BMJ Open Quality

Unintended consequences: quantifying the benefits, iatrogenic harms and downstream cascade costs of musculoskeletal MRI in UK primary care

Imran Mohammed Sajid ,[1,2] Anand Parkunan,[3] Kathleen Frost[4]

To cite: Sajid IM, Parkunan A, Frost K. Unintended consequences: quantifying the benefits, iatrogenic harms and downstream cascade costs of musculoskeletal MRI in UK primary care. *BMJ Open Quality* 2021;**10**:e001287. doi:10.1136/bmjoq-2020-001287

Received 23 November 2020
Accepted 7 June 2021

[1]NHS West London Clinical Commissioning Group, London, UK
[2]University of Global Health Equity, Kigali, Rwanda
[3]Healthshare Community NHS Musculoskeletal Services, London, UK
[4]NHS Central London Clinical Commissioning Group, London, UK

Correspondence to
Dr Imran Mohammed Sajid; imransajid@nhs.net

ABSTRACT

Objectives The largest proportion of general practitioner (GP) magnetic resonance imaging (MRI) is musculoskeletal (MSK), with consistent annual growth. With limited supporting evidence and potential harms from early imaging overuse, we evaluated practice to improve pathways and patient safety.

Methods Cohort evaluation of routinely collected diagnostic and general practice data across a UK metropolitan primary care population. We reviewed patient characteristics, results and healthcare utilisation.

Results Of 306 MSK-MRIs requested by 107 clinicians across 29 practices, only 4.9% (95% CI ±2.4%) appeared clearly indicated and only 16.0% (95% CI ±4.1%) received appropriate prior therapy. 37.0% (95% CI ±5.5%) documented patient imaging request. Most had chronic symptoms and half had psychosocial flags. Mental health was addressed in only 11.8% (95% CI ±6.3%) of chronic sufferers with psychiatric illness, suggesting a solely pathoanatomical approach to MSK care. Only 7.8% (95% CI ±3.0%) of all patients were appropriately managed without additional referral. 1.3% (95% CI ±1.3%) of scans revealed diagnoses leading to change in treatment (therapeutic yield). Most imaged patients received pathoanatomical explanations to their symptoms, often based on expected age or activity-related changes. Only 16.7% (95% CI ±4.2%) of results appeared correctly interpreted by GPs, with spurious overperception of surgical targets in 65.4% (95% CI ±5.3%) who suffered 'low-value' (ineffective, harmful or wasteful) post-MRI referral cascades due to misdiagnosis and overdiagnosis. Typically, 20%–30% of GP specialist referrals convert to a procedure, whereas MRI-triggered referrals showed near-zero conversion rate. Imaged patients experienced considerable delay to appropriate care. Cascade costs exceeded direct-MRI costs and GP-MSK-MRI potentially more than doubles expenditure compared with physiotherapist-led assessment services, for little-to-no added therapeutic yield, unjustifiable by cost–consequence or cost–utility analysis.

Conclusion Unfettered GP-MSK-MRI use has reached unaccceptable indication creep and disutility. Considerable avoidable harm occurs through ubiquitous misinterpretation and salient low-value referral cascades for two-thirds of imaged patients, for almost no change in treatment. Any marginally earlier procedural intervention for a tiny fraction of patients is eclipsed by negative consequences for the vast majority. Only 1–2 patients need to be scanned for one to suffer mismanagement. Direct-access imaging is neither clinically, nor cost-effective and deimplementation could be considered in this setting. GP-MSK-MRI fuels unnecessary healthcare utilisation, generating nocebic patient beliefs and expectations, whilst appropriate care is delayed and a high burden of psychosocial barriers to recovery appear neglected.

INTRODUCTION

General practitioner (GP) direct access musculoskeletal (MSK) magnetic resonance imaging (MRI) is widespread, under well-intentioned aspirations for earlier disease detection, efficient patient journeys and reduction of referrals by enabling greater GP management. One in 10 patients with back pain presenting to primary care receives advanced imaging.[1] Despite consistent imaging growth, there is a paucity of supporting evidence in this setting.

Imaging interpretation is nuanced as incidental age or activity-related findings are highly prevalent in asymptomatic joints (table 1). There are calls to shift away from a purely pathoanatomical model, towards a biopsychosocial approach to care, reducing 'low-value' (ineffective, harmful or wasteful) overuse and overdiagnosis.[2 3]

Concerns around GP-MSK-MRI

Early MSK-MRI is linked to greater disability and prolonged recovery,[4 5] with non-guideline imaging associated with transition to chronic back pain.[6] Findings can negatively affect patient perceptions, with lower confidence in conservative management, fear that exercise may worsen the condition, loss of control, over-reliance on surgery as well as poorer functional outcomes.[7–12] Cognitions influence distress, disability and quality-of-life.[13] The term 'Victims of

Table 1 Expected age or activity related epidemiological findings in musculoskeletal MRI

Body part	Prevalence
Neck	Up to 87% of asymptomatic individuals may have bulging discs,[107] with 58% of younger, asymptomatic athletes showing cervical disc degeneration.[108]
Shoulder	60% of asymptomatic older adults show subacromial bursitis on MRI and around half have rotator cuff tears,[109 110] whilst up to 72% of middle-aged individuals have asymptomatic superior labral tears.[111] In younger, asymptomatic athletes, 65% can have rotator cuff tears and 88% rotator cuff tendinosis.[112] 52% of pre-teen athletes demonstrate asymptomatic activity-related 'abnormal' shoulder MRIs.[113] With the exception of large rotator cuff tears, systematic review suggests little-to-no correlation between shoulder imaging findings and shoulder symptoms.[28 114]
Low back	At age 60, 88% of asymptomatic adults will have disc degeneration, 70% will show disc bulges, 50% will show facet degeneration and 23% spondylolisthesis.[115] Lumbar stenosis is seen in upto 20% of those under the age of 40.[116] Moderate or severe spinal stenosis is seen in up to 64% of those in their 50s and 93% in those in their 80s. The majority are asymptomatic, as only 17.5% of those with severe central stenosis may have symptoms.[117] In younger, asymptomatic adolescent sports players, up to 85% may show MRI changes including disc bulges, facet arthropathy as well as pars lesions.[118] Even 22% of asymptomatic children can show disc degeneration on MRI.[119]
Hip	Labral tears are seen in up to 69% of asymptomatic adults,[120] or even 89% of asymptomatic athletes[121] and labral cysts in 50% of dancers.[122] Acetabular dysplasia is seen in around 15% of asymptomatic people, with bilaterality in up to 39.5% of cases.[123 124] Cartilage defects may be seen in 12% of asymptomatic individuals.[125]
Knee	The majority of people with meniscal tears have no recent symptoms.[126] Meniscal tears are seen in around a third of middle-aged asymptomatic individuals, where 97% of knees will show incidental 'abnormalities', including bucket-handle tears.[127] Above the age of 40, MRI shows osteoarthritis features in up to 43% of asymptomatic individuals[128]
Ankle and Foot	Tibial stress fractures have been seen in 41% of asymptomatic runners.[129] In ankle MRI of asymptomatic amateur marathon runners, up to 80% may show tendon changes, 48% ligament injuries and 27% achilles tendinopathy.[130] Up to 37% of people may have incidental 'abnormal' anterior talofibular ligaments.[131 132] Achilles tendon changes may be seen in up to 63% of asymptomatic individuals, and retrocalcaneal bursal changes in 68% of runners.[133] Morton Neuroma's is present in 26%–33% of asymptomatic individuals.[134 135]

Modern Imaging Technologies' describes harmfully disease-labelling patients as a result of increased imaging access,[14] while incidental findings also place pressure on GPs.[15] A high proportion of GP-MSK-MRI may be inappropriate,[16] and disseminated scanning is an implicated driver behind 'low-value' arthroscopies.[17] Expanding use of specialist tests down to primary care, dubbed 'diagnostic downshift', often has unintended clinical and economic impacts.[18]

Imaging consequences include unnecessary surgical referrals. There has been a shift away from conventional surgical approaches in favour of conservative therapy for many common conditions. Shoulder decompression,[19 20] rotator cuff repair,[21] shoulder labral repair,[22] osteochondroplasty for femoroacetabular impingement[23] and knee meniscectomy[24] are just some examples. Strict procedural criteria are enforced in some regions, while some high-volume spinal injections have been decommissioned.[25] Non-specialists may be unfamiliar with such trends and even GPs with 'special interest' have been shown to hold antiquated beliefs, most resistant to current evidence.[26]

Radiology reporting has significant inter-observer variability,[27] for example agreement between radiologists and specialists is as low as 44% in shoulder MRI.[28] GPs cannot review images to clinically correlate findings, limited to written reports. Furthermore, GPs express low confidence in MSK conditions,[29] raising doubt over specialist diagnostic interpretation.

Lower disease prevalence in primary care results in lower yields from diagnostic strategies and guidelines have increasingly called for more selective imaging.[30 31] Additionally, investment in readily accessible and evidenced community MSK 'interface' triage services,[32–35] recommended in national MSK transformation strategy,[36] calls into question the need for continued GP-MSK-MRI access.

Utility of GP-MSK-MRI

One randomised controlled trial of knee MRI access almost two decades ago showed only modest improvement in GP confidence, with no change in diagnosis or treatment.[37] Cost-effectiveness was shown based on marginal, clinically non-significant improvements.[38 39] A recent multicentre randomised controlled trial demonstrated no difference in quality-of-life from GP knee-MRI, with no reduction in orthopaedic referrals, while lacking cost-effectiveness.[40]

Both studies relied on self-report for utilisation. Meta-analysis suggests little-to-no outcome benefit from GP MSK imaging.[41] Despite concerns around imaging overuse and iatrogenic downstream consequences,[42–44] we found no studies quantifying recent UK GP-MSK-MRI benefits or harms to inform commissioning decisions.[45]

AIMS & OBJECTIVES

This evaluation aimed to assess the utility of MSK-MRI in primary care, quantifying the appropriateness of use, interpretation and both therapeutic and harmful cascades, to inform local pathway development and improve patient safety as part of a sector-wide quality improvement initiative.

METHODS

Participants and design

Diagnostic suppliers provided activity data for January to December 2017 across three UK National Health Service (NHS) clinical commissioning groups (CCGs) in a metropolitan centre. Primary care records from invited practices were reviewed by clinical staff in this observational cohort evaluation of routinely collected data (retrospective study of prospectively collected data). A random number generator was used to select cases to avoid sampling bias. MRI request, results and least 12 months of follow-up records were required for inclusion.

Procedures and measures

Diagnostic 'value' goes beyond accuracy or direct-costs and evaluation frameworks cover accessibility, interpretation, as well as diagnostic and therapeutic yield (change in diagnosis and treatment based on results).[46 47] Therefore, patient characteristics were captured from records, along with timeframes, results, details of follow-up discussion, subsequent management or referral activity and outcomes from specialist referrals, including 'conversion rate' (patients receiving a specialist intervention). Conversion rate is a limited, yet accessible commonly adopted proxy measure for 'low-value' surgical or procedural MSK referrals, also highlighting therapeutic yield. Joint injections available in primary care were not considered specialist intervention.

Analysis

Assessing 'appropriateness' of requesting and interpretation is subjective.[45 48] Guidelines vary, often lacking detail, or setting-of-care. Data were reviewed by two clinicians. Reviewer one was a local GP, accredited in pain medicine, sector-wide commissioning policy chair for evidence appraisal and the local MSK and diagnostics clinical lead, managing pathway development. Reviewer two was a consultant extended-scope physiotherapist and clinical director of the local community MSK-interface service. Evaluators categorised imaging indication as 'likely, 'unclear' or 'unlikely'. Results were similarly classified as to whether they contained clinically relevant or incidental findings and whether GPs interpreted findings correctly, based on records and subsequent management. Categorisation was based on evaluators' expert opinion.

GP referral choices reflect their clinical impression. 'Procedural' referrals were classified as those sent directly for orthopaedic or spinal neurosurgical opinions, as well as to services for consideration of spinal injections . The local recommended pathway, to the physiotherapist-led community MSK-interface service, comprises triage and early patient access to physiotherapy, podiatry, rheumatology, orthopaedic and pain specialist expertise, with onward referral for surgical or secondary care input, where necessary. This interface service can also triage referrals following MRI findings, to direct appropriate patients to secondary care without additional consultation, based on results. Whilst there may be many reasons for a more specialist opinion, since such input is available within the community interface pathway, post-MRI GP referrals bypassing this recommended triage reflect setting an expectation of a structural target for which an interventional procedure may be likely. Such specialist opinions following MRI also carry a cost implication.

Cost–consequence and cost–utility analysis was performed based on recorded healthcare utilisation, which was recorded temporally as pre-MRI, peri-MRI (organised at the same clinical encounter as the MRI request) or post-MRI.

Descriptive and inferential statistics were computed in Microsoft Excel with Analysis ToolPak, using 'Wald method' two-tailed 95% CIs for proportion point estimates. χ^2 analysis was used to compare the audited sample against wider distribution of scans, while linear regression was used to compare practice imaging rate against appropriateness of imaging and interpretation. For both, p values were considered significant at the alpha level <0.05. Inter-rater reliability of all initial judgements by both evaluators was demonstrated both by weighted kappa measurement and percent agreement.[49]

Patient and public involvement

As part of local quality improvement in MSK pathway design, patient 'champions' and representatives from patient charity groups were interviewed. Patients echoed confusion over mixed messaging around their imaging results. The negative impact of clinician language was raised. Patients wanted more consistency than experienced, prompting this evaluation.

RESULTS

Patient and scan characteristics

During 2017, 6,621 MSK-MRIs were performed for a primary care population of approximately 670,000. The mean annual rate was 9.9 (range 0.2–31.8) GP-MSK-MRIs per-1,000 registered patients. Greater than 100-fold variation in requesting-rate reflects unwarranted variation in care.

Twelve cases were excluded due to incomplete records. A total of 306 MRI referrals (144 males and 162 females) were reviewed, requested by 105 different GPs and two

Table 2 Body part scans

	Scans within sample of GP-MSK-MRIs (342 body part scans for 306 referred patients)	Scans within all GP-MSK-MRIs (6,621 MRI referrals)
Cervical spine	11% (n=38)	16.1% (n=1,071)
Thoracic spine	4% (n=12)	5.7% (n=377)
Lumbar spine (inc. sacrum and sacroiliac joint)	28% (n=97)	40% (n=2,664)
Shoulder	4% (n=15)	7.3% (n=484)
Elbow	<1% (n=1)	<1% (n=48)
Wrist/hand/fingers	<1% (n=1)	1.9% (n=127)
Hip	6% (n=20) (4 × cases requested bilateral imaging)	6% (n=397)
Knee	40% (n=139) (4 × cases requested bilateral imaging)	35% (n=2,345)
Ankle/foot	4% (n=14) (2 × cases requests for bilateral imaging)	8.78% (n=581)
Other (sternum, sternoclavicular, brachial plexus, thoracic inlet, axillae, clavicle, scapula, upper arm, forearm, coccyx, groin, thigh, lower leg)	1% (n=5)	1.3% (n=84)

$\chi 2$ analysis of body parts in the sample against the distribution in all scans, revealed $x^2=9.54$, df=9 with p=0.388, that is, no significant difference, suggesting a sample representative of all MRIs.
GP, General practitioner (GP); MSK, musculoskeletal.

practice nurses across 29 practices, providing a 95% CI sampling error ≤5.6%. Practices covered a range of deprivation scores, from decile 2 to 9, including small (523) to large (19,533) list sizes, training and non-training practices, as well as high and low referrers. Median patient age was 53 (range 13–90, IQR 24 years). One-third of cases represented symptoms greater than 1 year, with remaining cases evenly distributed between acute (less than 7 days), 7–28 days, 29–84 days, 85–126 days and 127–365 days. Patient MRI request was documented in 37.0% (95% CI ±5.5%, n=113), including recommendations from private physiotherapists, social contacts or other specialties, such as emergency departments. Median wait-time from request to scan was 12 days (range 1–99 days). GPs prescribed sedation for 1.3% (95% CI±1.3%, n=4) and referred for open MRI in 0.3% (95% CI±0.6%, n=1). 23.9% (95% CI±4.8%, n=73) had prior imaging. 19.0% (95% CI±4.4%, n=58) had prior radiographs (most with degenerative changes), 2.3% (95% CI±1.7%, n=7) had prior MRI and 1.6% (95% CI±1.4%, n=5) had prior ultrasound. Conservative therapy (such as physical therapy or exercise) was documented in only 16.0% (95% CI±4.1%, n=49) prior to MRI. Body parts scanned are shown in table 2.

Growing demand has been met by increased supply, with routine scanning within 2 weeks. There is, however, fragmentation among a multiprovider landscape. Preappointment imaging was often not available at specialist consultation when carried out by alternate providers.

Direct imaging costs for the 306 patients came to £38,746.00, based on 2017/2018 NHS national tariff (local variation can exist).[50] This comprised 186 single area scans, 110 two or three part scans and 10 scans including more than three body parts.

Table 3 demonstrates prognostic flags for chronic pain.[51] 51.0% (95% CI±5.6%, n=156) had at least one psychosocial risk factor (orange, yellow, blue and black flags). During the study period, support, either from GP, mental health or third sector, was documented in only 11.8% (95% CI±6.3%, n=12) of the 101 chronic cases (symptoms >84 days) with orange flags (not including continuing ongoing medication).

MRI Ordering, Findings and Cascades

70.3% (95% CI±5.1%, n=215) of MRI requests directly copied GP records, varying in detail, often limited for robust vetting. Six requests were amended by radiology providers (two sacroiliac scans rejected and additional body parts added to four requests).

Table 4 shows indicated requests, incidental and relevant findings, as well as interpretation, along with initial inter-rater agreement. Only 16.3% (95% CI±6.2%, n=22) of 135 knee cases were traumatic, mostly low-energy twists or falls whilst walking. 63.0% (95% CI±8.1%, n=85) of knee patients were above age 50, with predominantly degenerative conditions.

Only 5.9% (95% CI±2.6%, n=18) of MRI results were unremarkable. 87.3% (95% CI±3.7%, n=267) likely contained incidental findings. 8.2% (95% CI±3.1%,

Table 3 Presence of 'flags' for musculoskeletal pain

Flag	Flag description	Cases where present and common themes
Red Flags	Signs of serious pathology, for example, fracture, malignancy	4.2% (95% CI ±2.3%, n=13) History of cancer, trauma, suspicious radiograph changes and urinary disturbance
Orange Flags	Psychiatric symptoms such as depression or personality disorder	42.5% (95% CI ±5.5%, n=130) Predominantly affective disorders of anxiety and depression, but also psychosis and substance dependence
Yellow Flags	Beliefs, emotional responses, pain behaviours, for example, catastrophising, avoidance behaviours, interest in passive treatments only, etc.	22.9% (95% CI ±4.7%, n=70) Fear avoidance (refusing physiotherapy without diagnosis) and negative structural beliefs about their condition
Blue Flags	Perceptions between occupational work and health, for example, that work or employers will cause further difficulty	18.0% (95% CI ±4.3%, n=55) Predominantly disputes with employers with majority medically signed off work long-term
Black Flags	Systemic obstacles, such as legal issues	8.0% (95% CI ±3.0%, n=23) Legal proceedings relating to assaults, road traffic accidents, marriage, disability or housing

n=25) had findings thought likely relevant to symptoms, with 42.9% (95% CI±5.5%, n=131) of unclear relevance to symptoms.

7.5% (95% CI±3.0%, n=23) never consulted for the issue again, likely reflecting self-resolution. Results were discussed with the same requesting clinician in only 47.1% (95% CI±5.6%, n=144) of cases.

GPs appeared to correctly interpret MRI changes, with appropriate advice and management in only 16.7% (95% CI±4.2%, n=51) of cases. MRI interpretation was unclear in 7.2% (95% CI±2.9%, n=22) and grossly erroneous in 68.6% (95% CI±5.2%, n=210), reflected by the high level of post-MRI procedural specialist referrals highlighted in yellow in table 5.

9.8% (95% CI ±3.3%, n=30) of patients had no associated referrals. 7.8% (95% CI ±3.0%, n=24) were safely, autonomously managed by the GP (without misdiagnosis, nor referral to other services).

66.7% (95% CI ±5.3%, n=204) of patients had 229 post-MRI referrals for suspected structural targets. These were to 'tier 2' MSK clinics and secondary care orthopaedic, neurosurgery, neurology (mis-referred for injection for radiculopathies) and pain clinics for spinal procedures. There were no referrals to pain services for

Table 4 MRI indication, results and interpretation of findings

		Likely	Unclear	Unlikely	Inter-rater agreement of initial independent assessments
Scan indicated		4.9% (95% CI ±2.4%, n=15)	9.8% (95% CI ±3.3%, n=30)	85.0% (95% CI ±4.0%, n=261)	Weighted kappa 0.23 (95% CI ±0.12), 78.6% (95% CI ±5.3%) observed agreement
Incidental findings present	5.9% (95% CI ±2.6%, n=18) unremarkable findings	87.3% (95% CI ±3.7%, n=267)	3.3% (95% CI ±2.0%, n=10)	3.6% (95% CI ±2.1%, n=11)	Weighted kappa 0.70 (95% CI ±0.11), 90.7% (95% CI ±4.0%) observed agreement
Clinically relevant findings present		8.2% (95% CI ±3.1%, n=25)	42.9% (95% CI ±5.5%, n=131)	43.1% (95% CI ±5.5%, n=132)	Weighted kappa 0.23 (95% CI ±0.08), 44.2% (95% CI ±5.6%) observed agreement
Findings interpreted correctly by GP	7.5% (95% CI ±3.0%, n=23) not discussed again	16.7% (95% CI ±4.2%, n=51)	7.2% (95% CI ±2.9%, n=22)	68.6% (95% CI ±5.2%, n=210)	Weighted kappa 0.84 (95% CI ±0.06), 90.2% (95% CI ±4.0%) observed agreement

GP, general practitioner.

Table 5 Associated referral activity for imaged patients

	Pre-MRI referrals	Peri-MRI referrals	Post-MRI referrals	First to follow-up ratio	First attendance unit cost	Follow-up unit cost	Episode of care cost	Total (costs)	Costs (post-MRI referrals only)
Community MSK interface (tier 1 physiotherapy):	31	35	52	1:3			£100.00	118 x £100.00 = £11,800.00	52 x £100.00 = £5,200.00
Community MSK interface (tier 2 'surgical or procedural'):	7	11	131	1:2			£125.00	149 × £125.00 = £18,625.00	131 x £125.00 = £16,375.00
Community MSK interface (tier 2 rheumatology):	0	1	2	1:3			£150.00	3 x £150.00 = £450.00	2 x £150.00 = £300.00
Secondary care referrals generated by MSK-interface Service:	0	0	7 × orthopaedic 2 × neurosurgery	1:1.8 1:1.6	£153.00 £198.00	£60.00 £73.00	£261.00 £314.80	(7 x £261.00) + (2 × £314.80) = £2,456.60	(7 x £261.00) + (2 × £314.80) = £2,456.60
Secondary care (orthopaedics):	0	0	59	1:1.8	£153.00	£60.00	£261.00	59 x £261.00 = £15,399.00	59 x £261.00 = £15,399.00
Secondary care (neurosurgery):	2	0	30	1:1.6	£198.00	£73.00	£314.80	32 x £314.80 = £10,0720.60	30 x £314.80 = £9,444.00
Secondary care (pain clinic):	0	1	3	1:2	£202.00	£72.00	£346.00	4 x £346.00 = £1,348.00	3 x £346.00 = £1,038.00
Secondary care (neurology):	0	0	6	1:1.6	£193.00	£97.00	£348.20	6 x £348.20 = £2,089.20	6 x £348.20 = £2,089.20
Secondary care (rheumatology):	1	0	7	1:3.9	£265.00	£89.00	£612.10	8 x £612.10 = £4,896.80	7 x £612.10 = £4,284.70
Secondary care (other):	1 × urology 1 × gastroenterology	0	1 × endocrinology 1 × general surgery	1:2					
Total:	41	48	299					£67,137.20	£56,586.50
Reasons for post-MRI GP 'procedural' referrals			**A wide range of findings underpinned post-MRI procedural opinion referrals. Common themes included: possible nerve root impingement from disc changes, stenosis due to arthropathy, or wedging of vertebrae in spinal imaging; meniscal tears, possible loose bodies, ganglion cysts or changes in anterior or medial collateral ligaments in knee imaging; gluteal medial tendonopathy in hip imaging; and subacromial bursitis or rotator cuff tears in shoulder imaging.**						

Post-MRI 'procedural' GP referrals for surgical or specialist injection opinions highlighted in yellow.
Table 5 ASSUMPTIONS:
1. First to follow-up ratios based on national 2017 hospital attendance data.[136]
2. Unit costs based on 2017 NHS national tariff costs.49 Secondary care costs are under-estimated as local market-forces-factor variation above national tariff was not included.
3. MSK first to follow-up ratios and episode of care costs, imaging and referral rates based on consensus of published evidence,[32] national tariff, published business cases[137 138] and local contract data (North West London CCGs 2018).
4. Community MSK-interface service tier 2 'surgical or procedural' referrals included those to extended scope physiotherapist orthopaedics as well as pain services for consideration of spinal injections.
5. Secondary care neurology was a frequent spurious GP referral pathway for suspected radiculopathic symptoms.
6. Non-MSK referrals not included in analysis totals.
MSK, musculoskeletal.

the documented purpose of a pain management or rehabilitation programme. Imaging can further fragment MSK care as 60.1% (95% CI ±5.5%, n=184) had multiple pre-MRI, peri-MRI or post-MRI referrals for the same condition. Many underwent GP-MSK-MRI while under concurrent care of other services. There was little-to-no documentation of patient-demand for post-MRI specialist referrals, nor of any shared decision-making.

Three 'false-positives' for serious disease (two cauda equina syndrome (CES)) and one osteomyelitis) in clinically unsuspicious cases, resulted in cascades of emergency referrals, further investigation, and patient distress. All were ultimately dismissed as clinically irrelevant. In low-prevalence settings, even highly specific tests result in high false-positive rates.

Therapeutic yield (change in treatment based on results) was 1.3% (95% CI ±1.3%, n=4). One patient received total knee replacement (which does not require MRI), with documented lack of benefit. One underwent cervical decompression for presumed radiculopathy, received no benefit, subsequently underwent cubital tunnel decompression, with no benefit, ultimately diagnosed with medically unexplained symptoms. Suprascapular nerve block for neck pain was offered but declined by one patient. One patient, diagnosed with knee osteoarthritis, which again does not require MRI, insisted on meniscectomy for a tear, rather than the arthroplasty recommended.

65.4% (95% CI ±5.3%, n=200) of imaged patients erroneously referred post-MRI directly for procedural opinions were not offered a specialist intervention; all ultimately advised to manage conditions conservatively. Their needs should have been met via the established community MSK-interface triage pathway, with tier 1 physiotherapy appropriate first-line management for the majority.

Of the 244 patients referred to physiotherapist-led services, 64.8% (95% CI ±6.0%, n=158) were only referred after MRI results, a median delay of 32 days. 10.8% (95% CI ±3.5%, n=33) of imaged patients were referred only to procedural secondary care pathways, waiting many months longer, only to be told they should receive physiotherapy.

Linear regression showed little correlation between practice imaging-rate and the rate of likely or unclear indicated requests (r=0.10, r^2=0.01, p=0.62), nor the rate of post-MRI 'low-value' cascades (r=0.24, r^2=0.06, p=0.20). Low imaging-rate practices had similar (in)appropriate requesting and cascades to high imaging-rate practices.

Cost-effectiveness

A cost–consequence analysis is shown in table 6, comparing GP direct access to MSK-MRI and secondary care referrals, versus the recommended community MSK-interface pathway for triage and management.

Patient satisfaction from imaging and potentially earlier referral of four surgical candidates from GP-MSK-MRI unlikely warrants the variation in care, fragmentation, significant misdiagnosis, as well as doubling of costs compared with a pathway where MRI responsibility is shifted further along the clinical journey, to the MSK-interface service (see table 6). GP-MRI direct costs were £38,746.00, while generating greater cascade costs of £53,135.20.

Additional therapeutic benefit for the GP-MSK-MRI pathway was only potentially demonstrated in one case of arthroscopic meniscectomy, for which quality-of-life-years (QALY) gain is 0.04 QALYs over a 9-year time horizon.[52] With a £69,332.90 cost difference between diagnostic strategies, the cost–utility incremental cost-effectiveness ratio is £1,733,322.50 (£69,332.90/0.04) per QALY for the GP-MSK-MRI diagnostic strategy, astronomically greater than UK willingness-to-pay thresholds of £20,000–30,000 per QALY.[53]

DISCUSSION

MRI ordering

Only 4.9% (95% CI ±2.4%, n=15) of MRIs appeared indicated. Patient demand, rather than clinical need, often influenced requesting. Causal structure-pain relationships are ambiguous, yet individuals often seek exact structural diagnoses.[54 55] These do not change management for the overwhelming majority of primary care presentations, based around education and goal-focused therapy. However, only 16.0% (95% CI ±4.1%, n=49) received conservative therapy prior to imaging.

While concern around sinister pathology may motivate imaging, no malignancy was identified in this, although limited, sample. UK guidelines[56] do not advocate GP-MSK-MRI for MSK malignancy, with alternate pathways for suspicious presentations. Furthermore, systematic review does not show faster time-to-cancer-diagnosis, nor improved outcomes, from GP advanced diagnostics.[57] Additionally, suspected CES requires same-day evaluation, not outpatient imaging. Of note, 'red-flags' lack validity and specificity in primary care, for example 80% of back pain patients may have at least one,[58] while 64% of those with malignancy may have none.[59]

GPs almost always documented CES screening in low back pain (despite being unlikely to ever see a true CES),[60] while rarely addressing highly prognostic psychosocial flags.[51 61–77] Most presentations were chronic, in itself not necessarily indication for imaging. The high burden of psychosocial distress seen reflects the bi-directional relationship between chronic pain and mental health.[78] Support for such potential recovery barriers was documented in only 11.8% (95% CI ±6.3%, n=12) of those with chronic pain and psychiatric illness. Poor clinician recognition of pain psychosocial factors is echoed in other studies.[54 79 80] Imaging overuse suggests practice wedded to the pathoanatomical approach alone, which may shift focus to irrelevant structural findings, distracting clinicians and patients from unmet psychosocial needs.

Spinal imaging was often requested for referred pain or minimal sensory symptoms, without suspicious features.

Table 6 Cost–consequence analysis

	Current pathway: gp direct-access to MSK-MRI +/– referral to community or secondary care MSK services	Alternate (recommended) pathway: all patients assessed in community MSK-interface triage service
Direct imaging costs	306 MRI referrals (£38,746.00) (see table 2)	10 MRI referrals (£11,600.00)
MRI follow-up appointment with GP	293 GP appointments (£8,790.00)	N/A
Community MSK-Interface referrals (tier 1)	118 referrals (£11,800.00)	245 referrals (£24,500.00)
Community MSK-Interface (tier 2 extended scope physiotherapists, orthopaedic, pain & rheumatology specialists)	149 x tier 2 (£18,625.00) 3 × tier 2 rheumatology (£450.00) = £19,075.00	61 referrals (£7,625.00)
Secondary care referrals	109 secondary care referrals (see table 5) = £33,805.00	9 × orthopaedic (£2,349.00) 3 × pain (£1,038.00) 2 × neurosurgery (£629.60) 1 × rheumatology (£612.10) = £4,628.70
MSK-service-generated secondary care referrals	9 MSK-generated referrals (£2 456.60)	(see row above)
Surgical procedures	1 × total knee replacement (£5,328.00) 1 × cervical decompression (£7,332.00) 1 × arthroscopic partial meniscectomy (£3,014.00) = £15,674.00	1 × total knee replacement (£5,328.00) 1 × cervical decompression (£7,332.00) = £12,660.00
Total pathway cost	**£130,346.60**	**£61,013.70**
	Cost difference of £69,332.90 between pathways	

Table 6 ASSUMPTIONS:
1. Unit and episode costs explained in table 5, based on 2017/2018 NHS National Tariff. GP costs based on NHS England report.[139]
2. Assumes all 306 patients are referred into community MSK-interface service. Estimates suggest 80% of patients are seen in tier 1 physiotherapy, 20% in tier 2 service, 5% referred on to secondary care and 3% have MRI organised, based on published data,[140] and local service contract data (North West London CCGs 2018).
3. Assumes no GP-access to MSK-MRI and that current 'bypassing' GP secondary care referrals would all be directed into the MSK service, as per local recommended pathway.
4. Procedure costs estimated from NHS national 2017/2018 reference costs.[141]
5. Since 90% of imaged patients were at some point seen in the community MSK-interface service, similar surgical outcomes can be assumed for both groups. However, a patient with osteoarthritic atraumatic knee pain, not willing for knee replacement, is unlikely to be referred for partial meniscectomy from the MSK service. Meniscectomy in osteoarthritis is not recommended by numerous guidelines, no better than physical therapy,[142] nor sham-surgery[24] and linked to earlier subsequent knee replacement.[143] Within the community MSK-interface service, MRI or surgical referral would have been unlikely, supported by local audit (Parkunan, Healthshare NHS Community MSK Services, 2018) showing no orthopaedic referrals for degenerative meniscal tears from the service.
GP, general practitioner; MSK, musculoskeletal; N/A, not applicable.

Identifying radicular symptoms is nuanced due to overlapping innervation territories, myotomal or sclerotomal pain referral and examination differences between small and large nerve fibres. Many conditions mimic neuropathy and there was no documented use of validated diagnostic tools such as the Leeds Assessment of Neuropathic Symptoms and Signs (LANSS) or the Douleur Neuropathique 4 (DN4). For foot, ankle or shoulder MRIs, ultrasound would often have been more appropriate, if necessary. Similarly, if required, plain radiographs should have replaced most knee MRIs for atraumatic elderly presentations. Many scans occurred for degenerative conditions in late decades, where MRI has a limited role.

Imaging interpretation, referrals and cascades

Only 5.9% (95% CI ±2.6%, n=18) of MRIs were unremarkable, reflecting ubiquitous (often incidental) findings. Incidental findings were also intra-abdominal, such as fibroids, haemangiomas and diverticular disease. With such high prevalence of imaging changes, imaging for reassurance is therefore problematic, despite contrary clinician beliefs.[54] Furthermore, evidence shows tests contribute little towards reassurance.[81 82] While some GPs hold MSK expertise, only half of results were discussed with the requesting clinician familiar with the presentation.

Only 16.7% (95% CI ±4.2%, n=51) of MRI reports appeared correctly interpreted. Most patients received pathoanatomical explanations, based on often incidental age-expected findings. Medicalising terminology reduces self-reported health,[83] increases anxiety, perceived severity and preference towards invasive management.[84] Structural disease-labelling can be nocebic, increasing fear-avoidance behaviours, perceptions that physical therapy is incompatible with recovery and over-reliance on surgical intervention.[7–12] This places pressure on specialists to subsequently re-frame engrained expectations away from a surgical fix. Negative patient cognitions,

which endure for years,[85] may influence MSK pain-related distress, disability and quality-of-life.[13]

GP referrals to surgical or pain interventional specialties have conversion-rates of 20%–30%,[34 86–90] whilst conversion is around 75% for referrals from MSK-interface services.[32 35 91] However, conversion to a procedure was only 1.9% (95% CI ±1.9%, n=4) for such GP referrals following MRI. MRI-access is unlikely to reduce referrals due to such deterioration in decision-making. While GP-MRI may reduce some community MSK-interface referrals, such pathways are more likely to benefit patients,[32] as well as being more cost-effective.

90.2% (95% CI ±3.3%, n=276) had one-or-more referrals to other services, equally capable of organising imaging, where appropriate, reflecting the additional input required beyond a test for persisting symptoms. GP-MSK-MRI does not appear to enable more autonomous management. Only 7.8% (95% CI ±3.0%, n=24) were safely managed within primary care, without misdiagnosis, overdiagnosis or further referral.

GP-MSK-MRI potentially accelerated procedures for 1.3% (95% CI ±1.3%, n=4) of imaged patients, of which only one improved, following a non-guideline intervention. However, erroneous over-perception of structural pathology resulted in delays, often of months, to appropriate care, with 'low-value' procedural referrals and potentially enduring negative perceptions for 65.4% (95% CI ±5.3%, n=200) of imaged patients. With a mean 9.9 MRI-scans per 1,000 GP-registered patients, we can extrapolate adverse consequences for 6.5 per 1,000 registered, or >4,000 patients annually across the study population. If misdiagnosis, mis-referral and delay-to-care are considered patient harm, the number-needed-to-harm (NNH) is only 1.5 (1/0.654). NNH is traditionally rounded-down, placing NNH at one for GP-MSK-MRI. Considering the likelihood-to-be-helped-versus-harmed metric,[92] (likelihood-of-benefit divided by likelihood-of-harm), the likelihood of therapeutic yield versus mismanagement from GP-MSK-MRI is as low as 0.02 (1.3/65.4). This is a limited metric, aggregating all gains and losses, but gives an approximation of the direction of trade-offs.

While MRI spending is a low proportion of MSK system costs,[93] cascades alter the economic analysis. Cascade costs were significantly greater than direct-imaging costs. There was little-to-no added therapeutic yield and compared with physiotherapist-led assessment services, both cost-consequence and a crude cost-utilty incremental cost-effectivenes ratio, do not justify GP-MSK-MRI funding. Cost-utility studies often neglect full costs, that is, all additional unindicated scans occurring for the small yield of patients who receive benefit, as well as unintended cascades.

Changing behaviour

Guidelines alone have limited impact, as over one-third of scans were lumbar, against 2016 National Institute for Health and Care Excellence recommendations against routine use in primary care.[30] Pressure from patients, other health professionals, defensive practice, risk-aversion, educational deficiencies and action-bias all drive 'low-value' testing. 'Illusory-causation' describes our propensity to perceive spurious causal relationships.[94] Widespread, often incidental, MRI findings create erroneous positive feedback to GPs, or 'belief-reinforcement', bolstering aberrant ordering behaviours. 'Harms' are not immediately tangible and without accurate real-time feedback, decision-making heuristics cannot be improved.

Benchmarking practice MRI-rates alone may be an inadequate quality-indicator as this lacked correlation to MRI appropriateness or interpretation. Education, incentives and behavioural 'nudges' within electronic ordering systems, may help, with limited impact.[95–98] While there is scope to improve radiology reporting,[99] benefit is mixed.[12 100] Educating on the low utility and potential harm of imaging, challenging beliefs and persuading that less-is-more, can be difficult, introducing back-fire and reactance effects.[54 101–103] This may be onerous within brief GP consultations, particularly when the majority expect imaging.[104]

Lack of access barriers or wait-time rationing can result in supply-induced demand. Per capita commissioned scanning capacity should be scrutinised, as supply-side volume controls can effectively contain inefficiencies.[105] Lack of clinical or cost-benefit, along with prevalent harm, invites consideration for GP-MSK-MRI deimplementation. Furthermore, the financial case underlying funding of MSK-interface services often includes assumptions around reduced imaging costs, unlikely to be realised with ongoing unfettered GP-MRI access.

Strengths and limitations

Random selection, with only 12 cases excluded, from a 1-year sample, diverse range of practices, clinicians and patients likely reflects UK practice.

Primary care records robustly capture healthcare utilisation, across providers and sectors. Records may not reflect real-world symptoms, nor consequences in all domains such as physical, psychological, social, financial, treatment burden and dissatisfaction.[106] Without patient-orientated outcome measures, the cost–utility assessments are largely estimated. Other studies, however, did not demonstrate significant quality-of-life benefits.[38–40] The cost–consequence estimates also compared against average activity patterns seen in the MSK-interface service, rather than a matched comparator group.

While we could not capture exact consultation dialogue, there was documentation in the majority of cases to demonstrate inaccurate perception of surgical targets, reflected by the subsequent higher-cost, triage-bypassing, direct referrals for surgical or procedural opinions.

Different cascades may be seen in regions without readily accessible MSK-interface pathways, which may themselves induce demand. While there was no difference between the two radiology providers, it may be worth evaluating more providers for potential reporting variation.

Separate evaluators mitigated individual rating bias inherent in measures based on expert opinion, without strict dichotomous criteria. There was only 'fair' agreement regarding MRI indication (k=0.23, 95% CI ±0.12) and clinical relevance of findings (k=0.23, 95% CI ±0.08), reflecting the subjective nature of such judgements. There was substantial agreement (k=0.70, 95% CI ±0.11) regarding incidental findings and almost perfect inter-rater agreement regarding result interpretation (k=0.84, 95% CI ±0.06). In all initial disagreement, consensus was achieved following further individual case review, including documented specialist consultations. Despite subjectivity of some measures, the extreme outcomes are unlikely explained by evaluator bias alone.

We did not have a comparator group of non-imaged patients. However, we could contrast against conventional GP referral conversion rates, including those without MSK-MRI access. The high proportion of 'low-value' post-MRI referrals could be related to confounding characteristics of imaged patients. However, such a high rate of referral cascades with near-zero conversion, provides convincing signal on the disutility of post-MRI care in this setting, even without comparator analysis.

Summary and policy implications

Structural pathology can change management, and imaging is useful in trauma, investigating rare sinister disease, or guiding specific procedures. Whilst judicious imaging with qualified interpretation no doubt occurs within primary care, this appears to be infrequent. Expanding MRI use outside of specialist settings is problematic, with significant imaging indication creep in primary care. Widespread 'biostatistically normal-for-age', or activity-related expected findings, along with a shift away from conventional surgical approaches, creates a salient problem of GPs overperceiving spurious surgical or procedural targets from imaging reports. MRI may appease biases underlying clinician autonomy and patient satisfaction, yet generates aggregate harm, through misdiagnosis and overdiagnosis. Imaging stewardship and improving the mixed messaging around results are priorities. Whilst a tiny fraction of patients may receive earlier surgery through GP-MSK-MRI, this is eclipsed by negative consequences for the vast majority. Less than two patients require MRI in primary care for one to suffer avoidable low-value cascades. As well as resource waste, this generates delay to appropriate care along with potentially nocebic patient perceptions impacting management and outcomes, which can endure for years. Such consequences raise overlooked safety and effectiveness concerns across currently commissioned imaging services. GP-MSK-MRI deimplementation may be appropriate, shifting scanning capacity to community-based MSK services in the UK. This will likely be more clinically and cost-effective, reducing iatrogenic harm and enabling primary care to focus on unmet psychosocial patient needs and delivering guideline care.

Twitter Imran Mohammed Sajid @imransajid

Acknowledgements We would like to thank Healthshare Community NHS Musculoskeletal Services for their collaboration with NHS clinical commissioners on this quality improvement work and supporting the open-access fees to improve accessibility for policy makers.

Contributors IMS (commissioning clinical lead) and KF (diagnostics programme lead) led the diagnostics optimisation and quality, innovation, productivity and prevention (QIPP) programmes for the NWL collaboration of clinical commissioning groups, under which this evaluation was carried out. IMS and AP (clinical director of MSK service) both acted as evaluators for key measures in the data analysis. All authors had input in design of the key measures. IMS drafted the manuscript which was reviewed and edited by AP and KF.

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not required.

Ethics approval This evaluation was undertaken as part of the NWL CCG diagnostics optimisation and quality, innovation, productivity and prevention (QIPP) transformation programmes. No patient identifiable data were shared outside of clinicians involved in patient care. Data were handled in accordance with locally published CCG fair processing policies. As a service development evaluation based on routinely collected data, by those involved in patient care, further ethics approval from NHS Research Authority was not required as per the NHS Health Research Authority online decision tool based on the UK Policy Framework for Health and Social Care Research.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Deidentified data can be made available on reasonable request from the corresponding author, ORCID ID 0000-0002-0332-9704.

ORCID iD

Imran Mohammed Sajid http://orcid.org/0000-0002-0332-9704

REFERENCES

1 Downie A, Hancock M, Jenkins H, *et al*. How common is imaging for low back pain in primary and emergency care? Systematic review and meta-analysis of over 4 million imaging requests across 21 years. Br J Sports Med 2020;54:642–51.
2 Lewis J, O'Sullivan P, O'Sullivan P. Is it time to reframe how we care for people with non-traumatic musculoskeletal pain? Br J Sports Med 2018;52:1543–4.
3 Zadro JR, Décary S, O'Keeffe M, *et al*. Overcoming overuse: improving musculoskeletal health care. J Orthop Sports Phys Ther 2020;50:113–5.
4 Webster BS, Bauer AZ, Choi Y, *et al*. Iatrogenic consequences of early magnetic resonance imaging in acute, work-related, disabling low back pain. Spine 2013;38:1939–46.
5 Graves JM, Fulton-Kehoe D, Jarvik JG, *et al*. Early imaging for acute low back pain. Spine 2012;37:1617–27.
6 Stevans JM, Delitto A, Khoja SS, *et al*. Risk factors associated with transition from acute to chronic low back pain in US patients seeking primary care. JAMA Netw Open 2021;4:e2037371.
7 O'Leary H, Ryan LG, Robinson K, *et al*. "You'd be better off to do the keyhole and make a good job of it" a qualitative study of the beliefs and treatment expectations of patients attending secondary care with degenerative meniscal tears. Musculoskelet Sci Pract 2021;51:102281.
8 I R de Oliveira B, Smith AJ, O'Sullivan PPB, *et al*. 'My hip is damaged': a qualitative investigation of people seeking care for persistent hip pain. Br J Sports Med 2020;54:858–65.

9 Cuff A, Littlewood C. Subacromial impingement syndrome - What does this mean to and for the patient? A qualitative study. Musculoskelet Sci Pract 2018;33:24–8.
10 Malliaras P, Rathi S, Burstein F, *et al*. 'Physio's not going to repair a torn tendon': patient decision-making related to surgery for rotator cuff related shoulder pain. Disabil Rehabil 2021:1–8.
11 Zadro JR, O'Keeffe M, Ferreira GE, *et al*. Diagnostic Labels for Rotator Cuff Disease Can Increase People's Perceived Need for Shoulder Surgery: An Online Randomized Controlled Experiment. J Orthop Sports Phys Ther 2021:1–45.
12 Rajasekaran S, DilipChandRajaS, Pushpa BT. The catastrophization effects of an MRI report on the patient and surgeon and the benefits of 'clinical reporting': results from an RCT and blinded trials. Eur Spine J Published Online First 2021.
13 Luque-Suarez A, Martinez-Calderon J, Falla D. Role of kinesiophobia on pain, disability and quality of life in people suffering from chronic musculoskeletal pain: a systematic review. Br J Sports Med 2019;53:554–9.
14 Hayward R. VOMIT (victims of modern imaging technology)--an acronym for our times. BMJ 2003;326:1273.
15 Najim R, Booth TC, Petkova H. Incidental findings (IFs) discovered during imaging: the impact on primary care. Br J Gen Pract 2018;68:bjgp18X696725.
16 Kapur B, Marlow W, Carroll A, *et al*. What has been the role for MRI scanning of the knee in primary care? Int J Surg 2015;23:S89.
17 Deveza LA, Matthews L, O'Connell R, *et al*. Is the use of knee magnetic resonance imaging one of the drivers of persistently high arthroscopy rates in older adults? – an analysis of national data in Australia. Osteoarthr Cartil 2018;26:S249.
18 Sajid IM, Frost K, Paul AK. 'Diagnostic downshift': clinical and system consequences of extrapolating secondary care testing tactics to primary care. *BMJ Evid Based Med* 2021. doi:10.1136/bmjebm-2020-111629. [Epub ahead of print: 07 Jun 2021].
19 Lähdeoja T, Karjalainen T, Jokihaara J, *et al*. Subacromial decompression surgery for adults with shoulder pain: a systematic review with meta-analysis. Br J Sports Med 2020;54:665–73.
20 Vandvik PO, Lähdeoja T, Ardern C, *et al*. Subacromial decompression surgery for adults with shoulder pain: a clinical practice guideline. BMJ 2019;55:l294.
21 Boorman RS, More KD, Hollinshead RM, *et al*. What happens to patients when we do not repair their cuff tears? five-year rotator cuff quality-of-life index outcomes following nonoperative treatment of patients with full-thickness rotator cuff tears. J Shoulder Elbow Surg 2018;27:444–8.
22 Schrøder CP, Skare Øystein, Reikerås O, *et al*. Sham surgery versus labral repair or biceps tenodesis for type II slap lesions of the shoulder: a three-armed randomised clinical trial. Br J Sports Med 2017;51:1759–66.
23 , Ayeni OR, Karlsson J, *et al*, Femoroacetabular Impingement Randomized Controlled Trial (FIRST) Investigators. Osteochondroplasty and Labral repair for the treatment of young adults with femoroacetabular impingement: a randomized controlled trial. Am J Sports Med 2021;49:0363546520952805.
24 Sihvonen R, Paavola M, Malmivaara A. Arthroscopic partial meniscectomy versus placebo surgery for a degenerative meniscus tear: a 2-year follow-up of the randomised controlled trial. Ann Rheum Dis 2017;77:1–9.
25 Iacobucci G. NHS proposes to stop funding 17 'unnecessary' procedures. BMJ 2018;362:k2903.
26 Buchbinder R, Staples M, Jolley D. Doctors with a special interest in back pain have poorer knowledge about how to treat back pain. Spine 2009;34:1218–26.
27 Herzog R, Elgort DR, Flanders AE, *et al*. Variability in diagnostic error rates of 10 MRI centers performing lumbar spine MRI examinations on the same patient within a 3-week period. Spine J 2017;17:554–61.
28 Barreto RPG, Braman JP, Ludewig PM, Camargo PR, *et al*. Bilateral magnetic resonance imaging findings in individuals with unilateral shoulder pain. J Shoulder Elbow Surg 2019;28:1699–706.
29 Goff I, Wise EM, Coady D, *et al*. Musculoskeletal training: are GP trainees exposed to the right case mix for independent practice? Clin Rheumatol 2016;35:507–11.
30 National Institute for Health and Care Excellence. Low back pain and sciatica in over 16S: assessment and management, 2016. Available: https://www.nice.org.uk/guidance/ng59
31 Hall AM, Aubrey-Bassler K, Thorne B, *et al*. Do not routinely offer imaging for uncomplicated low back pain. BMJ 2021;372:n291.
32 Hussenbux A, Morrissey D, Joseph C, *et al*. Intermediate care pathways for musculoskeletal conditions--are they working? A systematic review. Physiotherapy 2015;101:13–24.
33 Babatunde OO, Bishop A, Cottrell E, *et al*. A systematic review and evidence synthesis of non-medical triage, self-referral and direct access services for patients with musculoskeletal pain. PLoS One 2020;15:e0235364.
34 Bernstein I. Musculoskeletal services in Ealing 2013: care closer to home. Int Musculoskelet Med 2013;35:131–40.
35 Burn D, Beeson E. Orthopaedic triage: cost effectiveness, diagnostic/surgical and management rates. Clin Gov 2014;19:126–36.
36 NHS England. Transforming musculoskeletal and orthopaedic elective care services, 2017. Available: https://www.england.nhs.uk/publication/transforming-musculoskeletal-and-orthopaedic-elective-care-services
37 Brealey SD, DAMASK (Direct Access to Magnetic Resonance Imaging: Assessment for Suspect Knees) Trial Team. Influence of magnetic resonance of the knee on GPs' decisions: a randomised trial. Br J Gen Pract 2007;57:622–9.
38 Andronis L, Atwell C, Brealey S, *et al*. Effectiveness of GP access to magnetic resonance imaging of the knee: a randomised trial. Br J Gen Pract 2008;58:767–74.
39 Andronis L, Atwell C, Brealey S, *et al*. Cost-effectiveness of magnetic resonance imaging of the knee for patients presenting in primary care. Br J Gen Pract 2008;58:775–8.
40 van Oudenaarde K, Swart NM, Bloem JL, *et al*. General practitioners referring adults to MR imaging for knee pain: a randomized controlled trial to assess cost-effectiveness. Radiology 2018;288:170–6.
41 Karel YHJM, Verkerk K, Endenburg S, *et al*. Effect of routine diagnostic imaging for patients with musculoskeletal disorders: a meta-analysis. Eur J Intern Med 2015;26:585–95.
42 Darlow B, Forster BB, O'Sullivan K, *et al*. It is time to stop causing harm with inappropriate imaging for low back pain. Br J Sports Med 2017;51:414–5.
43 Deyo RA. Cascade effects of medical technology. Annu Rev Public Health 2002;23:23–44.
44 Webster BS, Choi Y, Bauer AZ, *et al*. The cascade of medical services and associated longitudinal costs due to nonadherent magnetic resonance imaging for low back pain. Spine 2014;39:1433–40.
45 Jenkins HJ, Downie AS, Maher CG, *et al*. Imaging for low back pain: is clinical use consistent with guidelines? A systematic review and meta-analysis. Spine J 2018;18:2266–77.
46 Ferrante di Ruffano L, Hyde CJ, McCaffery KJ, *et al*. Assessing the value of diagnostic tests: a framework for designing and evaluating trials. BMJ 2012;344:e686.
47 Horvath AR, Lord SJ, StJohn A, *et al*. From biomarkers to medical tests: the changing landscape of test evaluation. Clin Chim Acta 2014;427:49–57.
48 Yates M, Oliveira CB, Galloway JB, *et al*. Defining and measuring imaging appropriateness in low back pain studies: a scoping review. Eur Spine J 2020;29:519–29.
49 McHugh ML. Interrater reliability: the kappa statistic. Biochem Med 2012;22:276–82.
50 NHS Improvement. Proposed national tariff prices: planning for 2017/18 and 2018/19 | NHS Improvement. Available: https://improvement.nhs.uk/resources/proposed-national-tariff-prices-1718-1819
51 Nicholas MK, Linton SJ, Watson PJ, *et al*. Early identification and management of psychological risk factors ("yellow flags") in patients with low back pain: a reappraisal. Phys Ther 2011;91:737–53.
52 Rongen JJ, Govers TM, Buma P, *et al*. Arthroscopic meniscectomy for degenerative meniscal tears reduces knee pain but is not cost-effective in a routine health care setting: a multi-center longitudinal observational study using data from the osteoarthritis initiative. Osteoarthritis Cartilage 2018;26:184–94.
53 Nice, National Institute for Health and Care Excellence, Nice. How NICE measures value for money in relation to public health interventions. *NICE local goverment briefings*;1–9, 2013. Available: http://publications.nice.org.uk/how-nice-measures-value-for-money-in-relation-to-public-health-interventions-lgb10b/introduction
54 Hall AM, Scurrey SR, Pike AE, *et al*. Physician-reported barriers to using evidence-based recommendations for low back pain in clinical practice: a systematic review and synthesis of qualitative studies using the theoretical domains framework. Implement Sci 2019;14:49.
55 Sharma S, Traeger AC, Reed B, *et al*. Clinician and patient beliefs about diagnostic imaging for low back pain: a systematic qualitative evidence synthesis. BMJ Open 2020;10:e037820.

56 NICE. Suspected cancer: recognition and referral. NICE guideline NG12, 2015. Available: https://www.nice.org.uk/guidance/ng12 [Accessed 20 Feb 2021].
57 Smith CF, Tompson AC, Jones N, *et al*. Direct access cancer testing in primary care: a systematic review of use and clinical outcomes. Br J Gen Pract 2018;68:e594–603.
58 Henschke N, Maher CG, Refshauge KM, *et al*. Prevalence of and screening for serious spinal pathology in patients presenting to primary care settings with acute low back pain. Arthritis Rheum 2009;60:3072–80.
59 Premkumar A, Godfrey W, Gottschalk MB, *et al*. Red flags for low back pain are not always really red. The Journal of Bone and Joint Surgery 2018;100:368–74.
60 Lavy C, James A, Wilson-MacDonald J, *et al*. Cauda equina syndrome. BMJ 2009;338:b936.
61 Chester R, Jerosch-Herold C, Lewis J, *et al*. Psychological factors are associated with the outcome of physiotherapy for people with shoulder pain: a multicentre longitudinal cohort study. Br J Sports Med 2018;52:269–75.
62 George SZ, Beneciuk JM. Psychological predictors of recovery from low back pain: a prospective study. BMC Musculoskelet Disord 2015;16:49.
63 Lewis GN, Rice DA, McNair PJ, *et al*. Predictors of persistent pain after total knee arthroplasty: a systematic review and meta-analysis. Br J Anaesth 2015;114:551–61.
64 Deveza LA, Melo L, Yamato TP, *et al*. Knee osteoarthritis phenotypes and their relevance for outcomes: a systematic review. Osteoarthritis Cartilage 2017;25:1926–41.
65 Iijima H, Aoyama T, Fukutani N, *et al*. Psychological health is associated with knee pain and physical function in patients with knee osteoarthritis: an exploratory cross-sectional study. BMC Psychol 2018;6:19.
66 Riddle DL, Kong X, Fitzgerald GK. Psychological health impact on 2-year changes in pain and function in persons with knee pain: data from the osteoarthritis initiative. Osteoarthritis Cartilage 2011;19:1095–101.
67 Akin-Akinyosoye K, Sarmanova A, Fernandes GS, *et al*. Baseline self-report 'central mechanisms' trait predicts persistent knee pain in the Knee Pain in the Community (KPIC) cohort. Osteoarthritis Cartilage 2020;28:173–81.
68 Denison E, Åsenlöf P, Lindberg P. Self-efficacy, fear avoidance, and pain intensity as predictors of disability in subacute and chronic musculoskeletal pain patients in primary health care. Pain 2004;111:245–52.
69 Wylie JD, Suter T, Potter MQ, *et al*. Mental health has a stronger association with patient-reported shoulder pain and function than tear size in patients with full-thickness rotator cuff tears. J Bone Joint Surg 2016;98:251–6.
70 Smedbråten K, Øiestad BE, Røe Y. Emotional distress was associated with persistent shoulder pain after physiotherapy: a prospective cohort study. BMC Musculoskelet Disord 2018;19:1–8.
71 Mallen CD, Peat G, Thomas E, *et al*. Prognostic factors for musculoskeletal pain in primary care: a systematic review. Br J Gen Pract 2007;57:655–61.
72 Hill JC, Afolabi EK, Lewis M, *et al*. Does a modified start back tool predict outcome with a broader group of musculoskeletal patients than back pain? a secondary analysis of cohort data. BMJ Open 2016;6:12445.
73 Alhowimel A, AlOtaibi M, Radford K, *et al*. Psychosocial factors associated with change in pain and disability outcomes in chronic low back pain patients treated by physiotherapist: a systematic review. SAGE Open Med 2018;6:205031211875738.
74 Linton SJ. Occupational psychological factors increase the risk for back pain: a systematic review. J Occup Rehabil 2001;11:53–66.
75 Vlaeyen JWS, Crombez G, Linton SJ. The fear-avoidance model of pain. Pain 2016;157:1588–9.
76 Pincus T, Burton AK, Vogel S, *et al*. A systematic review of psychological factors as predictors of chronicity/disability in prospective cohorts of low back pain. Spine 2002;27:E109–20.
77 van der Hulst M, Vollenbroek-Hutten MMR, Ijzerman MJ. A systematic review of sociodemographic, physical, and psychological predictors of multidisciplinary rehabilitation-or, back school treatment outcome in patients with chronic low back pain. Spine 2005;30:813–25.
78 Mills SEE, Nicolson KP, Smith BH. Chronic pain: a review of its epidemiology and associated factors in population-based studies. Br J Anaesth 2019;123:e273:83–283.
79 Baker B, Kessler K, Kaiser B, *et al*. Non-traumatic musculoskeletal pain in Western Australian hospital emergency departments: a clinical audit of the prevalence, management practices and evidence-to-practice gaps. Emerg Med Australas 2019;31:1037–44.
80 Potier T, Tims E, Kilbride C, *et al*. Evaluation of an evidence based quality improvement innovation for patients with musculoskeletal low back pain in an accident and emergency setting. BMJ Qual Improv Rep 2015;4:u205903.w2411.
81 Rolfe A, Burton C. Reassurance after diagnostic testing with a low pretest probability of serious disease: systematic review and meta-analysis. JAMA Intern Med 2013;173:407–16.
82 van Ravesteijn H, van Dijk I, Darmon D, *et al*. The reassuring value of diagnostic tests: a systematic review. Patient Educ Couns 2012;86:3–8.
83 Jørgensen P, Langhammer A, Krokstad S, *et al*. Diagnostic labelling influences self-rated health. A prospective cohort study: the HUNT study, Norway. Fam Pract 2015;32:492–9.
84 Nickel B, Barratt A, Copp T, *et al*. Words do matter: a systematic review on how different terminology for the same condition influences management preferences. BMJ Open 2017;7:e014129.
85 Darlow B, Dowell A, Baxter GD, *et al*. The enduring impact of what clinicians say to people with low back pain. Ann Fam Med 2013;11:527–34.
86 Bernstein I. Integrated musculoskeletal service design by GP consortia. London J Prim Care 2011;4:16–26.
87 Napier C, McCormack RG, Hunt MA, *et al*. A physiotherapy triage service for orthopaedic surgery: an effective strategy for reducing wait times. Physiother Can 2013;65:358–63.
88 Bath B, Grona SL, Janzen B. A spinal triage programme delivered by physiotherapists in collaboration with orthopaedic surgeons. Physiother Can 2012;64:356–66.
89 Hourigan PG, Weatherley CR. Initial assessment and follow-up by a physiotherapist of patients with back pain referred to a spinal clinic. J R Soc Med 1994;87:213–4.
90 Mayman D, Yen D. Maximizing use of a surgical clinic for referrals of patients having back problems. Can J Surg 1999;42:117–9.
91 Griffiths S, Taylor C, Yohannes AM. Conversion rates and perceived barriers to referral: views of extended scope physiotherapists in the primary care setting. Musculoskeletal Care 2012;10:221–31.
92 Citrome L, Ketter TA. When does a difference make a difference? Interpretation of number needed to treat, number needed to harm, and likelihood to be helped or harmed. Int J Clin Pract 2013;67:407–11.
93 Burgess R, Hall J, Bishop A, *et al*. Costing methodology and key drivers of health care costs within economic analyses in musculoskeletal community and primary care services: a systematic review of the literature. J Prim Care Community Health 2020;11:215013271989976.
94 Lilienfeld SO, Ritschel LA, Lynn SJ, *et al*. Why ineffective psychotherapies appear to work: a taxonomy of causes of spurious therapeutic effectiveness. Perspect Psychol Sci 2014;9:355–87.
95 TB V, Underwood M, Mohamed N. Professional interventions for general practitioners on the management of musculoskeletal conditions (review). Cochrane Database of Systematic Reviews 2016.
96 Ip IK, Gershanik EF, Schneider LI, *et al*. Impact of IT-enabled intervention on MRI use for back pain. Am J Med 2014;127:512-8.e1.
97 Main C, Moxham T, Wyatt JC, *et al*. Computerised decision support systems in order communication for diagnostic, screening or monitoring test ordering: systematic reviews of the effects and cost-effectiveness of systems. Health Technol Assess 2010;14:1–227.
98 Goldzweig CL, Orshansky G, Paige NM, *et al*. Electronic health record-based interventions for improving appropriate diagnostic imaging: a systematic review and meta-analysis. Ann Intern Med 2015;162:557–65.
99 Farmer CI, Bourne AM, O'Connor D, *et al*. Enhancing clinician and patient understanding of radiology reports: a scoping review of international guidelines. Insights Imaging 2020;11:62.
100 Suri P, Meier EN, Gold LS, *et al*. Providing epidemiological data in lumbar spine imaging reports did not affect subsequent utilization of spine procedures: secondary outcomes from a Stepped-Wedge randomized controlled trial. Pain Med 2021;22:1272–80.
101 Traeger AC. Persuading the public that less is more. BMJ 2018;2956:k2956–1.
102 Sharma S, Traeger AC, O'Keeffe M, *et al*. Effect of information format on intentions and beliefs regarding diagnostic imaging for non-specific low back pain: a randomised controlled trial in members of the public. Patient Educ Couns 2021;104:595–602.
103 Sharma S, Traeger AC, Tcharkhedian E. I would not go to him": Focus groups exploring community responses to a public health campaign aimed at reducing unnecessary diagnostic imaging of low back pain. Heal Expect 2021;00:hex.13211.

104 Jenkins HJ, Hancock MJ, Maher CG, *et al*. Understanding patient beliefs regarding the use of imaging in the management of low back pain. Eur J Pain 2016;20:573–80.
105 Stadhouders N, Kruse F, Tanke M, *et al*. Effective healthcare cost-containment policies: a systematic review. Health Policy 2019;123:71–9.
106 Korenstein D, Chimonas S, Barrow B, *et al*. Development of a conceptual map of negative consequences for patients of overuse of medical tests and treatments. JAMA Intern Med 2018;178:1401–7.
107 Nakashima H, Yukawa Y, Suda K, *et al*. Abnormal findings on magnetic resonance images of the cervical spines in 1211 asymptomatic subjects. Spine 2015;40:392–8.
108 Abdalkader M, Guermazi A, Engebretsen L, *et al*. Mri-detected spinal disc degenerative changes in athletes participating in the Rio de Janeiro 2016 summer Olympics games. BMC Musculoskelet Disord 2020;21:45.
109 Gill TK, Shanahan EM, Allison D, *et al*. Prevalence of abnormalities on shoulder MRI in symptomatic and asymptomatic older adults. *Int J Rheum Dis* 2014;17:863–71.
110 Sher JS, Uribe JW, Posada A, *et al*. Abnormal findings on magnetic resonance images of asymptomatic shoulders. *J Bone Joint Surg Am* 1995;77:10–15.
111 Schwartzberg R, Reuss BL, Burkhart BG, *et al*. High prevalence of superior labral tears diagnosed by MRI in middle-aged patients with asymptomatic shoulders. Orthop J Sports Med 2016;4:232596711562321.
112 Lee CS, Goldhaber NH, Davis SM, *et al*. Shoulder MRI in asymptomatic elite volleyball athletes shows extensive pathology. J Isakos 2020;5:10–14.
113 Pennock AT, Dwek J, Levy E, *et al*. Shoulder MRI abnormalities in asymptomatic little League baseball players. Orthop J Sports Med 2018;6:232596711875682.
114 Tran G, Cowling P, Smith T, *et al*. What Imaging-Detected pathologies are associated with shoulder symptoms and their persistence? A systematic literature review. Arthritis Care Res 2018;70:1169–84.
115 Brinjikji W, Luetmer PH, Comstock B, *et al*. Systematic literature review of imaging features of spinal degeneration in asymptomatic populations. AJNR Am J Neuroradiol 2015;36:811–6.
116 Kalichman L, Cole R, Kim DH, *et al*. Spinal stenosis prevalence and association with symptoms: the Framingham study. Spine J 2009;9:545–50.
117 Ishimoto Y, Yoshimura N, Muraki S, *et al*. Associations between radiographic lumbar spinal stenosis and clinical symptoms in the general population: the Wakayama spine study. Osteoarthritis Cartilage 2013;21:783–8.
118 Alyas F, Turner M, Connell D. Mri findings in the lumbar spines of asymptomatic, adolescent, elite tennis players. *Br J Sports Med* 2007;41:836–41.
119 van den Heuvel MM, Oei EHG, Bierma-Zeinstra SMA, *et al*. The prevalence of abnormalities in the pediatric spine on MRI: a systematic review and meta-analysis. *Spine* 2020;45:E1185–96.
120 Register B, Pennock AT, Ho CP, *et al*. Prevalence of abnormal hip findings in asymptomatic participants: a prospective, blinded study. Am J Sports Med 2012;40:2720–4.
121 Briggs K, Philippon M, Ho C, *et al*. Prevalence of acetabular LABRAL tears in asymptomatic young athletes. Br J Sports Med 2017;51:303.1–303.
122 Blankenstein T, Grainger A, Dube B, *et al*. MRI hip findings in asymptomatic professional rugby players, ballet dancers, and age-matched controls. Clin Radiol 2020;75:116–22.
123 Kim C-H, Park JI, Shin DJ, *et al*. Prevalence of radiologic acetabular dysplasia in asymptomatic Asian volunteers. J Hip Preserv Surg 2019;6:55–9.
124 Yoon P, Kim C, Park J. Prevalence of radiologic hip dysplasia in asymptomatic Korean volunteers. Orthop Proc 2018;100-B.
125 Heerey JJ, Kemp JL, Mosler AB, *et al*. What is the prevalence of imaging-defined intra-articular hip pathologies in people with and without pain? A systematic review and meta-analysis. Br J Sports Med 2018;52:581–93.
126 Englund M, Guermazi A, Gale D, *et al*. Incidental meniscal findings on knee MRI in middle-aged and elderly persons. N Engl J Med 2008;359:1108–15.
127 Horga LM, Hirschmann AC, Henckel J, *et al*. Prevalence of abnormal findings in 230 knees of asymptomatic adults using 3.0 T MRI. *Skeletal Radiol* 2020;49:1099–107.
128 Culvenor AG, Øiestad BE, Hart HF. Prevalence of knee osteoarthritis features on magnetic resonance imaging in asymptomatic uninjured adults: a systematic review and meta-analysis. Br J Sports Med 2018;53:1–12.
129 Bergman AG, Fredericson M, Ho C, *et al*. Asymptomatic tibial stress reactions: MRI detection and clinical follow-up in distance runners. Am J Roentgenol 2004;183:635–8.
130 Yao W, Zhang Y, Zhang L, *et al*. MRI features of and factors related to ankle injuries in asymptomatic amateur marathon runners. Skeletal Radiol 2021;50:87–95.
131 Saxena A, Luhadiya A, Ewen B, *et al*. Magnetic resonance imaging and incidental findings of lateral ankle pathologic features with asymptomatic ankles. J Foot Ankle Surg 2011;50:413–5.
132 Joseph O'Neil, Elizabeth M, Talia C, *et al*. Anterior Talofibular ligament abnormalities on routine magnetic resonance imaging of the ankle. *Foot & Ankle Orthopaedics* 2017;2.
133 Lohman M, Kivisaari A, Vehmas T, *et al*. MRI abnormalities of foot and ankle in asymptomatic, physically active individuals. Skeletal Radiol 2001;30:61–6.
134 Espinosa N, Schmitt JW, Saupe N, *et al*. Morton neuroma: MR imaging after resection--postoperative MR and histologic findings in asymptomatic and symptomatic intermetatarsal spaces. Radiology 2010;255:850–6.
135 Bencardino J, Rosenberg ZS, Beltran J. Morton's neuroma: Is it always symptomatic. Am J Roentgenol 2000;175:649–53.
136 NHS Digital. Hospital Outpatient Activity, 2017-18 - NHS Digital, 2018. Available: https://digital.nhs.uk/data-and-information/publications/statistical/hospital-outpatient-activity/2017-18
137 Ealing Clinical Commissioning Group. Ealing CCG Governing Body. MSK Pathway Redesign - Business Case. London, 2013. Available: https://www.ealingccg.nhs.uk/media/1645/Paper-9-MSK_Business_Case_v5-1-20130319-JW-sign-off.pdf
138 Oxfordshire Clinical Commissioning Group. Oxfordshire CCG. Full Business Case - Integrating Musculoskeletal Services, 2017. Available: https://www.oxfordshireccg.nhs.uk/documents/work programmes/msk-business-case.pdf
139 NHS England. Missed GP appointments costing NHS millions. Available: https://www.england.nhs.uk/2019/01/missed-gp-appointments-costing-nhs-millions
140 Allan P, Dekka C, Brown R. Impact of an advanced physiotherapy practitioner-led pilot community spinal MSK service. Physiotherapy 2017;103:e121.
141 NHS Improvement. Archived reference costs | 2017/2018 reference costs and guidance, 2018. Available: https://improvement.nhs.uk/resources/reference-costs
142 van de Graaf VA, Noorduyn JCA, Willigenburg NW, *et al*. Effect of early surgery vs physical therapy on knee function among patients with nonobstructive meniscal tears: the escape randomized clinical trial. JAMA 2018;320:1328–37.
143 Navarro RA, Adams AL, Lin CC, *et al*. Does knee arthroscopy for treatment of meniscal damage with osteoarthritis delay knee replacement compared to physical therapy alone? Clin Orthop Surg 2020;12:304.