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Non-evidence-based variables affecting physicians' test-ordering tendencies: a systematic review

R. Sood, A. Sood, A.K. Ghosh*

Division of General Internal Medicine, Mayo Clinic, 200 First Street SW, 55905 Rochester, Minnesota, United States, *corresponding author: e-mail: Ghosh.Amit@mayo.edu

ABSTRACT

Background: The concept of evidence-based medicine (EBM) was introduced in 1992. Incorporation of EBM into physicians' practices, however, has been slow. Test-ordering tendencies are still based on variables that are not necessarily evidence-based.

Methods: The literature was reviewed to identify the non-EBM variables that affect physicians' practices of test ordering. Studies of interest were limited to original research on the determinants of physicians' test-ordering tendencies. The search strategy included queries in MEDLINE (1992-2006), Web of Science (1993-2006), EMBASE (1992-2006), and PsycINFO (1992-2006); checking of reference lists; hand searching relevant journals; and personal communication with experts. Two independent reviewers abstracted information on the design, quality, and limitations of the study. Review articles, letters, and editorials were excluded from analysis.

Results: 104 original studies reporting on the variables affecting test ordering were identified. Of these, 53 studies assessing physician variables affecting test ordering were identified. Some of the recognisable physician factors included age, sex, degree of specialisation, geographic location and practice setting, individual belief systems, experience, knowledge, fear of malpractice litigation, physician regret, financial incentives, awareness of costs of tests ordered, and provision of written feedback by peers or employers.

Conclusion: Despite considerable advances in our understanding of EBM and its application to patient care, several non-EBM physician variables influence physicians' test-ordering characteristics. Ongoing effort is needed to identify the modifiable non-EBM determinants of physicians' test ordering and to use appropriate tools and techniques to encourage evidence-based behaviours for test ordering.

KEYWORDS

Decision-making, diagnostic tests, evaluation studies, evidence-based medicine

INTRODUCTION

With technological advances creating newer diagnostic tests, along with easy accessibility of medical information on the World Wide Web, physicians and patients now have access to a larger amount of information. A critical understanding of newer medical information and incorporation of the data into everyday medical practice gradually evolved into the concept of evidence-based medicine (EBM), a term that was formally introduced in 1992.[1]

EBM includes an evidence-based approach toward therapeutic interventions and diagnostic processes. Diagnostic tests are an integral part of health care and contribute to a large percentage of health care costs. Ordering relevant laboratory and imaging tests is an essential component in the process of medical decision-making.

The process of medical decision-making usually starts with collection of relevant information, which then leads to the generation of a hypothesis. This hypothesis is then refined and its probability is increased or reduced based on the results of the diagnostic tests. Tests may be ordered in series (sequence of tests ordered in the future is based on the results of prior test) or in parallel (several tests ordered during one visit) depending on the urgency of making a diagnosis and the perceived risk (medical or legal) in a clinical situation. Understandably, several variables, involving the physicians, patients, and the health care environment, influence this multistep process.

Most medical schools in the United States and other countries have established curricula for teaching EBM in their undergraduate and postgraduate medical courses.[2] With increased focus on evidence-based practice, it was hoped that physicians would adopt a measured approach to test ordering and follow established algorithms, thereby reducing the variability in physician practice and subsequently the overall cost of health care. However, the health care environment is complex and rapidly changing. Thus, physicians experience changing expectations from the patients and the health care system and are unable to be algorithmic in their approach. Several determinants likely affect physicians' tendencies for test ordering.

In this study, we reviewed the literature on non-EBM physician determinants of test-ordering practices. Our goal was to delineate the factors that sway physicians away from evidence-based test ordering and identify possible targets of intervention for changing practice patterns.

METHODS

Data sources

The search was focused on studies performed since 1992. Data were abstracted from the following databases: MEDLINE (1992-2006) (National Library of Medicine, Bethesda, Maryland), Web of Science (1993-2006) (Thomson Scientific, Philadelphia, Pennsylvania), EMBASE (1992-2006) (Elsevier, Amsterdam), and PsycINFO (1992-2006) (American Psychological Association, Washington, DC). The searches were performed with the OVID search engine (Wolters Kluwer, New York).

Search strategy

A comprehensive retrieval of relevant articles was obtained by using different search strategies in different electronic databases. Searches were limited to human studies. In MEDLINE, EMBASE, and PsycINFO, the search terms used were laboratory techniques and procedures/utilisation or diagnostic tests, routine/ (also used laboratories, hospital/ utilisation) AND physician's practice patterns (also used unnecessary procedures/ or guideline adherence/ and attitude of health personnel/). Additionally, in EMBASE, the search terms used were diagnostic test/ or laboratory test/ AND professional practice/ or primary medical care/ or medical decision making/. In Web of Science, which uses only the key words, test order$ or (diagnostic test$ or laboratory test$ AND order$ or behavior$) were used to search for relevant articles. Two reviewers abstracted information on each study's eligibility for inclusion by screening its title, abstract, or full-text bibliographic citation.

We divided the factors affecting test ordering into three broad categories: physician factors, patient factors, and environmental factors. Original studies that addressed physician factors influencing test ordering were considered for inclusion. Several articles alluded to one or more of these factors as simultaneously affecting test ordering. These were included in all the relevant categories for the purpose of this review, with the recognition that these factors invariably interact in a clinical situation and, thereby, the exact contribution of a given variable is sometimes difficult to pinpoint. However, this simple categorisation still provided a useful starting point to understand the individual variables involved in test ordering. These factors were further subcategorised into potentially modifiable factors, that is, those that can be modified by a physician's own endeavour (belief system, experience, fear of malpractice, feedback, and education) *vs* nonmodifiable factors, over which physicians have no control (age and sex of physicians, practice settings, geographic location, and specialisation).

Disagreements regarding sorting out the factors affecting test ordering and classification under a subcategory were resolved by independent review by a third reviewer. If a study was considered appropriate for inclusion in our review, one reviewer assessed its design, quality, and limitations. In addition to searching of the electronic databases, other strategies included checking reference lists and educational websites, hand searching relevant journals, and personal communication with experts.

INCLUSION AND EXCLUSION CRITERIA

Studies of interest were limited to original research on the determinants of physicians' test-ordering tendencies. All studies using prospective study design, surveys (mailed and telephone), and chart reviews involving physicians and test-ordering characteristics were identified for review. We concentrated on articles published in the English literature since 1992, when the concept of evidence-based practice was well known to the medical community. A standard format was used to review data, including analysis of study design and study characteristics. Qualitative studies, review articles, letters, and editorials were excluded from the analysis.

Statistical analysis

Because the literature on test ordering is very heterogeneous, performing a meta-analysis was not considered appropriate. A narrative review of the topic is thus presented.

RESULTS

Search results

A total of 328 articles were retrieved. Of these, 104 articles were original studies and available in full text in English. A total of 53 articles that discussed the physician variables

comprised the final sample that was reviewed for this study. Fifty-one articles were excluded from the study because they dealt with patient factors, environmental factors, and physician uncertainty or disparities of medical care affecting test-ordering tendencies. All the studies reported were found in the Ovid databases. The non-evidence-based physician factors affecting test ordering tendencies are summarised in *tables 1* and *2*.

Nonmodifiable physician factors

Several nonmodifiable physician factors affected test ordering (*table 1*). These included practice location, practice setting, age and sex, and specialisation of the physician. Six studies evaluated the effect of geographic location on physicians' practices of test ordering.[3-8] In general, US physicians were reported to order more tests than physicians from the United Kingdom or Canada.[5,6] In Europe, there was considerable variation among countries, which was partly explained by the differences in the physician:population ratio.[7] Within the United States, physicians in the Northeast were reported to order more specialised tests than physicians in other geographic areas.[3] In Canada, according to a mail survey, bone densitometry was ordered more often by urban physicians than by their rural counterparts.[4] Finally, in a survey conducted in Norway, in areas that had a high turnover of physicians, such as municipalities, more tests were ordered, partly related to lack of continuity of care.[8]

Practice setting was evaluated in six studies.[9-14] Various practice settings were studied, including solo *vs* group practice, academic *vs* nonacademic practice, primary care *vs* tertiary care setting, and emergency *vs* outpatient setting. No clear pattern emerged from these studies, partly because of different study designs and difference in response rate between the different studies. Thus, a telephone survey of patients after physician visits (97% response rate) found that solo practitioners ordered more radiographic tests for acute low back pain,[11] but a mail-out survey of solo practitioners (56% response rate) showed that they tended to order fewer preventive services.[13] Hospital-based physicians ordered more tests than other practitioners,[9] academic physicians ordered more tests and nonacademic practice physicians had a higher threshold of test ordering,[14] the number of tests ordered by emergency room physicians did not differ from that by primary care physicians,[12] and a health-maintenance organisation setting did not affect test ordering.[10]

The effect of age and sex was reported in seven studies.[4,8,12,13,15-17] In general, across different settings, countries, and patient groups, female physicians tended to order more tests,[4,8,12] give more referrals,[16] and adhere better to guidelines than their male counterparts.[17] However, no attitudinal difference could be detected in this study to account for this difference.[17] Further, the older providers were reported to order tests more often,[8,15] and the younger providers adhered better to the guidelines.[13]

The degree of specialisation had a substantial impact on test ordering.[11,14,18-25] In general, a greater degree of specialisation was associated with more test ordering. Thus, gastroenterologists,[19] cardiologists,[20] orthopaedic surgeons,[11] vascular surgeons,[24] and infectious disease specialists,[14] all ordered more diagnostic tests or ordered tests earlier in the patient's illness than internal medicine physicians. The studies involving generalists specialising in hospital care (the hospitalists) showed variable results, ranging from ordering fewer tests with more evidence-based tests[18] to ordering more tests[25] than the community physicians. However, although specialists ordered more tests, they also ordered more focused tests and tests that were more likely to have positive results than internists.[23,24] In a chart-review study of patients with undifferentiated symptoms, family practitioners generated the lowest cost of all physicians.[21]

Modifiable physician factors

The modifiable physician factors (*table 2*) are among the most important because a better understanding of these variables can have a considerable impact on test ordering and health care costs. These variables include physician experience and knowledge, belief systems, fear of malpractice lawsuit and physician regret, financial incentives, awareness of the cost of testing, and education and feedback. Physician experience or knowledge was reported to affect test ordering in several studies; however, no consistent pattern emerged. Thus, increased physician knowledge or experience was reported to increase,[14,16] decrease,[25,26] or result in no change[12] in test ordering.

Physicians' personal beliefs that were not entirely evidence-based affected the frequency of test ordering.[27-34] Thus, physicians who doubted the effectiveness of mammography as a screening tool were, as expected, less likely to order the test,[33] whereas those who believed in its usefulness ordered it more often.[34] Physicians who believed that cancer screening reduced cancer-related mortality ordered the tests more often.[32] Physicians who believed strongly in doing routine baseline tests were more likely to perform them,[30] and physicians who doubted the interpretation of clinical trial results were less likely to adhere to guidelines.[29] Further, physicians' reasons for doing tests such as radiography of the lumbar spine for chronic back pain were related not only to medical necessity but also to a perception that radiography might provide psychological reassurance to the patient.[31]

Fear of malpractice consistently increased test ordering,[16,35-37] except in one study (54% response rate) in which physicians were asked to respond to hypothetical situations.[38] This finding was true for both specialists[35] and general practitioners.[16,36]

Table 1. *Nonmodifiable physician factors affecting test ordering*

Physician factors	Reference	Year	Study design	Results
Geographic location (n=6)	Wideroff *et al.*[3]	2003	National survey of 1251 physicians by mail, fax, Internet; response rate 71%	Physicians in Northeast ordered more testing for germline mutation than those in other locations
	Ridout and Hawker[4]	2000	Canadian mail survey of 711 FPs; response rate 64%	Urban physicians used bone densitometry more often than rural physicians
	Vickrey *et al.*[5]	1998	Mail survey involving 595 US and 210 UK neurologists; response rate, 92 and 63%, respectively	More tests ordered for each scenario by US neurologists
	Katz *et al.*[6]	1996	Chart review assessment of laboratory or x-ray utilisation in 7980 US and 6491 Canadian patients discharged from the hospital	Utilisation was higher in the US; explained by use of more expensive tests and more testing on elderly
	Leurquin *et al.*[7]	1995	European survey obtaining information from physicians and patients regarding ordered tests	Marked variations in test ordering were noticed between different countries; these were partly explained by the physician:population ratio
	Kristiansen and Hjortdahl[8]	1992	Chart review study in Norway involving 6848 surgery consultations from 128 GPs	Physicians in municipalities ordered more tests (high turnover of physicians)
Practice setting (n=6)	Bushnell *et al.*[9]	2001	Chart review involving 674 patients admitted for acute ischaemic stroke to assess for use of coagulation testing	Physicians practising at tertiary-care centres were more likely to order coagulation testing
	Landon *et al.*[10]	2001	Cross-sectional survey of national sample of 7423 primary-care physicians; response rate 65%	Solo practitioners ordered more tests, referrals, and treatments than physicians in academic setting. No effect of HMO setting *vs* non-HMO setting
	Carey and Garrett[11]	1996	Telephone serial survey of 1633 patients in a community setting after index visit; at 6 months, data for analysis were available for 97% of patients; a physician survey also was incorporated	Solo practitioners ordered more radiographic tests for acute low back pain than practitioners in group practices
	Scholer *et al.*[12]	1996	Chart review involving 1140 paediatric patients evaluated for acute abdominal pain in the emergency department or as an outpatient	The setting of evaluation did not affect the number of tests ordered
	Stange *et al.*[13]	1994	Mail survey of 480 FPs nationwide regarding adherence to USPSTF guidelines; response rate 56%	Solo practitioners ordered fewer preventive services
	Winkenwerder *et al.*[14]	1993	Mail survey about case scenarios of syphilis to 126 internal medicine and 31 infectious disease experts; response rates 35 and 62%, respectively	Nonacademic practice physicians had a higher threshold of doing serological tests
Age and sex (n=7)	Stafford and Misra[15]	2001	Chart review involving 190,238 visits in internal medicine group practices; assessed for variation in performance of ECG in patients with no heart disease	Older male providers were more likely to order ECG
	Franks *et al.*[16]	2000	A survey of 275 internal medicine and FPs along with analysis of claims database; response rate 66%	Being a female physician was associated with more referral rates
	Ridout and Hawker[4]	2000	Canadian mail survey of 711 FPs; response rate 64%	Female physicians were more likely to order bone mineral density tests
	Ferrier *et al.*[17]	1996	Canadian mail questionnaire involving 564 new FPs; response rate 70%	Female physicians adhered better to guidelines
	Scholer *et al.*[12]	1996	Chart review involving 1140 paediatric patients evaluated for acute abdominal pain in the emergency department or as an outpatient	Female physicians were more likely to order tests
	Stange *et al.*[13]	1994	Mail survey of 480 FPs nationwide regarding adherence to USPSTF guidelines; response rate 56%	Younger physicians adhered better to guidelines
	Kristiansen and Hjortdahl[8]	1992	Chart review study in Norway involving 6848 surgery consultations from 128 general practitioners	Female and older physicians ordered tests more often

Table 1. *Continued*

Physician factors	Reference	Year	Study design	Results
Specialisation (n=10)	Conway *et al.*[18]	2006	National survey of 213 hospitalist and random sample of 352 community paediatricians	Hospitalists reported greater adherence to evidence-based tests and less use of tests of unproven benefit
	Hilsden *et al.*[19]	2005	Questionnaire sent to gastroenterologists, internists, and surgeons in Alberta, Canada	Internists less likely to order for screening colonoscopy *vs* surgeons and gastroenterologists
	Cohen *et al.*[20]	1999	Analysis of national ambulatory medical care surveys involving 1.12 billion patient visits with 6.2 million exercise stress tests ordered	Cardiologists were 3.7 times more likely to order stress tests than internists (after adjusting for clinical and nonclinical variables associated with the office visit)
	Lin *et al.*[21]	1999	Retrospective chart review of 254 patients	FPs generated lower costs for undifferentiated problems such as unexplained weight loss than other specialists
	Collins *et al.*[22]	1997	Mail and telephone survey of a nationwide random sample of 444 primary-care providers and 394 urologists. Response rates were 51 and 68%, respectively	Primary-care physicians ordered routine creatinine measurement more often than urologists
	Glassman *et al.*[23]	1997	A survey of 318 cardiologists and 598 internists about three hypothetical non-life-threatening clinical scenarios	Cardiologists ordered more focused cardiac tests, whereas internists ordered broader tests; the overall cost of the two was the same
	Hill *et al.*[24]	1997	Chart review of 4764 scans for indications for carotid duplex scanning	Vascular surgeons were more likely to order carotid duplex scanning than internal medicine or FP; further, vascular surgeons were more likely to order scanning that had positive results
	Carey and Garrett[11]	1996	Telephone serial survey of 1633 patients in a community setting after index visit; at 6 months, data for analysis were available for 97% of patients; a physician survey also was incorporated	Orthopaedic surgeons and chiropractors ordered more radiography for acute low back pain evaluation than internists
	McGillivray *et al.*[25]	1993	Prospective chart review of 6191 visits of febrile children	Hospital-based subspecialists ordered more diagnostic tests than community physicians
	Winkenwerder *et al.*[14]	1993	Mail survey about case scenarios of syphilis to 126 internal medicine and 31 infectious disease experts; response rates were 35 and 62%, respectively	Infectious disease specialists tended to order serological testing and lumbar puncture sooner than internal medicine physicians

ECG = electrocardiography; FP = family practitioner; GP = general practitioner; HMO = health maintenance organisation; UK = United Kingdom; US = United States; USPSTF = US Preventive Services Task Force.

Table 2. *Modifiable physician factors affecting test ordering*

Physician factors	Reference	Year	Study design	Results
Experience/ knowledge (n=5)	Yuan *et al.*[26]	2005	Mail questionnaire survey of 1335 anaesthetists; response rate 46%	80% would order tests in asymptomatic low-risk individuals based on clinical indications, 15.1% to follow guidelines 44% had disagreement over need for routine preoperative ECG
	Franks *et al.*[16]	2000	A survey of 275 internists and FPs along with analysis of claims database; response rate 66%	More years in practice was associated with more referral rates
	Scholer *et al.*[12]	1996	Chart review involving 1140 paediatric patients evaluated for acute abdominal pain in the emergency department or as an outpatient	Level of training did not affect test ordering for the most part; students ordered fewer urinalyses, and paediatricians with more than 10 years of experience ordered fewer throat cultures
	McGillivray *et al.*[25]	1993	Prospective study involving 6191 visits of febrile children studied for test ordering	Physicians with more than 10 years of experience ordered fewer tests
	Winkenwerder *et al.*[14]	1993	Mail survey about case scenarios of syphilis to 126 internal medicine and 31 infectious disease experts; response rates were 35 and 62%, respectively	Infectious disease experts were more likely to obtain serological tests to diagnose syphilis and to do lumbar puncture to diagnose neurosyphilis
Belief system (n=8)	Prochazka *et al.*[27]	2005	Postal survey of attitudes and belief regarding annual physical examination of 1679 primary-care practice; response rate 47%	Despite lack of evidence, 88% of primary-care providers perform annual physical examination and order urinalysis (44%) and complete blood count (39%)
	Turner *et al.*[28]	2003	Mail survey of 413 primary-care practices affiliated with a managed care organisation; response rate 77%	Physicians with intermediate or high intentions to evaluate a positive haemoccult test were 2 times as likely to order diagnostic colon evaluation than physicians with low intention
	Rello *et al.*[29]	2002	Mail survey of 110 opinion leaders from 23 countries on reasons for nonadherence to EBM guidelines for ventilator-associated pneumonia; response rate 56%	Physicians disagreeing with interpretation of clinical trials did not adhere to guidelines
	Nakar *et al.*[30]	2002	A survey of 165 FPs in Israel; response rate 89%	Baseline screening laboratory tests were performed more often by physicians who believed that performing these tests results in more case finding
	Little *et al.*[31]	1998	A survey of 236 GPs in UK to determine the reasons for doing back radiography; response rate 70%	General practitioners ordered back radiography for both medical and psychosocial reasons, including patient satisfaction and reassurance
	Hicks *et al.*[32]	1995	Mail survey of 286 FPs in Oklahoma, asking them about reasons for ordering PSA test; response rate 53%	A belief that screening for prostate cancer reduces mortality and improves quality of life increased ordering of PSA test
	Taylor *et al.*[33]	1994	Mail survey of 129 internal medicine physicians; response rate 66%	Physicians doubting the effectiveness of mammography were less likely to order it
	Conry *et al.*[34]	1993	A study of 10 FPs involving 839 patient visits with 277 mammograms ordered	Physicians' belief in patient compliance and need for mammography was associated with increased ordering of mammography
Fear of malpractice lawsuit/physician regret (n=5)	Birbeck *et al.*[35]	2004	Survey of 595 US neurologists; response rate 92%	Higher malpractice concerns and reimbursement for testing were associated with more test ordering
	Sorum *et al.*[36]	2003	Survey of 32 US internal medicine physicians and 33 French generalists regarding cancer screening	Physicians ordered more tests because of high regret if cancer was missed
	Franks *et al.*[16]	2000	A survey of 275 internal medicine and FPs along with analysis of claims database; response rate 66%	Risk aversiveness and fear of malpractice were variables associated with higher referral rates
	Van Boven *et al.*[37]	1997	Prospective study of 16 Dutch FPs involving 31,343 patient visits and 8897 tests ordered	Of all the tests ordered, 27% were ordered as defensive testing
	Glassman *et al.*[38]	1996	Multispeciality survey of 1540 providers; response rate 54%	Malpractice experience and fear of malpractice had no substantial impact on test ordering in hypothetical clinical situations

Table 2. *Continued*

Physician factors	Reference	Year	Study design	Results
Financial incentives (n=3)	Birbeck *et al.*[35]	2004	Survey of 595 US neurologists; response rate 92%	Receiving reimbursement for testing was associated with a higher likelihood of ordering neuroimaging tests
	Stafford and Misra[15]	2001	Chart review involving 190,238 visits in internal medicine group practices; assessed for variation in performance of ECG in patients with no heart disease	Providers who billed for ECG interpretation ordered tests more often
	Carey and Garrett[11]	1996	Telephone serial survey of 1633 patients in a community setting after index visit; at 6 months, data for analysis were available for 97% of patients; a physician survey also was incorporated	More radiographic testing was done for low back pain evaluation by practitioners who owned these machines
Awareness of cost of testing (n=4)	Seguin *et al.*[39]	2002	Prospective observational and sequential study of all admitted patients over 4 months in a 21-bed ICU; 128 patients in period 1 and 159 in period 2	Almost all the tests, particularly blood gas analysis and urinalysis, were ordered less frequently when physicians were aware of the cost
	Rudy *et al.*[40]	2001	Hypothetical scenario study involving 23 internal medicine residents	Residents with charge data spent less on diagnostic tests
	Hampers *et al.*[41]	1999	A prospective study involving 5395 patients (90% of eligible patients) in a paediatric emergency department	Knowledge of the costs decreased test ordering by 27% in patients with acute illness not requiring admission
	Bates *et al.*[42]	1997	Two prospective randomised controlled trials involving 7090 (clinical laboratory tests) and 17,381 (radiological tests) in patients in which physicians were or were not shown charge of the test being ordered	Computerised display of charges had no effect on test ordering in hospitalised patients
Feedback/ education (n=13)	Bunting and Van Walraven[43]	2004	In a Canadian study involving 200 physicians who ordered the largest number of common laboratory tests, physicians were randomised to receive feedback or no intervention. Follow-up was up to 2 years after completion of the intervention that itself was carried out over 2 years	Utilisation decreased by 7.9% in the intervention group *vs* the control group, a difference that persisted until the end of study observation
	Baker *et al.*[44]	2003	Randomised controlled trial involving 46 general practitioners in UK. Physicians received guidelines and then feedback about ordering of specific tests	The intervention had no impact on test ordering
	Stafford[45]	2003	Nonrandomised design involving 117 primary care physicians. Study tested the effect of feedback on ordering screening ECG	A considerable decrease in ordering ECG was shown during the interventions and up to 9 months after the intervention (duration of the study)
	Verstappen *et al.*[46]	2003	In a randomised controlled trial in the Netherlands, 26 primary care physician groups received education in specific medical conditions. These physicians were divided into two arms that acted as a control for the other	Test ordering was modestly reduced as a result of these interventions
	Barazzoni *et al.*[47]	2002	Health professions from six practices in Switzerland were educated about appropriate preoperative testing. This was followed by observation of using preoperative testing in 17,978 patients admitted for elective surgery	Adoption of recommendations was associated with substantial reductions in utilisation of coagulation, glucose, and renal function tests, chest radiography, and ECG
	Beaulieu *et al.*[48]	2002	87 FPs in Canada randomised to receive a 90-minute workshop or no training in the Canadian Task Force Preventive service recommendations	At 6 months, physicians randomised to workshop group showed a substantial decrease in ordering of unnecessary screening tests
	Eccles *et al.*[49]	2001	Pragmatic cluster randomised trial with a factorial design in UK involving 6 radiology departments and 244 general practices served by them	Educational reminder messages substantially reduced number of radiography requests per 1000 patients per year, whereas 6-monthly feedback of audit data was ineffective
	Goodwin *et al.*[50]	2001	A group randomised trial involving 77 practices in Ohio. Physicians were given individualised tools and services to increase preventive services	Intervention group showed a considerable increase in use of preventive services recommended by USPSTF *vs* the control group at 1-year follow-up

Table 2. *Continued*

Physician factors	Reference	Year	Study design	Results
	Plapp *et al.*[51]	2000	Administrative changes and physician education initiatives were introduced in a hospital to reduce utilisation of tests that were of high volume, difficult to perform, or expensive or had questionable medical benefit	After 5 years of intervention, average number of tests per patient dismissed decreased from 44 at baseline to 29
	Sucov *et al.*[52]	1999	Standards for diagnostic tests were developed for all the staff members at an emergency room. Frequency of test ordering was compared before and after the education programme was introduced	The number of tests ordered per 100 patients substantially decreased after introducing the intervention
	Ramoska[53]	1998	Interventional study involving emergency room physicians; physicians' use of laboratory tests was presented at monthly meetings, and the effect of this intervention was observed on testing tendencies	Test ordering as a result of the intervention decreased by 17.8% with no adverse changes in quality of care
	Winkens *et al.*[54]	1996	The effect of 9 years of twice-a-year feedback was studied on test ordering by general practitioners in the UK *vs* a control region (Netherlands). The trends in use of tests were compared	Compared with the control region, the intervention group showed a considerable reduction in the number of tests ordered during the period studied. Repeated feedback had the greatest impact
	Winkens, *et al.*[55]	1995	A randomised controlled trial involving 79 physicians in the UK. Physicians were divided into 2 groups and received feedback on different tests ordered, thus acting as their own controls	Volume of tests ordered substantially decreased in the intervention group. Further, a greater decrease was found in the number of non-rational tests that were ordered in the intervention group

EBM = evidence-based medicine; ECG = electrocardiography; FP = family practitioner; GP = general practitioner; ICU = intensive care unit; PSA = prostate-specific antigen; UK = United Kingdom; US = United States; USPSTF = US Preventive Services Task Force.

Financial incentives, as expected, increased test ordering, as found in three different studies designed as patient survey,[11] chart review,[15] and physician survey.[35] An awareness of the cost of testing, in general, decreased test ordering.[39-41] However, in the largest and most rigorously designed study to test this variable, physicians in two prospective randomised controlled trials were either shown the cost of the test or were not. The intervention had no substantial impact on test ordering.[42]

The best-studied modifiable variable is the impact of feedback on test ordering. A total of 13 interventional studies have been reported,[43-55] seven of them randomised controlled trials.[43,44,46,48-50,55] In all but one of these studies,[44] provision of education or feedback or both considerably reduced the number of tests ordered.

Other physician variables affecting test ordering included individual risk-taking attitudes of the physicians,[56] endorsement of a professional organisation,[33] influence of peer practices,[57] and source of payment by private insurance compared with Medicare.[20]

DISCUSSION

The study shows that several physician variables that are not evidence-based affect test ordering. This issue is important because appropriate test ordering is central to cost-effective and quality patient care. Recognition of the modifiable physician variables is particularly important because a system-wide multicomponent intervention that addresses these variables might successfully optimise test ordering. As an example, a randomised trial from the Netherlands compared the effect of a multi-intervention strategy in one group compared with feedback only in the other group.[58] The intervention group received a multi-intervention strategy involving evaluation of personal test-ordering data compared with that of other colleagues, group education on national and evidence-based guidelines, and attendance at quality improvement meetings. Although the initial cost of development and running the intervention arm was expensive, the mean cost reduction per physician due to avoidance of unnecessary tests was larger in the intervention group (€ 144 per physician per six months). Admittedly, the long-term effects of implementing this strategy remain unclear.

Our study has several limitations. First, articles published before 1992 were not included. Thus, we are not able to determine time trends or any differences in physicians' tendencies to order tests before and after introduction of the concept of EBM. Second, the approach in this survey was inclusive; thus, studies included are very heterogeneous in their structure and quality. This feature may explain different conclusions from some of the studies. The heterogeneity of the studies precludes a quantitative pooling of the results to produce any statistical inference, our study is thus essentially descriptive. Third, most of the studies included used questionnaires that were not well validated. Finally, the review does not include description of designs and biases of the individual studies that were included.

Our study also has several strengths. Our literature search is exhaustive and gives a very good overview of the subject matter. The studies included are from multiple practice situations and geographic locations; thereby, the inferences of the review are generalisable to a large population.

Non-EBM test ordering does not always mean inappropriate test ordering. An exploration of the reasons why physicians deviate from EBM test ordering might be instructive. For example, family practitioners ordered fewer tests in routine practice and in situations of uncertainty. Several reasons may include a different training background, community-based practice that allows long-term relationships with families, a greater use of support and reassurance compared with specialists, less aversion to risk, and possibly less anxiety in the midst of uncertainty.[59] Similarly, Northeast US physicians ordered more germline mutation testing than physicians in other geographic locations, likely because of the geographic concentration of population at higher risk and also because of physicians' knowledge of and attitude toward the disease.[3] Rural family practitioners in Canada ordered bone densitometry less often because of nonavailability of this test locally or within reasonable distance.[4] Solo practitioners order more testing, at least partly related to the relative nonavailability of peers for informal consultation.[60] Primary-care physicians in health-maintenance-organisation settings ordered more tests for social and symbolic reasons and to resolve tensions and conflicts related to time constraints and access problems.[61]

Recent studies including interventions such as telephonic peer coaching sessions integrated with education resources for general practitioners,[62] use of preventive care checklist forms,[63] and hands-on supervision of resident test ordering behaviour by senior physicians[64] have all found a decrease in unnecessary test-ordering tendencies. However, despite the benefits of these interventions, it is unclear from these studies whether the beneficial effects could be sustained in the long term.

In general, test ordering is a skill that changes with time and is related to several complex interacting variables. Nevertheless, most clinical trials showed a sustained effect of education and feedback for improving test-ordering tendencies. Further, an optimised test ordering, although cost-effective, does not increase the risk of adverse events, including hospitalisation.[65]

In summary, the study found that several modifiable and nonmodifiable physician variables affect test ordering. Ongoing effort is needed to identify the modifiable

non-EBM determinants of physicians' test ordering and to use appropriate tools and techniques to encourage evidence-based behaviours for test ordering. Further studies are indicated to identify whether system-wide multicomponent strategies would be consistently useful for reducing physician variability in ordering tests.

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