinal imaging (x-ray, CT, MRI) was $2.2 million in 2001/2002. This increased to $5.0 million in 2010/2011, an increase of 127% over 10 years. Although spending increases were greatest for MRI spine over the 10 year study period, costs of spine x-ray were $2 million in 2010/2011, which still accounts for 40% of total spine imaging costs in Manitoba and is equal to the expenditures on MRI spine.

In Ontario, the total cost of spinal imaging (x-ray, CT, MRI) was $40.4 million in 2001/2002. This increased to $62.6 million in 2010/2011, an increase of 55% over 10 years. The costs of spine x-ray were $32.9 million in 2010/2011, accounting for 53% of total spine imaging costs in Ontario.

Compared to Ontario, the increase in spine imaging expenditures in Manitoba has been disproportionate to the increase in the number of procedures performed because of increases in unit cost over the 10 year study period in that province (i.e., fee schedule increases).

- **Differences in access to spinal imaging procedures according to socioeconomic status**

We observed differences in population rates of spinal imaging procedures according to socioeconomic status, both in Manitoba and Ontario.

In Manitoba, the effect of socioeconomic status on spinal imaging utilization was different in urban compared to rural areas. In urban areas, higher neighbourhood income was associated with higher rates of MRI utilization, but lower rates of x-ray or CT spine utilization. In rural areas, utilization of spinal imaging was greater (regardless of imaging modality) amongst individuals with higher socioeconomic status (**Figures 3, 4, 5).**

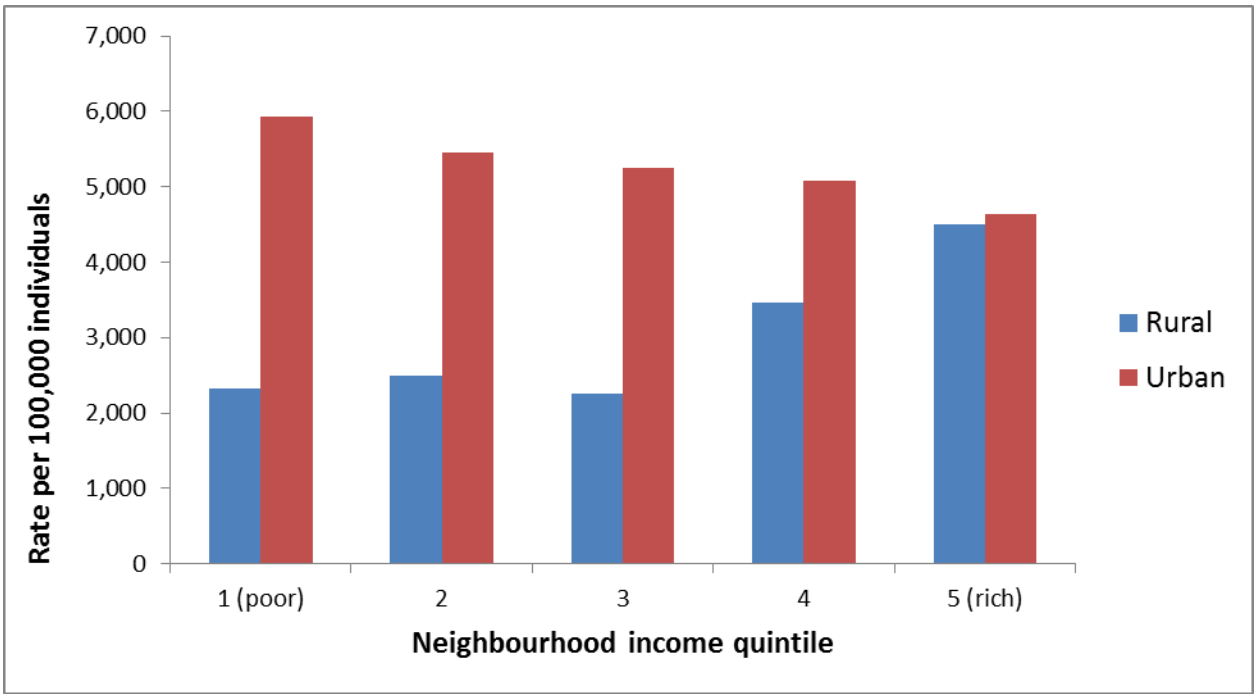


Figure 3. Spine x-ray use, by neighbourhood income, Manitoba (2010/11)

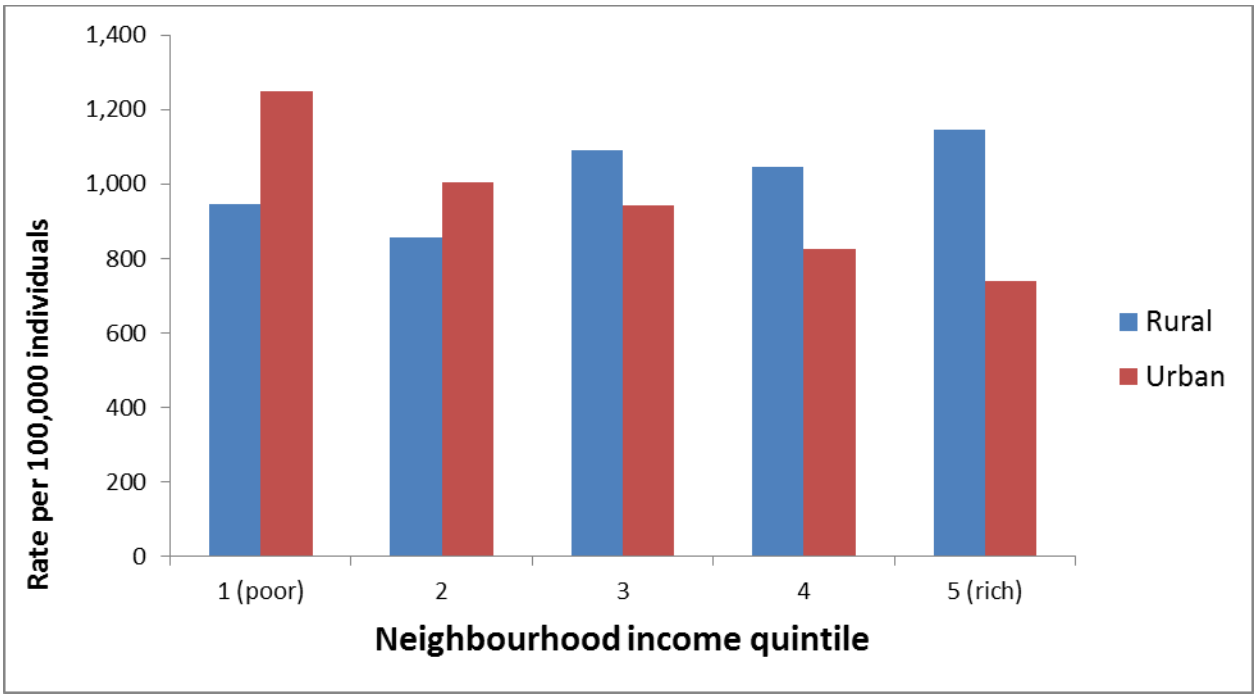


Figure 4. CT spine use by neighbourhood income, Manitoba (2010/11)

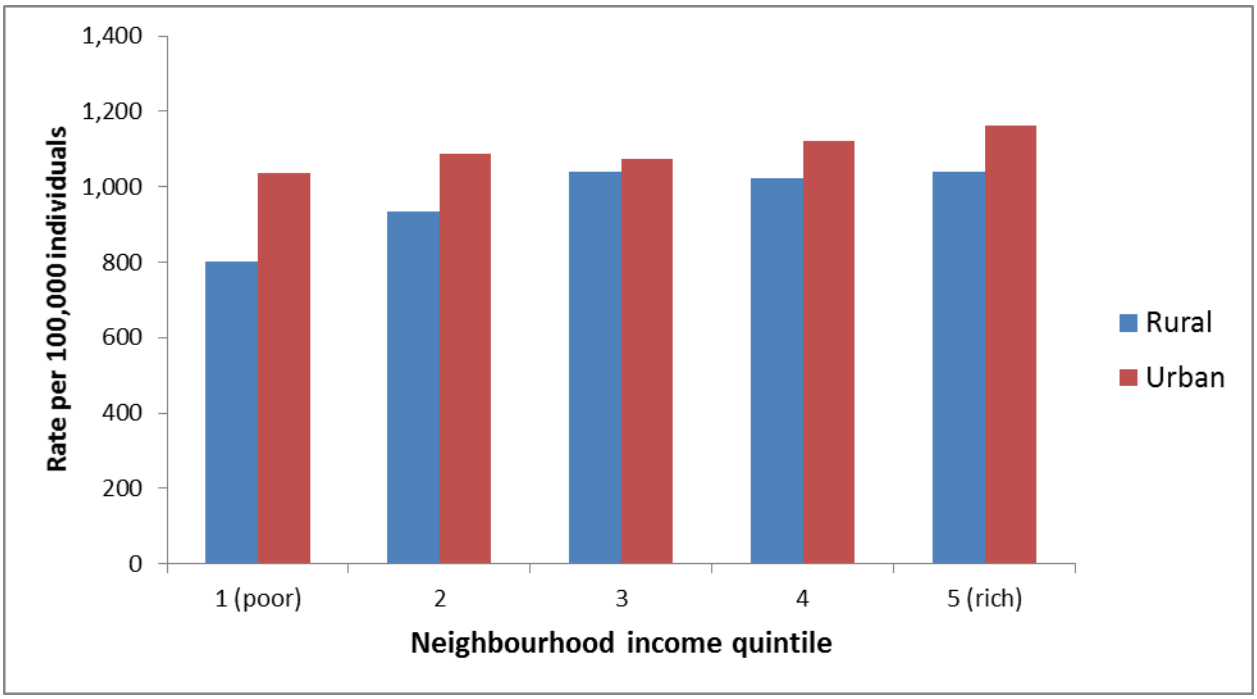


Figure 5. MRI spine use by neighbourhood income, Manitoba (2010/11)

In Ontario, there was somewhat greater use of MRI spine for individuals living in higher income neighbhourhoods, whereas rates of spine x-ray and CT spine utilization were lower. Rates of CT spine utilization were appreciably higher for individuals living in rural versus urban areas across all neighbhourhood income quintiles (**Figures 6, 7, 8).**

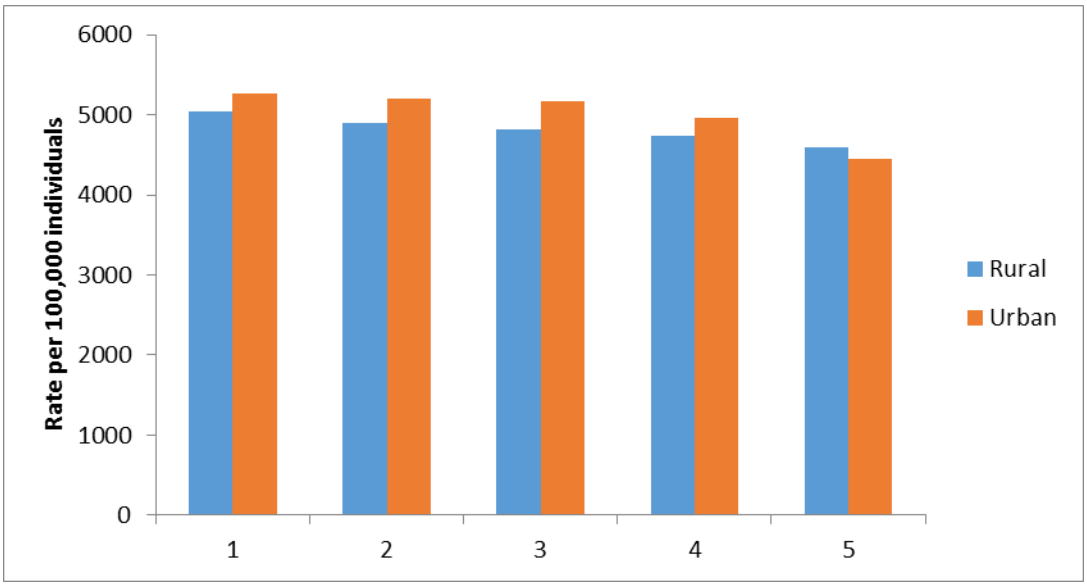


Figure 6. Spine x-ray use by neighbourhood income, Ontario (2010/11)

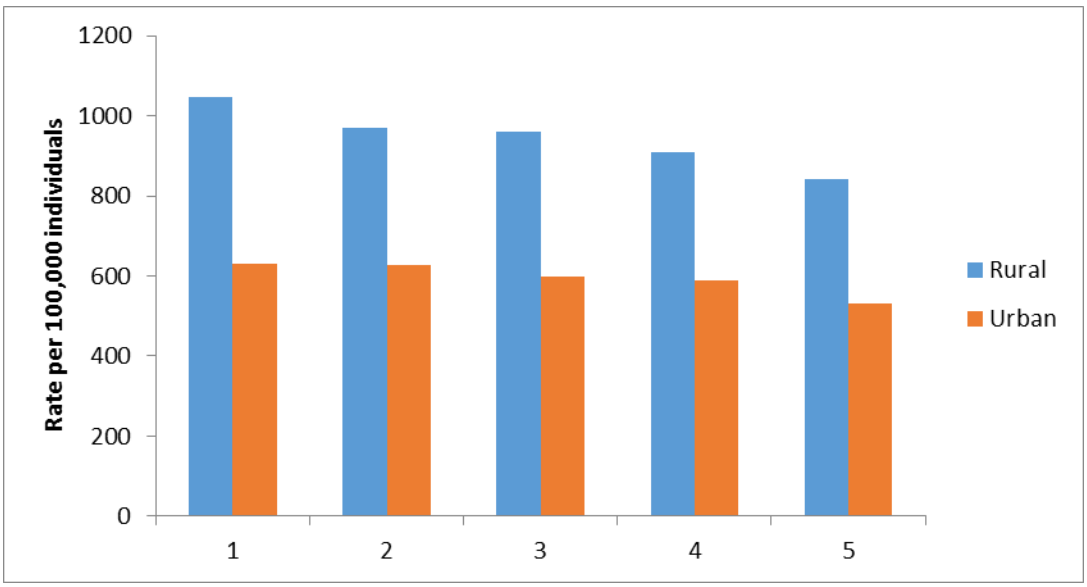


Figure 7. CT spine use by neighbourhood income, Ontario (2010/11)

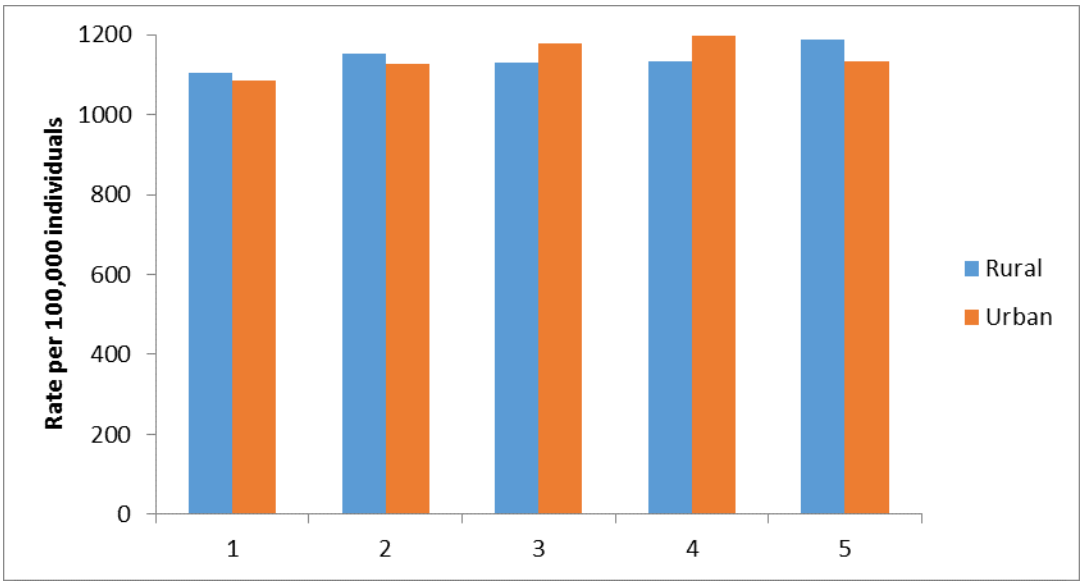


Figure 8. MRI spine use by neighbourhood income, Ontario (2010/11)

- **"Lead up" testing accounts for an important fraction of spine imaging**

In Manitoba, approximately half (45.7%) of all patients who received an MRI spine scan in 2009/2010 had received another type of spine imaging procedure (spine x-ray or CT spine) in the 1 year before their MRI scan. Similarly, approximately half (42.4%) of all patients who received a CT spine scan in 2009/2010 had received a spine x-ray in the 1 year before their CT scan. These "lead up" tests account for 14% of all CT spine procedures, and for as much as 16% of all spine x-rays performed in Manitoba in 2009/2010. The same patterns were observed in Ontario.

- **Most patients received advanced imaging (CT or MRI spine) before a spine surgery consult, but few patients receiving advanced imaging ultimately receive surgery**

In Manitoba, the majority (69%) of patients who saw a spine surgeon for a new consultation in 2009/2010 had received advanced imaging (CT or MRI spine) in the 2 years before the consultation. In contrast, for all patients receiving advanced imaging (CT or MRI spine) in 2005/2006, only 6.6% had undergone spine surgery by 2 years after the index imaging test (approximately 1 in every 15 patients scanned). The same patterns were observed in Ontario.

CONCLUSIONS

From 2001-2011, MRI spine utilization has increased markedly, but this has not reduced the use of spine x-ray or CT spine, and spine x-rays still currently account for nearly half (40%) of all spine imaging costs. “Lead up” testing prior to advanced spine imaging (CT or MRI), requirements for advanced imaging before surgical consultation, and low frequency of spine surgery after advanced imaging, are symptoms of fragmented care delivery for patients with spine-related complaints. Improved health system coordination for patients with spinal complaints may help to improve efficiency of spine imaging use. For example, diagnostic imaging pathways to reduce need for “lead up” testing with x-ray or CT spine before MRI, and alternative and innovative models of care which provide standardized assessment of patients with low back pain could streamline referral of appropriate patients for advanced spine imaging and surgical consultation.

References

1. Tu JV, Pinfold SP, McColgan P, Laupacis A, editors. Access to Health Services in Ontario. ICES Atlas 2nd edition. Toronto: Institute for Clinical Evaluative Sciences; 2006.
2. Chies M. Alberta Health Services, annual diagnostic imaging statistical data. 2011; personal communication.
3. Kung PT, Tsai WC, Yaung CL, et al. Determinants of computed tomography and magnetic resonance imaging utilization in Taiwan. International Journal of Technology Assessment in Health Care 2005; 21(1):81–88.
4. Alter DA, Stukel TA, Newman A. Proliferation of cardiac technology in Canada: a challenge to the sustainability of Medicare. Circulation 2006; 113(3):380–387.
5. Laupacis A, Evans W. Diagnostic imaging in Canada. HealthcarePapers 2005; 6(1):8–15.
6. Iglehart JK. The new era of medical imaging-progress and pitfalls. New England Journal of Medicine 2006; 354(26):2822–2828.
7. Levin DC, Rao VM. Turf wars in radiology: the overutilization of imaging resulting from self-referral. Journal of the American College of Radiology 2004; 1(3):169–172.
8. Stolberg HO. Yuppie scans from head to toe: unethical entrepreneurism. Canadian Association of Radiologists Journal 2003; 54(1):10–13.
9. Kim JSM, Dong JZ, Brener S, Coyte PC, Rampersaud YR. Cost-Effectiveness Analysis of a Reduction in Diagnostic Imaging in Degenerative Spinal Disorders. Healthcare Policy. 2011; 7(2): e105
10. Emery, D, Forster, A, Shojania, K, Feasby, TE. The appropriateness of magnetic resonance imaging. Submitted for publication.
11. Canadian Institute for Health Information. Medical Imaging in Canada, 2005. Accessed December 30, 2011 at http://secure.cihi.ca/cihiweb/products/MedImag05_e.pdf.
12. Organisation for Economic Co-operation and Development. OECD Health Data 2006. Accessed December 30, 2011 at http://www.ecosante.fr//index2.php?base=OCDE&langs=ENG&langh=ENG&ref=YESsessionid=cc2e5da50d8571efa57dac3df69721e1.
13. You JJ, Alter DA, Iron K, Slaughter PM, K opp A, Przbysz R, et al. Diagnostic Services in Ontario: Descriptive Analysis and Jurisdictional Review. ICES Investigative Report. Toronto: Institute for Clinical Evaluative Sciences; 2007.
14. Canadian Institute for Health Information January, 1, 2010: http://www.cihi.ca/cihi-ext-portal/internet/en/document/types+of+care/specialized+services/medical+imaging/release_22jul2010_fig3.
15. Ontario Ministry of Health and Long Term Outcomes: Provincial Progress on Wait Times. Accessed December 30, 2011 at: http://www.waittimes.net/SurgeryDI/EN/provincialsummary.aspx

16. Fisher ES, Wennberg DE, Stukel TA, et al. The implications of regional variations in Medicare spending. Part 1: the content, quality, and accessibility of care. Annals of Internal Medicine 2003; 138(4):273–287.
17. Fisher ES, Wennberg DE, Stukel TA, et al. The implications of regional variations in Medicare spending. Part 2: health outcomes and satisfaction with care. Annals of Internal Medicine 2003; 138(4):288–298.
18. Hackbarth GM. MedPAC Recommendations on Imaging Services. Statement before the US House of Representatives, Committee on Energy and Commerce, Subcommittee on Health, July 18, 2006. Accessed December 30, 2011 at http://www.medpac.gov/publications/congressional_testimony/071806_Testimony_imaging.pdf.
19. Health Canada. A ten year plan to strengthen health care. 2004 http://www.hc-sc.gc.ca/hcs-sss/delivery-prestation/fptcollab/2004-fmm-rpm/index-eng.php
20. Making the Best Use of a Department of Clinical Radiology. 5th edition. London: Royal College of Radiologists; 2003.
21. Diagnostic Imaging Referral Guidelines: A Guide for Physicians. Saint-Laurent, QC: Canadian Association of Radiologists; 2005.
22. Hoffman JR, Mower WR, Wolfson AB, Todd KH, Zucker MI. Validity of a set of clinical criteria to rule out injury to the cervical spine in patients with blunt trauma. National Emergency X-Radiography Utilization Study Group. N Engl J Med. 2000 Jul 13; 343(2): 94-9.
23. Oikarinen H, Meriläinen S, Pääkkö E, Karttunen A, Nieminen MT, Tervonen O. Unjustified CT examinations in young patients. Eur Radiol. 2009 May; 19(5): 1161-5.
24. Moak JH, Gong DX, Young JS, Sochor MR. Guidelines for cervical spine imaging in patients with blunt trauma: Utilization and outcomes. Annals Emerg Med.2011; 58(4 SUPPL. 1): S272-S273
25. Griffith B, Bolton C, Goyal N, Brown ML, Jain R. Screening cervical spine CT in a level I trauma center: overutilization? AJR Am J Roentgenol. 2011 Aug; 197(2): 463-7.
26. Kokabi N, Raper DM, Xing M, Giuffre BM. Application of imaging guidelines in patients with suspected cervical spine trauma: retrospective analysis and literature review. Emerg Radiol. 2011 Jan; 18(1): 31-8.
27. Sheikh K, Belfi LM, Sharma R, Baad M, Sanelli PC. Evaluation of acute cervical spine imaging based on ACR Appropriateness Criteria®. Emerg Radiol. 2012 Jan; 19(1): 11-7.
28. Vosburgh CL, Kopta JA. Appropriate use of magnetic resonance imaging of the spine and extremities. South Med J. 1994 Aug; 87(8): 801-4.
29. Lehnert BE, Bree RL. Analysis of appropriateness of outpatient CT and MRI referred from primary care clinics at an academic medical center: how critical is the need for improved decision support? J Am Coll Radiol. 2010 Mar; 7(3): 192-7.
30. Tacci JA, Webster BS, Hashemi L, Christiani DC. Clinical practices in the management of new-onset, uncomplicated, low back workers' compensation disability claims. J Occup Environ Med. 1999 May; 41(5): 397-404.

31. Hush JM. Clinical management of occupational low back pain in Australia: what is the real picture? J Occup Rehabil. 2008 Dec; 18(4): 375-80.
32. Hourcade S, Trèves R. Computed tomography in low back pain and sciatica. A retrospective study of 132 patients in the Haute-Vienne district of France. Joint Bone Spine. 2002 Dec; 69(6): 589-96.
33. Weiner DK, Kim YS, Bonino P, Wang T. Low back pain in older adults: are we utilizing healthcare resources wisely? Pain Med. 2006 Mar-Apr; 7(2): 143-50.
34. Boden SD, Swanson AL. An assessment of the early management of spine problems and appropriateness of diagnostic imaging utilization. Phys Med Rehabil Clin N Am. 1998 May; 9(2):411-7.
35. Schroth WS, Schectman JM, Elinsky EG, Panagides JC. Utilization of medical services for the treatment of acute low back pain: conformance with clinical guidelines. J Gen Intern Med. 1992 Sep-Oct; 7(5): 486-91.
36. Rao JK, Kroenke K, Mihaliak KA, Eckert GJ, Weinberger M. Can guidelines impact the ordering of magnetic resonance imaging studies by primary care providers for low back pain? Am J Manag Care. 2002 Jan; 8(1): 27-35.
37. Emery DJ, Shojania KG, Forster AJ, Mojaverian N, Feasby TE. Overuse of Magnetic Resonance Imaging. JAMA Intern Med. 2013 Mar 25: 1-3. [Epub ahead of print]
38. Deyo RA, Diehl AK. Lumbar spine films in primary care: current use and effects of selective ordering criteria. J Gen Intern Med. 1986 Jan-Feb; 1(1): 20-5.
39. Halpin SF, Yeoman L, Dundas DD. Radiographic examination of the lumbar spine in a community hospital: an audit of current practice. BMJ. 1991 Oct 5; 303(6806): 813-5.
40. Espeland A, Albrektsen G, Larsen JL. Plain radiography of the lumbosacral spine. An audit of referrals from general practitioners. Acta Radiol. 1999 Jan; 40(1): 52-9.
41. Espeland A, Baerheim A, Albrektsen G, Korsbrekke K, Larsen JL. Patients' views on importance and usefulness of plain radiography for low back pain. Spine (Phila Pa 1976). 2001 Jun 15; 26(12): 1356-63.
42. Ammendolia C, Côté P, Hogg-Johnson S, Bombardier C. Do chiropractors adhere to guidelines for back radiographs? A study of chiropractic teaching clinics in Canada. Spine (Phila Pa 1976). 2007 Oct 15; 32(22): 2509-14.
43. Baker SR, Rabin A, Lantos G, Gallagher EJ. The effect of restricting the indications for lumbosacral spine radiography in patients with acute back symptoms. AJR Am J Roentgenol. 1987 Sep; 149(3): 535-8.
44. Deyo RA, Diehl AK, Rosenthal M. Reducing roentgenography use. Can patient expectations be altered? Arch Intern Med. 1987 Jan; 147(1): 141-5.
45. Garala M, Craig J, Lee E. Reducing general practitioner referral for lumbar spine X-ray. Journal of Clinical Governance. 1999; 7(4): 186-189.
46. Oakeshott P, Kerry SM, Williams JE. Randomized controlled trial of the effect of the Royal College of Radiologists' guidelines on general practitioners' referrals for radiographic examination. Br J Gen Pract. 1994 May; 44(382): 197-200.

47. Solberg LI, Wei F, Butler JC, Palattao KJ, Vinz CA, Marshall MA. Effects of electronic decision support on high-tech diagnostic imaging orders and patients. Am J Manag Care. 2010 Feb; 16(2): 102-6.
48. Stevenson K, Hay E. An integrated care pathway for the management of low back pain. Physiotherapy. 2004; 90 (2): 91-96.
49. Werner, E. L. and Gross, D. P. The effects of a media campaign on beliefs and utilization of imaging examinations in Norwegian patients with low back pain. Norsk Epidemiologi. 2009; 19(1): 73-78.
50. Maurice S, Brown S, Robertson C, Beggs I. The effect of introducing guidelines for cervical spine radiographs in the accident and emergency department. J Accid Emerg Med. 1996 Jan; 13(1): 38-40.
51. Blackmore CC, Mecklenburg RS, Kaplan GS. Effectiveness of clinical decision support in controlling inappropriate imaging. J Am Coll Radiol. 2011 Jan; 8(1): 19-25.
52. Adams MJ, Adams JL. Elimination of unnecessary cervical spine radiographs in the emergency department. J Am Coll Radiol. 2010 Jul; 7(7): 531-2.
53. Stiell IG, Clement CM, Grimshaw J, Brison RJ, Rowe BH, Schull MJ, Lee JS, Brehaut J, McKnight RD, Eisenhauer MA, Dreyer J, Letovsky E, Rutledge T, MacPhail I, Ross S, Shah A, Perry JJ, Holroyd BR, Ip U, Lesiuk H, Wells GA. Implementation of the Canadian C-Spine Rule: prospective 12 centre cluster randomised trial. BMJ. 2009 Oct 29; 339: b4146.
54. Goergen SK, Fong C, Dalziel K, Fennessy G. Can an evidence-based guideline reduce unnecessary imaging of road trauma patients with cervical spine injury in the emergency department? Australas Radiol. 2006 Dec; 50(6): 563-9.
55. Klein BJ, Radecki RT, Foris MP, Feil EI, Hickey ME. Bridging the gap between science and practice in managing low back pain. A comprehensive spine care system in a health maintenance organization setting. Spine (Phila Pa 1976). 2000 Mar 15; 25(6): 738-40.
56. Kerry S, Oakeshott P, Dundas D, Williams J. Influence of postal distribution of the Royal College of Radiologists' guidelines, together with feedback on radiological referral rates, on X-ray referrals from general practice: a randomized controlled trial. Fam Pract. 2000 Feb; 17(1): 46-52.
57. Freeborn DK, Shye D, Mullooly JP, Eraker S, Romeo J. Primary care physicians' use of lumbar spine imaging tests: effects of guidelines and practice pattern feedback. J Gen Intern Med. 1997 Oct; 12(10): 619-25.
58. McNally E, de Lacey G, Lovell P, Welch T. Posters for accident departments: simple method of sustaining reduction in x ray examinations. BMJ. 1995 Mar 11; 310(6980): 640-2.
59. Tracey NG, Martin JB, McKinstry CS, Mathew BM. Guidelines for lumbar spine radiography in acute low back pain: effect of implementation in an accident and emergency department. Ulster Med J. 1994 Apr; 63(1): 12-7.