Characterizing and quantifying low-value diagnostic imaging internationally: a scoping review

Elin Kjelle1*, Eivind Richter Andersen1, Arne Magnus Krokeide1, Lesley J. J. Soril2, Leti van Bodegom-Vos3, Fiona M. Clement2 and Bjørn Morten Hofmann1,4

Abstract

Background: Inappropriate and wasteful use of health care resources is a common problem, constituting 10–34% of health services spending in the western world. Even though diagnostic imaging is vital for identifying correct diagnoses and administrating the right treatment, low-value imaging—in which the diagnostic test confers little to no clinical benefit—is common and contributes to inappropriate and wasteful use of health care resources. There is a lack of knowledge on the types and extent of low-value imaging. Accordingly, the objective of this study was to identify, characterize, and quantify the extent of low-value diagnostic imaging examinations for adults and children.

Methods: A scoping review of the published literature was performed. Medline-Ovid, Embase-Ovid, Scopus, and Cochrane Library were searched for studies published from 2010 to September 2020. The search strategy was built from medical subject headings (Mesh) for Diagnostic imaging/Radiology OR Health service misuse/Medical overuse OR Procedures and Techniques Utilization/Facilities and Services Utilization. Articles in English, German, Dutch, Swedish, Danish, or Norwegian were included.

Results: A total of 39,986 records were identified and, of these, 370 studies were included in the final synthesis. Eighty-four low-value imaging examinations were identified. Imaging of atraumatic pain, routine imaging in minor head injury, trauma, thrombosis, urolithiasis, after thoracic interventions, fracture follow-up, and cancer staging/follow-up were the most frequently identified low-value imaging examinations. The proportion of low-value imaging varied between 2 and 100% inappropriate or unnecessary examinations.

Conclusions: A comprehensive list of identified low-value radiological examinations for both adults and children are presented. Future research should focus on reasons for low-value imaging utilization and interventions to reduce the use of low-value imaging internationally.

Systematic review registration: PROSPERO: CRD42020208072.

Background

The use of health care and health care expenditures are increasing in most countries [1]. According to the Organization for Economic Co-operation and Development (OECD) 10–34% of health service spending is inappropriate and wasteful use of health care resources [2]. Diagnostic imaging is a health care resource aiding the physician in identifying correct diagnoses and...
administering the right treatment for the right patient at the right time [3]. However, imaging services can also be inappropriately used or be of low clinical value. While inappropriate imaging is characterized by not being in accordance with professional norms and guidelines, low-value care is defined as services that provide little or no benefit to patients, have potential to cause harm, incur unnecessary cost to patients, or waste limited healthcare resources. Diagnostic imaging would be of low-value when the examination has little or no impact on the management of the individual patient, thus in a societal perspective increasing costs and constituting an unnecessary risk to patients due to exposure to ionizing radiation [4] and/or contrast media [5]. Earlier research found that 20–50% of radiological examinations are overused, however, this rate varies between and within countries [2, 6–8]. Recommendations and guidelines such as the National Institute for Health and Care Excellence’s (NICE’s) “Do-not-do list,” iRefer, iGuide and the international Choosing Wisely campaign have been introduced to reduce overutilization in health care and reduce low-value care, including diagnostic imaging [9–11]. So far, the impact of such efforts is reportedly low, as patient expectations of advanced diagnostic tests, lack of knowledge among health care professionals on the right use of imaging, established clinical practice, fear of malpractice, and fee-for-service reimbursement systems continue to drive the use of low-value care [6, 12–16]. Knowledge about low-value imaging in terms of characteristics, quantities and contexts is warranted to enable adequate prioritizing of resource utilization and designing de-implementation initiatives. A recent systematic review previously estimated the prevalence of low-value diagnostic testing, which included some radiological services, but did not provide a complete overview of which diagnostic imaging examinations that may be regarded as low-value [17]. Therefore, the objective of this scoping review was to identify, characterize, and quantify the extent of low-value diagnostic imaging examinations.

Methods
A scoping review was completed in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) extension for scoping reviews [18]. The protocol for this scoping review is registered on the PROSPERO website (CRD42020208072). Medline-Ovid, Embase-Ovid, Scopus, and Cochrane Library were searched for studies published from January 2010 to September 9, 2020. The search strategy was developed in Medline-Ovid (Table 1) and adapted for the other databases with assistance/support from librarians. Terms were built from medical subject headings (Mesh) for Diagnostic imaging/Radiology OR Health service misuse/Medical overuse OR Procedures and Techniques Utilization/Facilities and Services Utilization with text word synonyms of these terms, and more specific terms not having a Mesh term. Language filters were used to include articles written in English, German, Dutch, Danish, Norwegian, and Swedish. Animal studies

| # | Medline (Ovid) |
|---|---|
| 1 | Diagnostic imaging/or cardiac imaging techniques/or imaging, three-dimensional/or neuroimaging/or radiography/or radionuclide imaging/or respiratory-gated imaging techniques/or tomography/or ultrasonography/or whole body imaging/ |
| 2 | exp Radiology/ |
| 3 | (MRI or x-ray* or xray* or mammography or ultrasonography or DEXA or DXA or CT or radiograph* or radiolog* or tomography or imaging).tw |
| 4 | (CAT adj scan).tw |
| 5 | (bone adj scan).tw |
| 6 | (Magnetic adj resonance adj imaging).tw |
| 7 | 1 or 2 or 3 or 4 or 5 or 6 |
| 8 | exp Health Services Misuse/ or exp Medical Overuse/ |
| 9 | (Unnecessar* or overuse* or Inappropriate* or waste or wasted or low-value or overdiagn* or overutili* or misuse* or (Low adj value) or unwarrent or redundant).tw |
| 10 | (Choosing adj wisely).tw |
| 11 | 8 or 9 or 10 |
| 12 | 7 and 11 |
| 13 | Animal/ not (animal/ and human/) |
| 14 | 12 not 13 |
| 15 | limit 14 to ((danish or Dutch or English or German or Norwegian or Swedish) and last 10 years) |
were excluded. The complete search strategy is available in Additional file 1.

The search was expanded through a snowballing technique of hand-searching the reference lists of articles included following full-text screening.

Selection of records

The records were archived using Thomson Reuters EndNote X9.3.3 library and duplicates were removed. All remaining records were transferred to Rayyan QCRI [19] where titles and abstracts were screened by EK, ERA, LvB-V, FC, and BMH for eligibility; 10% of citations were screened by two of the authors as quality assurance. Full-text screening was completed by EK, ERA, AMK LvB-V, LJJS and BMH after a calibration meeting for quality assurance. Disagreements with regards to inclusion or exclusion were resolved through discussion and consensus among the authors.

Eligibility criteria

The inclusion and exclusion criteria are presented in Table 2. In brief, empirical studies, including randomized controlled trials (RCTs), non-randomized controlled trials, cohort studies, descriptive qualitative studies, case studies, mixed-methods studies, and multi-methods studies assessing the value of radiological examinations for all patient groups were included.

Data extraction and synthesis

Data of the included studies were extracted using a summary table consisting of the following variables: author and year, country, design/methods, population, clinical setting, medical condition, low-value practice, reason for being low-value, alternative to low-value practice, and extent of use (when applicable). EK, ERA, AMK, and BMH extracted data after a calibration meeting where 10 publications were discussed for quality assurance. Narrative synthesis of included articles was completed. Articles were first categorized by adult or pediatric, the imaging modality, type of radiological examination evaluated, and the anatomical area imaged.

Results

The electronic database search identified 39,986 records (findings are documented in Additional file 1) and 17,429 duplicates were removed. A total of 22,557 records were screened for titles (and abstracts) in Rayyan QCRI [19] excluding 21,907 records. Through additional searches and snowballing, 44 additional records were found, resulting in 694 articles for full-text assessment. Following full-text screening 324 articles were excluded; an overview of the excluded articles and the reason for exclusion is presented in Additional file 2. Ultimately, 370 studies were included in the final synthesis. A PRISMA flow diagram of the screening and selection process is presented in Fig. 1.

Among the 370 included studies, 84 low-value imaging examinations were identified. Studies were conducted in 35 different countries, with most from the United States (n=215) and Europe (n=78). In-hospital imaging was the most common clinical setting (>65%). Fourteen different study designs were employed among the included studies; most studies were designed as retrospective chart reviews (n=262), cohort studies (n=39), and cross-sectional studies (n=19). Three hundred and eight studies included adult patients, 60 studied pediatric populations, and 2 studies included both adults and children. The characteristics of the included articles are provided in Additional file 3.

Table 2 Inclusion and exclusion criteria

| Inclusion criteria | Exclusion criteria |
|--------------------|-------------------|
| Empirical study    | Published before 2010 |
| Value of radiological examination | Patient case report, letter, comment, editorial, guidelines |
| Identifying low-value/inappropriate diagnostic imaging (radiology) | Mass-screening related studies |
| Extent/use of low-value diagnostic imaging (radiology) | Dental imaging, optical imaging, thermal imaging, microscopic imaging |
| RCT, non-randomized controlled trial, cohort study, descriptive study, case studies, mixed-methods, multi-methods | Animal studies, studies on cells/tissue |
| Studies comparing two or more imaging procedures | Studies where imaging is shown to avoid other inappropriate medical procedures/treatments |
| English, German, Dutch, Danish, Swedish, or Norwegian language | Image quality evaluation/improvement projects |
|                      | Interventions to reduce low-value imaging |
Outcomes measured for identifying low-value examinations varied across the studies and the most common were diagnostic yield ($n = 213$), and impact or change in treatment or management ($n = 137$). Importantly, the examinations defined as low-value were dependent on the clinical symptoms of patients e.g. a lumbar spine MRI is only valuable when the patient present with red flag symptoms.

In the following sections, results are stratified by body areas (neurologic (central nervous system [CNS]), thoracic, musculoskeletal, abdominopelvic, vascular, whole body, breast, cardiac, and ear, nose, and throat, and neck imaging) and population type (i.e., adult versus pediatric population).

**Low-value radiological examinations in adults**

**Neurologic imaging**

Low-value imaging of the brain was explored in 49 studies [20–66]. Specifically, routine use of head CT or repeat head CT in minor head injury and brain MRI were reported to be low-value for many clinical indications and conditions. The reason for being low-value was either low diagnostic yield where the majority of scans were reported to have no relevant findings, or a low rate in change of management for patients examined. To reduce the use of low-value neurologic imaging the studies indicated that the scan should be warranted based on patient symptoms rather than routine. Details are presented in Table 3.
Further, low-value imaging examinations of the cervical spine was identified in eleven studies [67–77] including routine imaging in trauma and routine follow-up after surgery in patients without symptoms (Table 4).

**Thoracic imaging**

Thirty-eight studies reported chest X-rays to be low-value, while four studies reported on low-value use of chest CT [78–117]. Of these, eighteen reported on chest X-rays in follow-up after procedures known to cause pneumothorax, where the X-ray did not change management in patients without symptoms [94–112]. Further, routine chest X-ray was found to not change patient management when used as a pre and post op screening, at hospital admission, in medical check-ups, or in staging of cervical and breast cancer. Repeat chest X-ray in trauma and ICU patients was found to be low-value and clinical symptoms should be used as an indicator to do an X-ray [78–93, 113, 118–120]. In CT, low-value examinations were found in emergency department patients, pleural effusion, and in staging of low-grade breast cancer as the diagnostic yield is

---

**Table 3** Overview of low-value imaging of the head and brain with reported outcome and suggested practice

| Type of imaging | Reason for examination | Outcome | Suggested practice by included study/studies | References |
|-----------------|------------------------|---------|---------------------------------------------|------------|
| Head CT         | Minor head injury      | 2–7.4% relevant findings | Examine patients after trauma or when life-threatening conditions are expected only | [20–27]    |
|                 | Delirium               | 3–11% relevant findings |                                             | [28, 29]   |
|                 | Headache               | 2–8% relevant findings  |                                             | [30–33]   |
|                 | Hepatic encephalopathy | 4% relevant findings    | Examine patients with history of head trauma or focal neurologic findings only | [34]      |
|                 | Meningitis             | 12–14% relevant findings |                                             | [35]      |
|                 | Hip fracture (geriatric) | <1–6% relevant findings |                                             | [36, 37]  |
|                 | Medical patients       | 4% relevant findings    |                                             | [38]      |
|                 | Lamotrigine toxicity   | No impact on patient management | The condition is clinically misinterpreted as stroke | [39] |
| Repeat head CT  | Minor head injury      | 0–6.5% had change in management | Examine patients with neurological decline only | [33, 40–50] |
|                 | Traumatic brain injury | 5.2–11.4% had change in management |                                             | [48]      |
|                 | Delayed intracranial hemorrhage | 1% relevant findings | Do not repeat routinely for patients on anticoagulation treatment | [51, 52] |
| Follow-up head CT | Traumatic epidural hematomas | 7% relevant findings |                                             | [53]      |
|                 | Shunt surgery          | 2.3% reoperated         |                                             | [54]      |
|                 | Chronic subdural hematoma | No change in treatment | Do not routinely do an early post-op CT | [55] |
|                 | Anterior skull base surgery | 12% relevant findings | Examine patients with neurological decline only | [56] |
| Brain MRI       | Multiple sclerosis patients in the emergency department | 27.8% relevant findings |                                             | [57]      |
|                 | Pure ground glass nodular adenocarcinomas | No relevant findings |                                             | [58]      |
| Follow-up brain MRI | Macroprolactinoma | 1.7% relevant findings |                                             | [59]      |
| Head CT/Brain MRI | Syncope               | 0–3.8% relevant findings | Not recommended in guidelines | [60, 61] |
|                 | Migraine               |                                |                                             | [62]      |
| Head XR         | Shunt malfunction      | Did not change patient management | CT should be used instead | [63]      |
| Head CTA        | In stroke patients after brain MRI | 50% relevant findings | Examine patients with neurological decline only | [64] |
| Carotid ultrasound | Syncope               | 2.2–2.8% relevant findings |                                             | [65, 66] |

*XR*-ray, CT computed tomography, MRI magnetic resonance imaging
Further, repeat chest CT in Covid-19 patients showing clinical improvement was shown to be of low-value [117]. Details are presented in Table 5.

### Table 4: Reported imaging of the cervical (c)-spine with low-value to patients

| Type of imaging       | Reason for examination                                      | Outcome                                                                 | Suggested practice by included study/studies                                      | References |
|-----------------------|-------------------------------------------------------------|------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------|
| C-spine CT/MRI        | Blunt trauma                                                | Identified no fractures in patients with negative clinical examination | Imaging is only required in patients with positive physical examination         | [67–70]   |
|                       | Near hanging                                                | 1.4% relevant findings                                                 | Imaging is only required in patients with positive physical examination         | [71]       |
| Routine c-spine XR    | High-energy trauma                                          | Identified no fractures                                                 | XR is only required in patients with positive physical examination             | [72]       |
| Follow-up c-spine XR  | Radiculopathy due to a herniated intervertebral disc or an osteophyte | No change in patient management                                         | Intra operative verification is sufficient                                      | [73]       |
|                       | Spine fusion                                                | No change in patient management                                         | XR is only required in patients with positive physical examination             | [74, 75]  |
|                       | Anterior cervical discectomy                                | No patients were reoperated based on imaging                            | XR patients with clinical deterioration only                                     | [76]       |
| C-spine flexion/extension XR | Neck pain                                                  | After normal CT—no change in patient management                        |                                                                                  | [77]       |

**Musculoskeletal imaging**

**Spine and hip or pelvis** The most commonly reported low-value procedures in musculoskeletal imaging was for low back pain [121–130]. Ten studies demonstrated that

### Table 5: Reported low-value thoracic imaging

| Type of imaging            | Reason for examination                                     | Outcome                              | Suggested practice by included study/studies                                      | References |
|----------------------------|-------------------------------------------------------------|--------------------------------------|--------------------------------------------------------------------------------|------------|
| Routine chest XR           | Pre/post-operative Elective surgery                        | 0–4% change in management            | XR is indicated pre-op for cancer, trauma, and cardiac patients                  | [78–81]   |
|                            | Post-op soft tissue sarcoma and stage I germ cell cancer    | No change in management              | Use chest CT instead                                                            | [82, 83]  |
|                            | Staging in breast or cervical cancer                       | 2.8% relevant findings               |                                                                                 | [84, 85]  |
|                            | Medical check-up                                            | 0.25% change in management           |                                                                                 | [86]       |
|                            | At admission to hospital                                   | Up to 4% relevant findings           |                                                                                 | [87, 88]  |
|                            | Acute abdominal pain                                       | 6% change in management              |                                                                                 | [89]       |
|                            | Trauma patients                                            | Marginal effect on management       |                                                                                 | [90, 91]  |
|                            | Congenital lung malformations                              | No change in management              |                                                                                 | [92]       |
| Repeat chest XR            | Trauma patients                                            | 19% relevant findings                | Use routine repeats only when initial chest XR is abnormal                      | [93]       |
| Routine follow-up chest XR | After thoracic invasive interventions                      | <1–5.6% change in management         | XR patients with symptoms of pneumothorax only                                  | [94–112]  |
|                            | ICU patients                                               | <8% change in management             | Image patients with positive physical examination only                          | [113]      |
| Chest CT                   | Pleural effusion                                            | 4% relevant findings                 |                                                                                 | [114]      |
|                            | Emergency department patients                              | About 20% relevant findings          |                                                                                 | [115]      |
|                            | Pre-op staging of breast cancer                            | 1.5% relevant findings               | Usefull for stage III patients only                                            | [116]      |
| Repeat chest CT            | Covid-19                                                   | No change in management when patient is clinically improving             |                                                                                 | [117]      |
X-ray, CT and MRI have a low impact on the treatment of patients without red flags, and 58.7% of MRI scans were negative [121–131], imaging for pain in the rest of the spine was also shown as low-value [131]. In addition, change in management were only seen in <1% of routine post-op X-rays after cervical (c) or lumbar (l)-spine fusion [132–134]. Another study found that even though 93% of the referrals for lumbar MRI were appropriate according to guidelines, only 13% of the scans showed actionable findings [125]. In cases of pelvic fracture or trauma, routine pelvic X-ray had a low impact on treatment. The same was shown for MRI or CT in pelvic ring fracture [91, 135–137]. In hip fracture and hemiarthroplasty, routine post-op X-ray of the hip was low-value for patients without symptoms [138, 139]. One study showed that MRI is low-value in patients with hip pain when an X-ray is already acquired [140]. Details are presented in Table 6.

**Upper and lower limb** The second most common studied musculoskeletal low-value examination was MRI in knee pain without red flags, reported in eight studies [121, 141–147]. In addition, MRI of acute Achilles tendon rupture, X-ray of adjoined joints in ankle fracture, and CT of lower extremities stress fractures were also reported as low-value examinations [148–150]. X-ray of the knee changed management in 0–0.7% of patients after ligament reconstructions, tibia plateau fixation, and partial or total knee arthroplasty [151–156]. In the upper limb, shoulder MRI in patients with shoulder pain or rotator cuff tear had a low impact on treatment [157–159]. X-ray of the shoulder in atraumatic shoulder pain or frozen shoulder had a low impact on clinical management [160, 161]. Further, orthopedic trauma, post-op, or post-splinting X-ray gave little to no change in management [162–169]. MRI of the wrist in ligamentous injury changed the surgical plan in 28% of patients and was thus low-value for many patients [170]. On general use of imaging in the musculoskeletal system, four studies showed that skeletal CT for peri-articular fractures (post-op) [171], and long bone cartilaginous lesions (also MRI) [172] were of low-value. Details are presented in Table 7.

**Abdominopelvic imaging** In abdominopelvic imaging, eighteen studies reported imaging with low-value in typical emergency or general medicine conditions [175–191]. X-rays for abdominal pain and upper gastrointestinal imaging (UGI) for reflux resulted in a change in management in only 4% of patients and is often of poor diagnostic quality [187–189]. In acute pancreatitis, < 1.2% of CT and MRI examinations yielded relevant findings [175–178]. Low-value imaging related to surgery or other invasive procedure in the abdomen was reported in seven studies [192–198]. Contrast esophagogram had a low impact on treatment in suspected esophageal perforation, and anastomotic leaks after esophagectomy [195, 197, 198]. In addition, staging of cancer using a different kind of MRI or CT in the abdominal/pelvic area was described as low-value in six studies for various types of cancer [199–203]. In urology, abdominal CT in urolithiasis had a low impact on the treatment of patients with self-limiting episodes or at follow-up [190, 204–206]. Renal

---

**Table 6** Overview of low-value imaging in the spine, pelvis, and hip

| Type of imaging | Reason for examination | Outcome | Suggested practice by included study/studies | References |
|-----------------|------------------------|---------|-------------------------------------------|------------|
| L-spine XR, CT, MRI | Low back pain | Low rate in change of management | MRI: 41.3% relevant findings | [121–130] |
| Post-op L or C-spine XR | Instrumented single-level degenerative spinal fusions | Does not change treatment of patient | Check with fluoroscopy during surgery | [132] |
| Post-op L-spine XR | Lumbar fusion | 0–1% relevant findings | XR if positive physical examination only | [133, 134] |
| Spine XR | Acute neck or back pain | 0.4% relevant findings | | [131] |
| Pelvic XR | Severe trauma | No change in management | | [91] |
| CT/MRI pelvis | Pelvic ring fracture | No change in management | | [135] |
| Routine Pelvic XR | Pelvic fracture | No change in management in patients with painless straight leg raise | Among awake, alert patients without spinal or lower limb injury, painless straight leg raise can exclude pelvic fractures | [136] |
| | Trauma | 10% change in management | XR if positive physical examination only | [137] |
| Post-op Hip XR | Hip hemiarthroplasty | No change in management | XR if positive physical examination only | [138] |
| | Hip fracture | No change in management | XR if positive physical examination only | [139] |
| MRI Hip | Hip pain | After XR—low impact on treatment | | [140] |

*XR*X-ray, CT: computed tomography, MRI: magnetic resonance imaging
ultrasound in new-onset acute kidney injury to screen for hydronephrosis led to changes in management in just 1.8% of patients in one study [207]. In addition, retrograde urethrography in penile fracture had a low impact on treatment in patients without hematuria or urethrorrhagia [208]. An overview of low-value imaging in abdominopelvic imaging is given in Table 8.
Vascular imaging
The two most reported low-value vascular imaging examinations were CTA of the chest in patients with low risk of pulmonary embolism (7 studies) and ultrasound in patients with low risk for deep venous thrombosis (5 studies). Negative result was demonstrated in 97% of examinations [210–221]. Further, CTA of the abdominal aorta after endovascular aneurysm repair (EVAR) in patients without endoleak 1 month after the EVAR procedure, was identified as low-value [222–224]. Ultrasound was reported to be better as surveillance for EVAR patients as ultrasound increased the negative predictive value to 97.6% [222–224]. In addition, CTA was shown to be of low-value in patients with blunt vertebral artery injuries and vascular injuries of the lower limbs [225, 226]. Details are presented in Table 9.

Whole body imaging
Whole body imaging examinations were identified as low-value in trauma and oncology in six studies. Whole body scanning in trauma should be made only when clinically indicated [227–232]. In addition, one study identified CT in soft tissue infections as low-value, with the exception of intra-abdominal abscesses [233]. In oncology, whole body imaging used for staging and follow-up was identified as low-value in 18 studies [58, 234–250]. Details on low-value whole body imaging in oncology is presented in Table 10.
Breast imaging
In breast cancer follow-up, mammography or MRI of the breasts less than 1-year after treatment were described as low-value [255–262]. Follow-up of benign breast tumors with short intervals showed only 0–0.5% identified malignancy in three studies, thus low-value to the majority of patients [260–262]. According to one study [263] on male patients only, 0.9% of breast ultrasound or mammography found malignancy. Details are presented in Table 11.

Cardiac imaging
Stress imaging such as myocardial perfusion imaging (MPI) and echocardiography were described as low-value in low risk patients, and patients with more than one risk factor for cardiac disease [264, 265]. In patients with infective endocarditis, only 10% of the findings in FDG PET/CT of the heart led to changes in treatment [266]. Routine transthoracic echocardiography in acute ischemic stroke patients had relevant findings in 38% of patients, however only 8.5% of patients had additional work-up [267]. Elective coronary angiography investigating coronary heart disease had relevant findings in 40% of patients in one study [268]. Yet another study found that during coronary angiography left ventriculography is of poor quality [269]. An overview of low-value cardiac imaging is given in Table 12.

Neck and ear, nose, and throat imaging
Post-operative thyroid cancer ultrasound was found to be low-value as 98% of the scans were negative [270] and the risk for relapse is small [271]. Furthermore, increased use of ultrasound uncovered more benign and low-risk cancers [272, 273]. Radioactive iodine scanning found 17% concordant findings with earlier examinations. Thus, fine needle aspiration should be used in diagnostics instead of imaging [274]. Thyroid ultrasound as follow-up after lobectomy found tumor or recurrence in only 1.5% of patients [275]. According to one study, in patients with secondary hyperparathyroidism routine pre-op Tc-99 m-sestamibi scans are unnecessary as nodules are found during surgery [276].

X-ray and CT of the sinuses in acute rhinosinusitis did not change patient management [277]. In patients with facial fractures, X-ray and CT was identified as low-value in five studies [278–282], as imaging did not change the management of the patient. One study introduced the use of ultrasound combined with an X-ray, instead of CT in zygomatic arch and mandibular fractures [281]. Another study described MRI of the face for juvenile ossifying fibroma as low-value [283].

Imaging of templar bones was described as low-value in patients with chronic Eustachian tube dysfunction and pre-op for cochlear implants [284, 285]. Details are presented in Table 13.
Table 10  Overview of identified low-value whole body imaging for staging and follow-up in oncology

| Type of imaging | Type of cancer | Outcome | Suggested practice by included study/studies | References |
|-----------------|----------------|---------|--------------------------------------------|------------|
| **Cancer staging** |                |         |                                            |            |
| PET/CT          | Endometrial    | Low diagnostic accuracy |                                            | [244]      |
|                 | Pure ground glass nodular adenocarcinomas | No additional information |                                            | [58]       |
|                 | Non-colorectal gastrointestinal | 11.2% change in patient management |                                            | [235]      |
|                 | Adenocarcinoma Early Esophageal | Low diagnostic accuracy |                                            | [237]      |
| **CT**          | Localized Diffuse Large B-cell lymphoma | No new information | CT is unnecessary in combination with PET/CT | [245]      |
| Multiparametric MRI | Prostate (low risk) | No change in management |                                            | [234]      |
| Bone scan       | Prostate (low risk) | < 1% of bone scans gave relevant information | PET/CT and prostate-specific antigen gives better metastasis detection | [251–253] |
|                 | Prostate cancer (radical prostatectomy) | 52% change in patient management |                                            | [254]      |
| **CT and PET/CT** | Melanoma | No change in staging based on imaging |                                            | [241]      |
|                 | High-Risk Melanoma | 18% change in patient management |                                            | [236]      |
|                 | Pancreatic adenocarcinoma | 2% relevant findings |                                            | [243]      |
| **CT, PET, MRI, bone scan** | Breast | 0.8% risk of distant metastases | 15% clinically relevant findings | [238] [242] |
| **Follow-up**   |                |         |                                            |            |
| Post treatment CT, PET, MRI, bone scan | Breast | No increased disease detection < 12 months after treatment |                                            | [250] [246] |
| Post treatment PET/CT | Early-Stage, Non-bulky Hodgkin Lymphoma | Low risk of disease recurrence |                                            | [239]      |
|                  | Breast Non-Hodgkin lymphoma Hodgkin disease Colorectal Melanoma Lung | 31.6% of inappropriate imaging changed patient management |                                            | [247]      |
| Surveillance PET/CT | Esophageal | Does not improve 2-year survival |                                            | [240]      |
|                  | Lung | Does not improve 2-year survival |                                            | [240]      |
| Post treatment CT and PET/CT | Diffuse large B-cell lymphoma | 1.6–1.8% change in patient management |                                            | [248]      |
|                  | Non-Hodgkin lymphoma | 22.1% relevant findings |                                            | [249]      |

PET positron emission tomography, CT computed tomography, MRI magnetic resonance imaging

Table 11  Overview of identified low-value breast imaging

| Type of imaging | Reason for examination | Outcome | Suggested practice by included study/studies | References |
|-----------------|-------------------------|---------|---------------------------------------------|------------|
| Follow-up mammography, breast US/MRI | Benign breast tumors | 0–0.5% identified malignancy No reduction in reoperations |                                            | [260–262] |
| Follow-up mammography/Breast MRI | < 1-year follow-up malign tumor | 0.3% of patients needed treatment for malign disease | Follow-up is only required after 12 months | [255–262] |
| Mammography/breast US | Male breast cancer | 0.9% relevant findings |                                            | [263]      |

US ultrasound, MRI magnetic resonance imaging
The use of low-value imaging in pediatric patients was reported in 62 studies presented in Table 14 [168, 286–345]. The most frequently reported low-value examinations were CT and MRI of the head/brain, CT and X-ray related to trauma, chest X-ray, and musculoskeletal X-rays in fracture follow-up.

The quantity in use of low-value imaging in adults

The proportion of low-value imaging examinations in specific body areas differed from 4 to 100% (86 studies), and varied both between and within different countries and clinical settings. The results are presented in Fig. 2 [20–23, 26–29, 35, 40–42, 54, 64, 68, 69, 122, 123, 125, 127–130, 140, 141, 143, 145–147, 157–159, 172–174, 176, 177, 179, 182, 190, 210, 211, 213, 215, 216, 229, 242, 252, 277, 284, 353–387]. From these studies, imaging examinations with a high proportion of low-value examinations (more than 50% inappropriate use reported) was: Head CT (routine and repeat), routine trauma scan, MRI in musculoskeletal pain, dual-energy x-ray absorptiometry (DEXA) in low risk patients or low interval DEXA follow-ups.

| Table 12 | Overview of identified low-value examinations in cardiac imaging |
|----------|---------------------------------------------------------------|
| Type of imaging | Reason for examination | Outcome | Suggested practice by included study/studies | References |
| Stress myocardial perfusion imaging | Cardiac disease | 27% relevant findings | Use risk stratification to screen patients | [264, 265] |
| Stress echocardiography | Cardiac disease | 18% relevant findings | | [265] |
| Routine transthoracic echocardiography | Acute ischemic stroke | 8.5% change in management | | [267] |
| Elective coronary angiography | Coronary heart disease | 40% relevant findings | Use risk stratification to screen patients | [268] |
| Left ventriculography during angiography | Coronary heart disease | Low diagnostic accuracy | Echocardiography, nuclear scintigraphy, or MRI have better diagnostic results | [269] |
| PET/CT | Infective endocarditis | 10% change in treatment | | [266] |

PET: positron emission tomography, CT: computed tomography, MRI: magnetic resonance imaging

| Table 13 | Overview of low-value imaging in Neck and ear, nose, and throat imaging |
|----------|---------------------------------------------------------------|
| Type of imaging | Reason for examination | Outcome | Suggested practice by included study/studies | References |
| Post-op thyroid US | Thyroid cancer | 2% relevant findings | Use fine needle aspiration diagnostics | [270, 271] |
| Radioactive iodine scanning | Thyroid cancer | Does not find more than other type of imaging | | [274] |
| Follow-up thyroid US | After lobectomy | 1.5% relevant findings | | [275] |
| Pre-op Tc-99 m-estamibi | Secondary hyperparathyroidism | Nodules are found during surgery | | [276] |
| Sinus CT/XR | Acute rhinosinusitis | Does not change patient management | | [277] |
| Face CT/XR | Facial fracture | Does not change patient management | | [278–282] |
| Face CT | Zygomatic arch/ mandibular fracture | Using other examinations reduce radiation dose with similar quality | Face US often combined with face XR | [281] |
| Face MRI | Juvenile ossifying fibroma | Low diagnostic accuracy | Face CT is of better quality | [283] |
| Pre-op templar bones CT | Cochlear implants | 14% relevant findings | | [284] |
| Templar bones CT | Chronic Eustachian tube dysfunction | Does not change patient management | | [285] |

XR: X-ray, CT: computed tomography, MRI: magnetic resonance imaging, US: ultrasound

Low-value imaging examinations in children

The use of low-value imaging in pediatric patients was reported in 62 studies presented in Table 14 [168, 286–345]. The most frequently reported low-value examinations were CT and MRI of the head/brain, CT and X-ray related to trauma, chest X-ray, and musculoskeletal X-rays in fracture follow-up.

The quantity in use of low-value examinations

The proportion of low-value examinations varied greatly in the 103 included studies reporting proportion. Seven studies explored low-value imaging in adults on an overarching level with several medical conditions and modalities, showing an overall rate of low-value imaging of 2–31% [346–352].
Table 14  Overview of imaging identified as low-value in pediatrics sorted by body system

| Type of imaging | Reason for examination | Outcome | Suggested practice by included study/studies | References |
|-----------------|------------------------|---------|---------------------------------------------|------------|
| **Neuro imaging** |                        |         |                                             |            |
| Head CT         | Minor head injury       | 33–50% relevant findings | MRI diffusion weighted imaging should be used | [286–288] |
|                 | Shunt-related complications | Few relevant findings | Repeat only if patient develops symptoms | [289] |
| Repeat head CT  | Skull fracture          | No relevant findings | Repeat only if patient develops symptoms | [290, 291] |
| Brain MRI/CT    | Minor head injury       | 0–6.6% relevant findings | MRI diffusion weighted imaging should be used | [292, 293] |
| Post-op head XR | Headache                | 4–28.8% relevant findings | Repeat only if patient develops symptoms | [294–297] |
| C-spine CT/XR   | Trauma                  | Of all included patients 12.8% screened with imaging while 0.2% needed treatment | X-ray would suffice | [298] |

| **Abdominopelvic imaging** |                        |         |                                             |            |
| Abdominal CT      | Liver injury            | CT should be avoided to reduce the use of ionizing radiation | Physical examination, FAST and Serum Transaminases should be used as screening | [300] |
| Repeat abdominal CT | Abdominal pain         | Did not change patient management | Repeat only if patient develops symptoms | [301] |
| Abdominal MRI     | Appendicitis            | CT should be avoided to reduce the use of ionizing radiation | US should be used instead | [302] |
| Abdominal XR      | Children doing UGI     | Do not change patient management | Repeat only if patient develops symptoms | [303] |
| Rectal US         | Idiopathic constipation | Low diagnostic accuracy | Clinical examination would be sufficient | [304, 305] |
| Colonic transit study |                                    |                         |                                             |            |
| Thoracoabdominal XR | Determining the Position of Umbilical Venous Catheters | XR should be avoided to reduce the use of ionizing radiation | Use ultrasound instead | [307] |
| UGI              | Laparoscopic Gastrostomy Tube Placement | Do not change patient management | Repeat only if patient develops symptoms | [308, 309] |
| Gastroesophageal reflux (neonates) | | Do not change patient management | Repeat only if patient develops symptoms | [310] |
| Scrotal US        | Pediatric Cryptorchidism | Low diagnostic accuracy | Clinical examination would be sufficient | [311, 312] |
| Tc-99 m MAG3/DMSA scan | Multicystic dysplastic kidney | Avoid for reducing the use of ionizing radiation | Use US instead | [313] |

| **Whole body imaging** |                        |         |                                             |            |
| Trauma CT          | Blunt trauma           | 18% relevant findings | Repeat only if patient develops symptoms | [314–316] |
|                    | Falls                  | Two-fold increase in use of CT | Repeat only if patient develops symptoms | [317] |
|                    | Trauma                 | No relevant findings in low level injury | Repeat only if patient develops symptoms | [287, 318, 319] |
| Follow-up torso CT | Hodgkin's lymphoma     | Do not change patient management | Repeat only if patient develops symptoms | [320, 321] |

| **Musculo-skeletal imaging** |                        |         |                                             |            |
| Skeletal CT         | Orthopedic trauma (spine, pelvis, lower extremities) | 20% relevant findings | Repeat only if patient develops symptoms | [168] |
| Type of imaging          | Reason for examination                      | Outcome                                          | Suggested practice by included study/studies | References |
|-------------------------|---------------------------------------------|--------------------------------------------------|----------------------------------------------|------------|
| Post-op humerus XR      | Supracondylar humerus fracture              | Do not change patient management                 |                                              | [323]      |
|                         |                                             | Do not change patient management                 |                                              |            |
|                         |                                             | Do not change patient management                 |                                              | [324]      |
|                         |                                             | Do not change patient management                 |                                              |            |
|                         |                                             | Type III fractures—XR within 7–10 days post-op   |                                              | [325]      |
|                         |                                             | or if clinical symptoms                          |                                              |            |
| Elbow XR                | Supracondylar humerus fracture              | Do not change patient management                 |                                              | [326]      |
|                         | Wrist fracture                              | Do not change patient management                 | Image only children with symptoms           | [327]      |
| Follow-up forearm XR    | Forearm fracture                            | Do not change patient management                 |                                              | [328]      |
| Serial follow-up wrist XR | Distal wrist fracture                       | Do not change patient management                 |                                              | [329]      |
| Routine XR pelvis       | Blunt trauma                                | Do not change patient management                 |                                              | [330, 331]|
| Routine follow-up Hip XR and US | Hip dysplasia | Routine follow-up (genetic risk)—do not change patient management |                                             | [332]      |
|                         |                                             | XR after normal ultrasound do change patient     |                                              | [333]      |
|                         |                                             | management                                      |                                              |            |
|                         |                                             | Clinical examination as screening                |                                              |            |
| Routine follow-up calf XR | Physisal facture of distal tibia            | Do not change patient management                 |                                              | [334]      |
| Ankle XR                | Sever’s disease                             | Low diagnostic accuracy                         | Clinical examination should be sufficient   | [335]      |
| Follow-up Spine XR      | Adolescent idiopathic scoliosis             | Do not change patient management                 | 4-month control only should suffice         | [336]      |
|                         |                                             | Do not change patient management                 |                                              |            |
|                         |                                             | X-ray only patients with pain                    |                                              | [337]      |
| Thoracic imaging        |                                             |                                                 |                                              |            |
| Chest CT                | Esophageal atresia and tracheoesophageal fistula | Do not change patient management                 |                                              | [338]      |
| Chest XR                | Chest tube removal                          | 6.4% relevant finding                           | X-ray symptomatic children only             | [339, 340]|
|                         | CVC placement                               | Do not change patient management                 |                                              | [341]      |
|                         | Pneumonia                                   | Do not change patient management                 | Use ultrasound chest instead                | [342]      |
|                         | Bronchiolitis                                | Do not change patient management                 |                                              | [343]      |
| Cardiac imaging         |                                             |                                                 |                                              |            |
| Echocardiogram          | Cardiac disease                             | 11% change in patient management                 |                                              | [344]      |
|                         | Myelomeningocele                            | Do not change patient management                 | Critical condition is clinically identifiable| [345]      |

XR X-ray, CT computed tomography, MRI magnetic resonance imaging, US ultrasound

Echocardiography, carotid imaging, chest X-ray, X-ray in acute rhinosinusitis, CTA in pulmonary embolism, early-stage breast cancer staging, acute pancreatitis, and special imaging for pre-op templar bone CT in cochlear implantation, and CT/MRI in long bone cartilaginous lesions. In addition, one study reported a sevenfold increase in knee MRI, while there was a reduction in knee arthroscopy [145].
Quantity of low-value imaging in children

In pediatrics the use of low-value examinations varied between 3.6 and 93.7% (11 studies) [286, 297, 299, 301, 314, 315, 320, 321, 356, 388, 389]. Abdominal CT in appendicitis (3.6%), repeat CT in trauma patients (5%) and C-spine CT in cervical spine injury (13%) were the least over-used examinations. Head CT (50–93.7%), CT scan in case of blunt abdominal trauma (18–80%) and pretransfer CT in trauma patients (66%) were the low-value examinations most used.

Discussion

In summary, through this scoping review, we found 84 different low-value imaging examinations performed among both adult and pediatric populations, for all imaging modalities, and body areas. Several of these examinations already have established referral criteria or have recommendations against them in the Choosing Wisely list, however this review show that these are still being used in clinical practice, and more examinations might need referral guidelines. The most commonly practices reported as low-value was head CT in several clinical queries (especially related to minor head injury [20–33, 36, 37, 40–53, 55, 56, 286–293]), chest X-ray for routine checkup or follow-ups [78–113, 118–120, 339–343], trauma CT in patients without clinical symptoms or as repeat scans [227–232, 287, 314–322], and skeletal X-rays in non-traumatic pain or in fracture follow-ups [132, 138, 139, 151–156, 160–167, 169, 323–337]. The following were the most frequently reported low-value examinations: imaging in low back pain [121–131] and knee MRI without red flags [121, 141–147], staging and follow-up in several types of cancer (X-ray, CT, MRI and nuclear medicine) [58, 116, 172, 199–203, 209, 234–262], abdominal CT in self-limiting episode of suspected urolithiasis [190, 204–206], chest CTA [210–216] and ultrasound lower limb veins in patients with low risk of thrombosis [217–221] were most prominent among adult populations. When analyzing the extent in use of low-value imaging additional examinations were identified; low interval DEXA screening, echocardiography in patients with low risk of cardiac disease, carotid imaging in syncope, X-ray in rhinosinusitis, and MRI for pain in the hip or upper extremities [140, 157–159, 173, 277, 365, 366, 369, 373, 376].

The variation in the proportion of low-value imaging was large (2–100% inappropriate or unnecessary examinations) and varied between studies of the same examination. There is no obvious threshold in proportion for when to define examinations as low-value. Even though the examinations found in this review are low-value on a group level, certain patient sub-groups or individual
patients could have clinical findings justifying the use of imaging. However, in several studies there were identified a rate of ≥90% inappropriate imaging examinations. This provides a reason for altering the utilization of these examinations in practice. We found this to be the case in: repeat head or routine trauma CT, echocardiography, MRI in hip, knee and upper extremity pain, CT/MRI in acute pancreatitis, and pre-op templar bone CT in cochlear implantation [40–42, 54, 140, 141, 143, 145–147, 173, 176, 177, 229, 284, 357, 369, 388].

Our review found additional examinations that are potentially low-value to the examinations presented in the Choosing Wisely list [17, 390]. Additionally, we report the extent of low-value imaging. Our additional findings merit further investigation, including chest X-ray after invasive lung procedures such as CVC placement, chest tube placement/removal, biopsies, and other procedures [94–112, 339–341], musculoskeletal follow-ups after fractures or invasive procedures, MRI and X-ray in atraumatic shoulder or upper-extremity pain [138, 139, 151–156, 160–167, 169, 173, 323–329, 334, 336] and staging and follow-up procedures in cancers other than breast, cervical, prostate, and lymphoma [58, 172, 199, 202, 203, 209, 235–237, 239–241, 243–245, 247–249]. Hence, while we confirm previous findings, we also add new findings to the literature. Not all examinations in the Choosing Wisely list were included in this in this review such as cardiac imaging in asymptomatic patients or head CT in patients with sudden hearing loss [390]. This could be caused by the search being incomplete (for instants excluding screening programs), evidence of their low-value was given before 2010 or that some of the Choosing Wisely recommendations were based on clinical experience rather than research reports.

There are many ways to measure low-value imaging, including diagnostic yield, diagnostic accuracy, and impact/change in treatment or management, where diagnostic yield (n = 213) and change in patient management (n = 137) were most common. By applying the Fryback and Thornbury value model as stated by Brady et al. [391], measures of change in patient management and trends in imaging and related treatments, seems a better way to identify low-value imaging, rather than measuring diagnostic accuracy [391].

This scoping review has strengths and limitations in its methods. Although the search in databases was systematic and exhaustive, the cut-off was set at 2010, which excluded examinations identified as low-value imaging or adopted to clinical practice before 2010. Due to the large number of citations retrieved from the database searches, a wide range of inconclusive studies, studies identifying conditional low-value imaging, and articles reporting clinical practice guidelines were excluded. Hence, a wide range of supportive studies were excluded as the inclusion criteria were strict. Therefore, it is likely that there are several studies of low-value examinations that are not included in this review. Accordingly, the excluded studies in Additional file 2 may provide useful information for those who want to pursue specific examinations. The quality of included studies was also not assessed; it is likely that the included studies were of variable quality, limiting the strength of the conclusions made in this review. While the strict inclusion criteria may to some extent compensate for the lack of study quality assessment, quality assessment is not required [392] as the purpose of a scoping review is to identify and map the available evidence. While this review provides a valuable overview of identified low-value imaging, especially useful for clinicians and policymakers to be able to take actions to reduce overuse of diagnostic imaging. However, contextual assessment is needed before changing clinical practice. In addition, the risk of ionizing radiation or contrast media has not been considered in this analysis, this would be interesting issues to consider in later studies. There is also need for research on barriers and facilitators for reducing low-value imaging care to assess where to target policy changes, guidelines, and clinical practice.

Conclusions

In this study, we provide a comprehensive list of low-value radiological examinations for both adults and children. Our overview reaches beyond earlier published lists and adds information on the quantity of low-value imaging utilization, which reportedly varied from 2 to 100% among included studies. Imaging of atraumatic pain, routine imaging in minor head injury, trauma, thrombosis, urolithiasis, after chest interventions, fracture follow-up and cancer staging, or follow-up were the most frequently identified low-value imaging examinations. This overview can be of great value for clinicians, policymakers, and researchers for revising appropriateness criteria and planning de-implementation. Efforts should be made to reduce the extension and variation of inappropriate imaging which generates huge opportunity costs and is potentially harmful to patients.

Abbreviations

CT: Computed tomography; CTA: Computed tomography angiography; DEXA: Dual-energy X-ray absorptiometry; EVAR: Endovascular aneurysm repair; MRI: Magnetic resonance imaging; PET: Positron emission tomography; US: Ultrasound; XR: X-ray.
Supplementary Information
The online version contains supplementary material available at https://doi.org/10.1186/s12880-022-00798-2.

- Additional file 1. Search strategy and hits.
- Additional file 2. Excluded studies.
- Additional file 3. Characteristics of the included studies.

Acknowledgements
We would like to thank Senior Research Librarian Karen Marie Øvern at NTNU and academic librarian Jana Myrvold at University of South-Eastern Norway for helping with the development of the search strategy.

Author contributions
EK—planning and searching, screening, full-text screening, analysis, drafting, and revision of manuscript. ERA—planning, full-text and quality assessment, snowballing, analysis, and revision of manuscript. AMK—full-text screening, analysis, and revision of manuscript. LJJS—planning, full-text and quality assessment, analysis, and revision of manuscript. LtB—V—planning, full-text screening, analysis, and revision of manuscript. FMC—planning, screening, and revision of manuscript. BMR—planning, screening, full-text screening, quality assessment, analysis, and revision of manuscript. All authors read and approved the final manuscript.

Funding
This project received financial support from The Research council of Norway (Project number 302503).

Availability of data and materials
Data sharing is not applicable to this article as no datasets were generated or analyzed during the current study.

Declarations
Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Author details
1Institute for the Health Sciences, The Norwegian University of Science and Technology (NTNU) at Gjøvik, NTNU Gjøvik, Postbox 191, 2802 Gjøvik, Norway. 2Department of Community Health Sciences and The Health Technology Assessment Unit, O’Brien Institute for Public Health, University of Calgary, 3280 Hospital Dr NW, Calgary, AB T2N 4Z6, Canada. 3Medical Decision Making, Department of Biomedical Data Sciences, Leiden University Medical Center, PO Box 9600, 2300 RC Leiden, The Netherlands. 4Centre of Medical Ethics, The University of Oslo, Blindern, Postbox 1130, 0318 Oslo, Norway.

Received: 28 June 2021  Accepted: 12 April 2022
Published online: 21 April 2022

References
1. Expert Panel on effective ways of investing in Health (EXPH). Defining value in “value-based healthcare. 2019.
2. Socha K, Couffignal A, Fordie I, Nader C, Cecchini M, Lee S, et al. Tackling wasteful spending on health. OECD 2017. 2017.
3. Brady A, Brink J, Slavotnek J. Radiology and value-based health care. JAMA. 2020;324(13):1286–7. https://doi.org/10.1001/jama.2020.14930.
4. Brenner DJ, Doll R, Goodhead DT, Hall EJ, Land CE, Little JB, et al. Cancer risks attributable to low doses of ionizing radiation: assessing what we really know. Proc Natl Acad Sci. 2003;100(24):13761. https://doi.org/10.1073/pnas.2235592100.
5. Andreucci M, Solomon R, Tasanarong A. Side effects of radiographic contrast media: pathogenesis, risk factors, and prevention. Biomed Res Int. 2014;2014:741018. https://doi.org/10.1155/2014/741018.
6. Hendee WR, Becker GB, Borgstede JP, Bosma J, Casarella WJ, Erickson BA, et al. Addressing overutilization in medical imaging. Radiology. 2010;257(1):240–5. https://doi.org/10.1148/radl.2010100063.
7. Sheng AY, Castro A, Lewiss RE. Awareness, utilization, and education of the ACR appropriateness criteria: a review and future directions. J Am Coll Radiol. 2016;13(2):131–6. https://doi.org/10.1016/j.jacr.2015.08.026.
8. Ingraham B, Miller K, Iaia A, Sneider MB, Naqui S, Evans K, et al. Reductions in high-end imaging utilization with radiology review and consultation. J Am Coll Radiol. 2016;13(9):1079–82. https://doi.org/10.1016/j.jacr.2016.04.016.
9. Choosing Wisely [Internet]. 2021. https://www.choosingwisely.org/getting-started/lists/.
10. Improving health and social care through evidence-based guidance [Internet]. 2021. https://www.nice.org.uk/.
11. Ryan JW, Hollywood A, Stirling A, Glynn M, MacMahon PJ, Bolster F. Evidenced-based radiology? A single-institution review of imaging referral appropriateness including monetary and dose estimates for inappropriate scans. J Med Sci. 2019;188(4):1385–9. https://doi.org/10.1017/s11547-019-02005-8.
12. Chandra K, Atkinson PR, Chatur H, Fraser J, Adams CL. To choose or not to choose: evaluating the effect of a choosing wisely knowledge translation initiative for imaging in low back pain by emergency physicians. Cureus. 2019;11(2):e4002. https://doi.org/10.7759/cureus.4002.
13. Barth JH, Misra S, Aakre KM, Langlois MR, Watine J, Twomey PJ, et al. Why are clinical practice guidelines not followed? Clin Chem Lab Med. 2016;54(7):1133–9. https://doi.org/10.1515/cclm-2015-0871.
14. DeAngelis J, Lou V, Li T, Tran H, Bremjit P, McCann M, et al. Head CT for minor head injury presenting to the emergency department in the era of choosing wisely. West J Emerg Med. 2017;18(5):821–9. https://doi.org/10.1080/15347326.2017.133985.
15. Anderson TS, Leonard S, Zhang AJ, Madden E, Mowery D, Chapman WW, et al. Trends in low-value carotid imaging in the veterans health administration from 2007 to 2016. JAMA Netw Open. 2020;3(9):e201250-e.
16. Berezin I, Thompson C, Rojas-Luengas V, Borgundvaag B, McLeod SL. Lumbosacral spinal imaging for patients presenting to the emergency department with nontraumatic low back pain. J Emerg Med. 2020;58(2):269–74. https://doi.org/10.1016/j.jemermed.2019.12.017.
17. Muskens JLM, Kool RB, van Dulmen SA, Westert GP. Overuse of diagnostic testing in healthcare: a systematic review. BMJ Qual Saf. 2021. https://doi.org/10.1136/bmjqs-2020-012576.
18. Tricco AC, Lillie E, Zarin W, O’Brien KK, Colquhon H, Levac D, et al. PRISMA extension for scoping reviews (PRISMA-ScR): checklist and explanation. Ann Intern Med. 2018;169(7):467–73. https://doi.org/10.7326/m18-0850.
19. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A, Rayyan—a web and mobile app for systematic reviews. Syst Rev. 2016;5(1):210. https://doi.org/10.1186/s13643-016-0384-4.
20. Cellina M, Parzeri M, Floridi C, Martinenghi CMA, Clesceri G, Oliva G. Overuse of computed tomography for minor head injury in young patients: an analysis of promoting factors. Radiol Med. 2018;123(7):507–14. https://doi.org/10.1007/s11547-018-0871-x.
21. Parma C, Carney D, Grim R, Bell T, Shoff K, Ahuja V. Unnecessary head computed tomography scans: a level 1 trauma teaching experience. Am Surg. 2014;80(7):664–8. https://doi.org/10.1177/000313481408000720.
22. Shobeirian F, Ghomi Z, Soleimani R, Mirshahi R, Saniei Taheri M. Overuse of brain CT scan for evaluating mild head trauma in adults. Emerg Radiol. 2020. https://doi.org/10.1007/s10140-020-01846-6.
23. Ferorelli D, Donno F, De Giorgio G, Mele F, Favia M, Riefoli F, et al. Head CT scan in emergency room: is it still abused? Quantification and causes analysis of overprescription in an Italian Emergency Department.
24. Yildizhan S, Boyaci MG, Ozdinc S. How necessary is the computerized brain tomography in minor head trauma? Ulus Travma ve Acil Cerrahi Derg. 2019;25(4):378–82.

25. Yun BJ, Borczuk P, Zachrison KS, Goldstein JN, Berlyand Y, Raja AS. A prospective evaluation of the use of routine repeat cranial CT scans in patients with intracranial hemorrhage and GCS score of 13 to 15. J Trauma Acute Care Surg. 2012;73(3):685–8. https://doi.org/10.1097/TA.0b013e318252c6d9.

26. Zargar Balaye Jame S, Majdzadeh R, Akbari Sari A, Rashidian A, Arab M, Rahmanii H. Indications and overuse of computed tomography in head trauma. Iran Red Crescent Med J. 2014;16(5):3067–73. https://doi.org/10.5812/ircmj.13067.

27. Zuzek P, Rigler I, Podnar S. Validation of clinical criteria for referral to head imaging in the neurologic emergency setting. Neurol Sci. 2019;40(12):2541–8. https://doi.org/10.1007/s10072-019-04009-9.

28. Theisen-Touplaj J, Breu AC, Mattison ML, Amaout S. Diagnostic yield of head computed tomography for the hospitalized medical patient with delirium. J Hosp Med. 2014;9(8):497–501. https://doi.org/10.1002/jhm.2198.

Vijayakrishnan R, Ramasubramanian A, Dhand S. Utility of head CT scan for acute inpatient delirium. Hosp Top. 2015;53(1):9–12. https://doi.org/10.1080/00185868.2015.1012928.

29. Ali AHA, Al-Ghamdi S, Karrar MH, Almutairi OS, Aldalbahi A. Head CT scan overuse in frequently admitted medical patients. Am J Med. 2015;127(5):406–10. https://doi.org/10.1016/j.amjmed.2014.01.023.

30. Ali AHA, Al‑Ghamdi S, Karrar MH, Almutairi OS, Aldalbahi A. The value of sequential computed tomography imaging in patients with an abnormal neurologic examination after minimal head injury. J Trauma. 2011;71(6):1605–10. https://doi.org/10.1097/TA.0b013e31821bb2a76.

31. Kae, A., Jimenez-Roldan L, Arrese, I., Amosa Delgado, M., Loped, A., Alday R, et al. The value of sequential computed tomography imaging in anticoagulated patients suffering from minor head injury. J Trauma. 2010;68(4):895–8. https://doi.org/10.1097/TA.0b013e3181b28a76.

32. McCallum KD, Sadler C, Guo Y, Ramaswamy RS, Farid N. Routine repeat head CT may not be indicated in patients on anticoagulant/ antiplatelet therapy following mild traumatic brain injury. J West J Emerg Med. 2015;16(1):13–9. https://doi.org/10.5811/westjem.2014.10.19488.

33. Relic, T., Mahony H, Djulbegovic B, Etchason J, Paxton H, Flores M, et al. Value of repeat head computed tomography after traumatic brain injury: a systematic review and meta-analysis. J Neurotrauma. 2014;31(1):78–98. https://doi.org/10.1089/neu.2013.2873.

34. Sifri ZC, Nyak N, Homnick AT, Mohr AA, Yoknais R, Livingston DH. Utility of repeat head computed tomography in patients with an abnormal neurologic examination after minimal head injury. J Trauma. 2011;71(6):1605–10. https://doi.org/10.1097/TA.0b013e31821bb2a76.

35. Washington CW, Grubb RL. Are routine repeat imaging and intensive care unit admission necessary in mild traumatic brain injury? J Neurosurg. 2012;116(3):549–57.

36. Peck KA, Sise CB, Shackford SR, Sise MJ, Calvo RY, Sack DJ, et al. Delayed intracranial hemorrhage after blunt trauma: are patients on anticoagulants and prescription antiplatelet agents at risk? J Trauma. 2011;71(6):1600–4. https://doi.org/10.1097/TA.0b013e3182b39c61.

37. Ukcella L, Zola C, Perlasca F, Bongetta D, Codecà R, Gaetani P. Mild traumatic brain injury in patients on long-term anticoagulation therapy: do they really need repeated head CT scan? World Neurosurg. 2016;93:100–3. https://doi.org/10.1016/j.wneu.2016.05.061.

38. Flaherty BF, Moore HE, Riva-Cambrin J, Bratton SL. Repeat head CT for expectant management of traumatic epidural hematoma. Pediatrics. 2018;142(3):e20180385. https://doi.org/10.1542/peds.2018-0385.

39. Behmanesh B, Keil F, Dubinski D, Won SY, Quick-Weller J, Seifert V, et al. The value of computed tomography imaging of the head after ventriculoperitoneal shunt surgery in adults. World Neurosurg. 2019;121:e159–64. https://doi.org/10.1016/j.wneu.2019.08.063.

40. Ng HY, Ng WH, King IK. Value of routine early post-operative computed tomography in determining short-term functional outcome after drainage of chronic subdural hematoma: an evaluation of residual volume. Surg Neurol Int. 2014;5(1):136. https://doi.org/10.4103/2152-7806.141299.

41. Nadimi S, Caballero N, Carpenter P, Sowa L, Cunningham R, Welch KC. Immediate postoperative imaging after uncomplicated endoscopic approach to the anterior skull base: is it necessary? Int Forum Allergy Rhinol. 2014;4(12):1024–9.

42. Abboud H, Mente K, Seay M, Kim J, Ali B, Bemmel R, et al. Triaging patients with multiple sclerosis in the emergency department: room for improvement. Int J MS Care. 2017;19(6):290–6. https://doi.org/10.7224/1537-2073.2016-069.

43. Cho H, Lee HY, Kim J, Kim HK, Choi JY, Um SW, et al. Pure ground glass nodular adenocarcinomas: are preoperative positron emission tomography/computed tomography and brain magnetic resonance imaging useful or necessary? J Thorac Cardiovasc Surg. 2015;150(3):514–20. https://doi.org/10.1016/j.jtcvs.2015.06.024.

44. Eroukhmanoff J, Tejedor I, Potorac I, Cuny T, Bonneville JF, Dufour H, et al. MRI follow-up is unnecessary in patients with macroprolactinomas.
and long-term normal prolactin levels on dopamine agonist treat-
ment. Eur J Endocrinol. 2017;176(3):323–8. https://doi.org/10.1530/
EJE-16-0897.

60. Vaa JA, Chaudry H, Hanniryan A, Boutet M, Mukarram M, Thirugana-
sambandamothy S. The yield of computed tomography of the head
among patients presenting with syncope: a systematic review. Acad
Emerg Med. 2019;26(5):479–90. https://doi.org/10.1111/acem.13568.

61. Johnson PC, Ammar H, Zohdy W, Fouda R, Govindu R. Yield of diag-
nostic tests and its impact on cost in adult patients with syncope
presenting to a community hospital. South Med J. 2014;107(1):707–14.
https://doi.org/10.1097/SMJ.0000000000000184.

62. Peres MFR Swerts DB, de Oliveira AB, Silva-Neto RP. Migraine
patients’ journey until a tertiary headache center: an observational
study. J Headache Pain. 2019;20(1):88. https://doi.org/10.1186/s10194-
019-1039-3.

63. Shuaib W, Johnson JO, Pande V, Salastekar N, Kang J, He Q, et al. Ven‑
ous thromboembolism in patients presenting with syncope: a systematic review. Acad
Emerg Med. 2019;26(5):479–90. https://doi.org/10.1111/acem.13568.

64. Raza SA, Javalkar V, Dehkharghani S, Kudrimoti A, Saindane A, Mullins
M, et al. Utility of repeat cerebrovascular imaging among hospitalized
stroke patients. J Stroke Cerebrovasc Dis. 2017;26(7):1588–93. https://
doi.org/10.1016/j.jstrokecerebrovasdis.2017.02.029.

65. Al Shakarchi J, Lovry D, Nath J, Khawaja AZ, Inston N, Tiwari A. Duplex
ultrasound surveillance after carotid artery endarterectomy. J Vasc Surg.
2016;63(6):1647–50. https://doi.org/10.1016/j.jvs.2016.01.054.

66. Scott JW, Schwartz AL, Gates JD, Gerhard-Herman M, Havens JM.
Choosing wisely for syncope: low-value carotid ultrasound use. J Am
Heart Assoc. 2014;3(4):e001063. https://doi.org/10.1161/JAHA.114.
001063.

67. Rose MK, Rosal LM, Gonzalez RP, Rostas JW, Baker JA, Simmons JD,
Novick D, Wallace R, DiGiacomo JC, Kumar A, Lev S, Angus LDG. The cer‑
ebrovascular imaging for patients with neck pain after negative cervical CT scan.
J Surg Res. 2013;184(1):411–3. https://doi.org/10.1016/j.jss.2013.
05.100.

68. Ali IS, Khan M, Khan MA. Routine preoperative chest x‑ray and its
impact on decision making in patients undergoing elective surgical
procedures. J Ayub Med Coll Abbottabad. 2013;25(1–2):23–5.

69. Kröner A, Beenen L, du Raan M, Meijer P, Spronk PE, Stoker J, et al. The
clinical value of routinely obtained postoperative chest radiographs in
post‑anaesthesia care unit patients seems poor‑a prospective observa‑
tional study. Ann Trans Med. 2018;6(18):360. https://doi.org/10.21037/
atm.2018.08.33.

70. Loggers SAJ, Giannakopoulos GF, Vandewalle E, Ertvemten M, Berger
F, Zuidema WP. Preoperative chest radiographs in hip fracture
patients: is there any additional value? Eur J Orth Surg Traumatol.
2017;27(7):953–9. https://doi.org/10.1007/s00590-017-1971-3.

71. Thanh NX, Rashiq S, Jonsson E. Routine preoperative electro‑
cardiogram and chest x‑ray prior to elective surgery in Alberta, Canada.
Can J Anaesth. 2010;57(2):127–33. https://doi.org/10.1007/s12630-009-9234-3.

72. De La Pena H, Sharma A, Glicksman C, Joseph J, Subesinghe M, Traill Z,
et al. No longer any role for routine follow‑up chest x‑rays in men with
stage I germ cell cancer. Eur J Cancer. 2017;84:354–9. https://doi.org/
10.1016/j.ejca.2017.07.005.

73. Hovgaard TB, Nymark T, Skov O, Petersen MW. Follow‑up after initial
surgical treatment of soft tissue sarcomas in the extremities and trunk
wall. Acta Oncol. 2017;56(7):1004–12. https://doi.org/10.1080/02841
86P.2017.1299937.

74. Hooogendam JP, Zieleskiewicz L, Fresco R, Duclos G, Antonini F, Mathieu C, Medam S,
et al. The utility of routine admission chest X‑ray films on patient care.
Eur J Intern Med. 2011;22(3):286–8. https://doi.org/10.1016/j.ejim.2010.
03.003.

75. Subramanian M, Hranjec T, Liu L, Hodgman EL, Minshall CT, Minei JP.
A case for less workup in near hanging. J Trauma Acute Care Surg.
2016;81(5):925–30. https://doi.org/10.1097/TA.0000000000001231.

76. Benayoun MD, Allen JW, Lovasz BP, Benayoun MD, Spandorfer RM,
Holder CA. Utility of computed tomographic imaging of the cervical spine
in evaluation of ground‑level fall. J Trauma Acute Care Surg. 2016;81(2):339–44. https://
doi.org/10.1097/TA.0000000000001073.

77. Novick D, Wallace R, DiGiacoome JC, Kumar A, Lev S, Angus LDG. The
cervical spine can be cleared without MRI after blunt trauma: a retrospec‑
tive review of a single level 1 trauma center experience over 8 years.
Am J Surg. 2018;216(3):427–30. https://doi.org/10.1016/j.amjsurg.2018.
03.003.

78. Ghaffarpasand F, Paydar S, Foroughi M, Saberi A, Abbasi H, Karimi AA,
et al. Role of cervical spine radiography in the initial evaluation of stable
high‑energy blunt trauma patients. J Orthop Sci. 2011;16(5):498–502.
https://doi.org/10.1007/s00776-011-0932-5.

79. Bartels RHMA, Beems T, Schutte PJ, Verbeek ALM. The rationale of post‑
operative radiographs after cervical anterior discectomy with stand‑
alone cage for radicular pain. J Neurosurg Spine. 2010;12(3):275–9. https://
doi.org/10.3171/2009.9.SPINE09263.

80. Martin SC, Dabbous BO, Riderone EE, Magdum SA, Cadoux-Hudson
TA, Pereira EA. Routine radiographs one day after anterior cervical
discectomy and fusion are neither necessary nor cost‑effective. Br J
Neurosurg. 2017;31(1):50–3. https://doi.org/10.1080/02688697.2016.
1233320.

81. Tran B, Saxe JM, Ekeh AP. Are flexion extension films necessary for cervi‑
cal spine clearance in patients with neck pain after negative cervical CT scan? J Surg Res.
2013;184(1):411–3. https://doi.org/10.1016/j.jss.2013.
05.100.

82. Ali IS, Khan M, Khan MA. Routine preoperative chest x‑ray and its
impact on decision making in patients undergoing elective surgical
procedures. J Ayub Med Coll Abbottabad. 2013;25(1–2):23–5.

83. Kröner A, Beenen L, du Raan M, Meijer P, Spronk PE, Stoker J, et al. The
clinical value of routinely obtained postoperative chest radiographs in
post‑anaesthesia care unit patients seems poor‑a prospective observa‑
tional study. Ann Trans Med. 2018;6(18):360. https://doi.org/10.21037/
atm.2018.08.33.

84. Paydar S, Johari HG, Ghaffarpasand F, Shahidian D, Dehbozorgi A,
Ziaeean B, et al. The role of routine chest radiography in initial evalua‑
tion of stable blunt trauma patients. Am J Emerg Med. 2012;30(1):1–4.
https://doi.org/10.1016/j.ajem.2011.08.010.

85. Zieleskiewicz L, Fresco R, Duclus G, Antonini F, Mathieu C, Medam S,
et al. Integrating extended focused assessment with sonography for trauma (eFAST) in the initial assessment of severe trauma: impact on
the management of 756 patients. Injury. 2018;49(10):1774–80. https://
doi.org/10.1016/j.injury.2018.07.002.

86. Lemmers M, Saltzther TP, Beenen LF, Ponsen KJ, Goslings JC. Are routine
repeat chest x‑rays before leaving the trauma room useful? Emerg Med
J. 2010;27(7):522–5. https://doi.org/10.1136/emj.2009.078519.

87. Bjerringræd LS, Jensen K, Petersen RH, Hansen JU. Routinely obtained
chest X‑rays after elective video‑assisted thoracoscopic surgery can

Page 19 of 28
be omitted in most patients; a retrospective, observational study. Gen Thorac Cardiovasc Surg. 2015;63(8):465–71. https://doi.org/10.1007/s11748-015-0560-9.

95. Leschberger M, May CJ, Simbrey-Chryselius N. Do thoracic surgery patients always need a postoperative chest X-ray? Zentralbl Chir. 2014;139(Suppl 1):S43–9. https://doi.org/10.1055/s-0033-1383034.

96. Chiu J, Saeed R, Jakobowski L, Wang W, Eldeyasty B, Zhu F, et al. Is routine chest X-ray after ultrasound-guided central venous catheter insertion choosing wisely? A population-based retrospective study of 6875 patients. Chest. 2018;154(1):148–56. https://doi.org/10.1016/j.chest.2018.02.017.

97. Cunningham JP, Knott EM, Gasior AC, Juan D, Snyder CL, St. Peter SD, et al. Is routine chest radiograph necessary after chest tube removal? J Pediatr Surg. 2014;49(10):1493–5. https://doi.org/10.1016/j.jpedsurg.2014.01.004.

98. Dalton BA, Gonzalez KW, Keisly MC, Rivard DC, St. Peter SD. Chest radiograph after fluoroscopic guided line placement: no longer necessary. J Pediatr Surg. 2016;51(9):1490–1. https://doi.org/10.1016/j.jpedsurg.2016.02.003.

99. Eisenberg RL, Khabbaz KR. Are chest radiographs routinely indicated after chest tube removal following cardiac surgery? AJR Am J Roentgenol. 2011;197(1):122–4. https://doi.org/10.2214/AJR.10.5856.

100. Farzan R, Shojaei R, Haghdoost A, Mobayen M. Comparison of chest X-ray and clinical findings in trauma patients after chest tube removal. J Clin Diagn Res. 2018;12(7):Pc19–21. https://doi.org/10.7860/jcdr/2018/31989.11833.

101. Goodman MD, Huber NL, Johannigman JA, Pritts TA. Omission of routine chest X-ray after chest tube removal is safe in selected trauma patients. Am J Surg. 2010;199(2):199–203. https://doi.org/10.1016/j.amjsurg.2009.03.011.

102. Hourmozdi JJ, Markin A, Johnson B, Fleming PR, Miller JB. Routine chest radiograph after fluoroscopic guided line placement: no longer necessary. J Pediatr Surg. 2016;51(9):1490–1. https://doi.org/10.1016/j.jpedsurg.2016.02.003.

103. Izbicki G, Romem A, Arish N, Cahan C, Azulai H, Chen-Shuali C, et al. Chest X-ray after fluoroscopic-guided tube insertion: an observational study. Eur J Pediatr Surg. 2019;29(5):408–11. https://doi.org/10.1016/j.ejps.2019.02.001.

104. Johnson B, Rylander M, Beres AL. Do X-rays after chest tube removal? J Pediatr Surg. 2014;49(10):1493–5. https://doi.org/10.1016/j.jpedsurg.2014.01.004.

105. Miccini M, Cassini D, Gregori M, Gazzanelli S, Cassibba S, Biacchi D. Routine postoperative chest X-ray is unnecessary following the Nuss procedure for pectus excavatum. Eur J Pediatr Surg. 2019;29(5):408–11. https://doi.org/10.1016/j.ejps.2019.02.001.

106. Woodland DC, Randall Cooper C, Farzan Rashid M, Rosario VL, Weyker PD, Weintraub J, et al. Routine chest X-ray is unnecessary after ultrasound-guided central venous line placement in the operating room. J Crit Care. 2018;46:13–6.

107. Cerfolio RJ, Bryant AS. Daily chest roentgenograms are unnecessary in nonhypoxic patients who have undergone pulmonary resection by thoracotomy. Ann Thorac Surg. 2011;92(2):440–3. https://doi.org/10.1016/j.athoracsur.2011.04.002.

108. Eisenmann S, Winantea J, Karpf-Wissel R, Funke F, Stenzel E, Taube C, et al. Thoracic ultrasound for immediate exclusion of pneumothorax after interventional bronchoscopy. J Clin Med. 2020;9(10):2353–8. https://doi.org/10.1007/s00268-016-01368-7.

109. Velicković JV, Hajdarević SA, Palibrk IG, Janić NR, Djukanović M, Milićković B, et al. Routine chest radiographs in the surgical intensive care unit: can we change clinical habits with no proven benefit? Acta Chirurgiologica. 2013;60(3):39–44.

110. Pathak T, Parmar MS. (Flu)larity of computed tomography of the chest in the presence of pleural effusion. Pleura Peritoneum. 2017;2(4):181–6. https://doi.org/10.1515/pp-2017-0019.

111. Fathihoglu E, Aydin S, Gokharman FD, Ece B, Kosar PN. X-ray use in chest imaging in emergency department on the basis of cost and effectiveness. Acad Radiol. 2016;23(10):1239–45. https://doi.org/10.1016/j.acra.2015.06.008.

112. Kim H, Han W, Moon H-G, Min J, Ahn S-K, Kim T-Y, et al. The value of preoperative staging chest computed tomography to detect asymptomatic lung and liver metastasis in patients with primary breast carcinoma. Breast Cancer Res Treat. 2011;126(3):637–41. https://doi.org/10.1007/s10549-011-1368-7.

113. Velicković JV, Hajdarević SA, Palibrk IG, Janić NR, Djukanović M, Milićković B, et al. Routine chest radiographs in the surgical intensive care unit: can we change clinical habits with no proven benefit? Acta Chirurgiologica. 2013;60(3):39–44.

114. Pathak T, Parmar MS. (Flu)larity of computed tomography of the chest in the presence of pleural effusion. Pleura Peritoneum. 2017;2(4):181–6. https://doi.org/10.1515/pp-2017-0019.

115. Fathihoglu E, Aydin S, Gokharman FD, Ece B, Kosar PN. X-ray use in chest imaging in emergency department on the basis of cost and effectiveness. Acad Radiol. 2016;23(10):1239–45. https://doi.org/10.1016/j.acra.2015.06.008.

116. Velicković JV, Hajdarević SA, Palibrk IG, Janić NR, Djukanović M, Milićković B, et al. Routine chest radiographs in the surgical intensive care unit: can we change clinical habits with no proven benefit? Acta Chirurgiologica. 2013;60(3):39–44.

117. Velicković JV, Hajdarević SA, Palibrk IG, Janić NR, Djukanović M, Milićković B, et al. Routine chest radiographs in the surgical intensive care unit: can we change clinical habits with no proven benefit? Acta Chirurgiologica. 2013;60(3):39–44.

118. Velicković JV, Hajdarević SA, Palibrk IG, Janić NR, Djukanović M, Milićković B, et al. Routine chest radiographs in the surgical intensive care unit: can we change clinical habits with no proven benefit? Acta Chirurgiologica. 2013;60(3):39–44.

119. Velicković JV, Hajdarević SA, Palibrk IG, Janić NR, Djukanović M, Milićković B, et al. Routine chest radiographs in the surgical intensive care unit: can we change clinical habits with no proven benefit? Acta Chirurgiologica. 2013;60(3):39–44.

120. Velicković JV, Hajdarević SA, Palibrk IG, Janić NR, Djukanović M, Milićković B, et al. Routine chest radiographs in the surgical intensive care unit: can we change clinical habits with no proven benefit? Acta Chirurgiologica. 2013;60(3):39–44.
review and meta-analysis of medical record reviews. PLoS ONE. 2019;14(12):e0225414. https://doi.org/10.1371/journal.pone.0225414.

130. Schlemer E, Mitchener JC, Brown M, Wasilevich E. Imaging during low back pain ED visits: a claims-based descriptive analysis. Am J Emerg Med. 2015;33(3):414–8. https://doi.org/10.1016/j.ajem.2014.12.060.

131. Leichtle UK, Wunschel M, Socci M, Kurze C, Niemeyer T, Leichtle CI. Spine radiography in the evaluation of back and neck pain in an orthopaedic emergency clinic. J Back Musculoskelet Rehabil. 2015;28(1):43–8. https://doi.org/10.3233/BMR-140488.

134. Yamashita T, Steinmetz MP, Lieberman IH, Modic MT, Mroz TE. The utility of repeated post-operative radiographs after instrumented single-level degenerative spinal fusions: utility after intraoperative fluoroscopy. Spine. 2012;17(2):559–67. https://doi.org/10.1097/01.spine.0000385890.68032.4e.

135. Natoli RM, Fogel HA, Holt D, Schiff A, Bernstein M, Summers HD, et al. Advanced imaging lacks clinical utility in treating geriatric pelvic ring injuries caused by low-energy trauma. J Orthop Trauma. 2017;31(4):194–9. https://doi.org/10.1097/BOT.0000000000000761.

136. Bolt C, O’Keeffe F, Finnegan P, Dickson K, Smit V, Fitzgerald MC, et al. Straight leg elevation to rule out pelvic injury. Injury. 2018;49(2):279–83. https://doi.org/10.1016/j.injury.2017.09.009.

137. van Trigt J, Schep NWL, Peters RW, Goslings JC, Schepers T, Halm JA. The utility of post-operative hip radiographs in patients treated with hip hemiarthroplasty for femoral neck fractures. Injury. 2019;50(8):1448–51. https://doi.org/10.1016/j.injury.2019.06.001.

138. Issa K, Jauregui JJ, McElroy M, Banerjee S, Kapadia BH, Mont MA. Unnecessary knee imaging requested by primary care physicians for patients with knee pain. Int J Qual Health Care. 2018;30(7):565–70. https://doi.org/10.1093/intqhc/mzy067.

140. Westerterp M, Emous M, Vermeulen MC, Eerenberg JP, van Geloven AA. Routine pelvic X-rays in asymptomatic hemodynamically stable blunt trauma patients: a meta-analysis. Injury. 2019;50(1):20–24. https://doi.org/10.1016/j.injury.2018.09.009.

142. Parent ME, Vezina F, Carrier N, Masetto A. Indications for and clinical utility of MRI scans for a painful knee in the elderly patient. Int J Med Sci. 2020;17:64(3):e16–29.

146. Issa K, Jauregui JJ, McElroy M, Banerjee S, Kapadia BH, Mont MA. Value-based care analysis of magnetic resonance imaging in patients with suspected rotator cuff tendinopathy and the implicated role of conservative management. J Shoulder Elbow Surg. 2019;28(11):2153–60. https://doi.org/10.1016/j.jse.2019.07.025.

151. Werner BC, Burrus MT, Kew ME, Dempsey U, Gwathmey FW, Miller MD, et al. Limited utility of routine early postoperative radiography after primary ACL reconstruction. Knee. 2016;23(2):237–40. https://doi.org/10.1016/j.knee.2015.09.006.

154. Jennewine B, Fiorino D, Kew M, Byrne A, Yarboro S. Routine postoperative radiographs after tibia plateau fixation have minimal impact on patient care. Injury. 2019;50(11):2093–6. https://doi.org/10.1016/j.injury.2019.07.025.

155. Kampfert AS, Kazanian GS, Boyer GP, Lonner J. Radiographic imaging in the postanesthesia care unit is unnecessary after partial knee arthroplasty. J Arthroplasty. 2017;32(5):1431–3. https://doi.org/10.1016/j.arth.2016.11.033.

156. Moussa ME, Malchau H, Freiberg AA, Kwon YM. Effect of immediate postoperative portable radiographs on reoperation in primary total knee arthroplasty. Orthopedics. 2014;37(9):e817–21. https://doi.org/10.3928/01477447-20140825-99.

158. Freeman R, Khanna S, Ricketts D. Inappropriate Requests for magnetic resonance scans of the shoulder. Int Orthop. 2013;37(7):1281–4. https://doi.org/10.1007/s00264-013-1968-4.

159. Cortes A, Quinlan NJ, Nazal MR, Upadhyaya S, Alpacha K, Martin SD. A value-based care analysis of magnetic resonance imaging in patients with atraumatic shoulder pain: are they useful? J Am Acad Orthop Surg. 2019;27(2):86–94. https://doi.org/10.5435/JAAOS-D-16-00884.

160. Freiman R, Khanna S, Ricketts D. Inappropriate requests for magnetic resonance scans of the shoulder. Int Orthop. 2013;37(7):1281–4. https://doi.org/10.1007/s00264-013-1968-4.

164. Eastley N, Aujla R, Khan Z. Radiographic imaging in the evaluation of ankle fractures. Injury. 2016;47(10):2366–9. https://doi.org/10.1016/j.injury.2016.09.008.
167. Van Gerven P, El Moumni M, Zuidema WP, Rubinstein SM, Krijnen P, Van Tulder MW, et al. Omitting routine radiography of traumatic distal radial fractures after initial 2-week follow-up does not affect outcomes. J Bone Joint Surg Am. 2019;101(15):1342–50.

168. Imerci A, Kaya A, Bozoglan M, Adam G, Canbek U, Savran A. Evaluation of computed tomography use in emergency department orthopedic trauma patients. Turk J Emerg Med. 2013;13(2):75–80.

169. Chaudhry S, DelSole EM, Egol KA. Post-splinting radiographs of minimally displaced fractures: good medicine or medicolegal protection? J Bone Joint Surg Am. 2012;94(17): e128. https://doi.org/10.2106/JBJS.K.00944.

170. Michelotti BF, Mathews A, Chung KC. Appropriateness of the use of magnetic resonance imaging in the diagnosis and treatment of wrist soft tissue injury. Plast Reconstr Surg. 2018;141(2):410–9. https://doi.org/10.1097/PRS.0000000000005423.

171. Stott S, Balogh ZJ. Postoperative computed tomography for articular fractures: a systematic review. J Orthop Trauma. 2017;31(1):56–61. https://doi.org/10.1097/BOT.0000000000001060.

172. Wilson RJ, Zumsteg JW, Hartley KA, Long JH, Mesko NW, Halpern JL, et al. Overutilization and cost of advanced imaging for long-bone cartilaginous lesions. Ann Surg Oncol. 2015;22(11):3466–73. https://doi.org/10.1245/s10434-015-4435-5.

173. Babbel D, Rayan G. Magnetic resonance imaging in evaluating workers’ compensation patients. J Hand Surg Am. 2012;37(4):811–5. https://doi.org/10.1016/j.jhsa.2011.12.008.

174. Nyström LM, Reimer NB, Dean CW, Bush CH, Scarborough MT, Gibbs CP Jr. Evaluation of imaging utilization prior to referral of musculoskeletal trauma patients. Turk J Emerg Med. 2013;13(2):75–80.

175. Kothari S, Kalinowski M, Kabesko M, Almouradi T. Computed tomographic magnetic resonance imaging in the diagnosis and treatment of wrist fractures after initial computed tomography. Rofo. 2012;184(1):53–8. https://doi.org/10.1055/s-0031-1281638.

176. Nojkov B, Duffy MC, Cappell MS. Utility of repeated abdominal CT scans after prior negative CT scans in patients presenting to ER with nontraumatic abdominal pain. Dig Dis Sci. 2013;58(4):1074–83. https://doi.org/10.1007/s10620-012-2473-0.

177. Sreedharan S, Fioreninto M, Sinha S. Plain abdominal radiography in acute abdominal pain—not is it really necessary? Emerg Radiol. 2014;21(6):597–603. https://doi.org/10.1007/s10140-014-2444-y.

178. Valasek PA, St Peter SD, Keckler SJ, Laituin CA, Snyder CL, Oxlade DJ, et al. Does an upper gastrointestinal study change operative management for gastroesophageal reflux? J Pediatr Surg. 2010;45(6):1169–72. https://doi.org/10.1016/j.jpedsurg.2010.02.083.

179. van Randen AMD, Laméris W, Luitse JSM, Gorzeman MMD, Hesselink EJMD, Dolmans DEEJMPD, et al. The role of plain radiographs in patients with acute abdominal pain at the ED. Am J Emerg Med. 2011;29(6):582–9. https://doi.org/10.1016/j.ajem.2011.09.008.

180. Westphalen AC, Hsaia RY, Maselli JH, Wang R, Gonzales R. Radiological imaging of patients with suspected urinary tract stones: national trends, diagnoses, and predictors. Acad Emerg Med. 2011;18(7):699–707. https://doi.org/10.1111/j.1553-2712.2011.01103.x.

181. Wuj J, Zhang T, Zhu YS, Gong NM. Diagnostic value of ultrasound compared to CT in patients with suspected acute appendicitis. Int J Clin Exp Radiol. 2014;7(4):143–7. https://doi.org/10.5811/ijcer.2014.7.17243.

182. Brockmeyer JR, Simon TE, Jacob RK, Husan F, Choi Y. Upper gastrointestinal swallow study following bariatric surgery: institutional review and review of the literature. Obes Surg. 2012;22(7):1039–43. https://doi.org/10.1007/s11695-012-0658-4.

183. Diaz Vilco T, Ellis EF. Utility of immediate postoperative upper gastrointestinal contract study in bariatric surgery. Obes Surg. 2019;29(4):1130–3. https://doi.org/10.1007/s11695-018-03639-w.

184. Abou Hussein BM, Khammass A, Makki M, Makki M, Al Batsai U, Al Mazrouei A, et al. Role of routine abdominal ultrasound before bariatric surgery: review of 937 patients. Obes Surg. 2018;28(9):2969–80. https://doi.org/10.1007/s11695-018-3210-3.

185. Hu Z, Wang X, An X, Li W, Feng Y, You Z. The diagnostic value of routine contrast esophagogram in anastomotic leaks after esophagectomy. World J Surg. 2017;41(8):2062–7. https://doi.org/10.1007/s00261-017-03923-9.

186. Mittermair R, Sucher R, Perathoner A, Wykypiel H. Routine upper gastrointestinal swallow studies after laparoscopic sleeve gastrectomy are unnecessary. Am J Surg. 2014;207(6):897–901. https://doi.org/10.1016/j.amjsurg.2013.06.015.

187. Wu CH, Chen CM, Chen CC, Wong YC, Wang CJ, Lo WC, et al. Esophagography after pneumoendoscopy without CT findings of esophageal perforation: is it necessary? Am J Roentgenol. 2013;201(5):977–84.

188. Yonis G, Cabalag CS, Link E, Duong CP. Utility of oral contrast study for detecting postesophagostomy anastomotic leak—a systematic review and meta-analysis. Dis Esophagus. 2019. https://doi.org/10.1093/dote/doz011.

189. Baker W, Pelkofski E, Te Paske J, Erickson S, Duska L. Preoperative imaging of uterine malignancy: a low-value service. Gynecol Oncol. 2015;137(2):285–90. https://doi.org/10.1016/j.ygyno.2015.02.015.

190. Lavery HJ, Brattbord JS, Levinson AW, Nabizada-Pace F, Pollard ME, Samadi DB. Unnecessary imaging for the staging of low-risk prostate cancer is common. Urology. 2011;77(2):274–8. https://doi.org/10.1016/j.urology.2010.07.491.

191. Drangsholt S, Walter D, Ciprut S, Lepor A, Seidleander E, Curnyn C, et al. Quantifying downstream impact of inappropriate staging imaging in a cohort of veterans with low- and intermediate-risk incident prostate cancer. Urol Oncol. 2019;37(2):145–9. https://doi.org/10.1016/j.urolonc.2018.11.022.

192. Han K, Park SH, Kim KW, Kim HJ, Lee SS, Kim JC, et al. Use of liver magnetic resonance imaging after standard staging abdominopelvic computed tomography to evaluate newly diagnosed colorectal cancer patients. Ann Surg. 2015;261(3):480–6. https://doi.org/10.1097/SLA.0000000000000708.

193. Lou I, Schneider DF, Levinson GE, Sippel RS, Chen H. Do additional imaging studies change operative management in patients undergoing adrenalectomy? Surgery. 2015;158(4):1003–9. https://doi.org/10.1016/j.surg.2015.05.031 (discussion 9–11).
patients with early tumor stages. Oncol Res Treat. 2014;37(7–8):400–5. https://doi.org/10.1159/000363528.

239. Hartridge-Lambert SK, Schoder H, Lim RC, Maragulia JC, Portlock CS. ABVD alone and a PET scan complete remission negates the need for radiologic surveillance in early-stage, nonbulky Hodgkin lymphoma. Cancer. 2013;119(6):1203–9. https://doi.org/10.1002/cncr.27873.

240. Healy MA, Yin H, Reddy RM, Wong SL. Use of positron emission tomography to detect recurrence and associations with survival in patients with lung and esophageal cancers. J Natl Cancer Inst. 2016. https://doi.org/10.1093/jnci/djv429.

241. Holtkamp LH, Reid RL, Emmett L, Thompson JF, Nieweg OE. Futility of imaging to stage melanoma patients with a positive sentinel lymph node. Melanoma Res. 2017;27(2):457–62. https://doi.org/10.1097/CMR.0000000000000362.

242. Kamal A, Zhang T, Power S, Marcom PK. Is advanced imaging in early-stage breast cancer ever warranted? Reconciling clinical judgment with common quality measures. J Natl Compr Cancer Netw. 2016;14(8):993–8. https://doi.org/10.6004/jnccn.2016.0106.

243. Pappas SG, Christians KK, Tolat PP, Mautz AP, Lal A, McCloy L, et al. Staging chest computed tomography and positron emission tomography/computed tomography in node-negative endometrial cancer on magnetic resonance imaging. Ann Surg Oncol. 2017;24(8):2303–10. https://doi.org/10.1245/s10434-017-5901-8.

244. Park JY, Lee JI, Choi HJ, Song IH, Sung CO, Kim HO, et al. The value of preoperative emission tomography/computed tomography in node-negative endometrial cancer on magnetic resonance imaging. Ann Surg Oncol. 2017;24(8):2303–10. https://doi.org/10.1245/s10434-017-5901-8.

245. Sabate-Llobera A, Cortes-Romera M, Mercadal S, Hernandez-Ganan J, Pomeres H, Gonzalez-Barca E, et al. Low-dose PET/CT and full-dose contrast-enhanced CT at the initial staging of localized diffuse large B-cell lymphomas. Clin Med Insights-Blood Distr. 2016;9:29–32. https://doi.org/10.14317/Cmbld.538468.

246. Simos D, Catley C, van Walraven C, Arnaout A, Booth CM, McInnes M, et al. Imaging for distant metastases in women with early-stage breast cancer: a population-based cohort study. CMAJ. 2015;187(12):E387–97. https://doi.org/10.1503/cmaj.150003.

247. Taghipour M, Marcus C, Sheikhhahaei S, Mena E, Prasad S, Jha AK, et al. Clinical indications and impact on management: fourth and subsequent posttherapy follow-up (18F-FDG PET/CT scans in oncology patients. J Nucl Med. 2017;58(5):737–43. https://doi.org/10.2967/jnumed.116.183111.

248. Thompson CA, Ghesquiere H, Maurer MJ, Cerhan JR, Biron P, Ansell SM, et al. Utility of 6-month interval imaging after benign radiologic-pathologic concordant minimally invasive breast biopsy. Ann Surg Oncol. 2013(2010):3163–8. https://doi.org/10.1245/s10434-013-3114-3.

249. Maldonado S, Gandhi N, Ha T, Choi P, Khalkhali I, Kalantari BN, et al. Utility of short-interval follow-up mammography after a benign-concordant stereotactic breast biopsy result. Breast. 2018;42:50–3. https://doi.org/10.1016/j.breast.2018.08.101.

250. Lapid O, Siebenga P, Zonderland HM. Overuse of imaging the male breast-findings in 557 patients. Breast. 2015;21(3):219–23. https://doi.org/10.1016/j.breast.2015.12.001.

251. Galvao De Lima JJ, Wolff Goudak LH, de Paula FJ, Franchini Ramires JA, Bortolotto LA. The role of myocardial scintigraphy in the assessment of cardiovascular risk in patients with end-stage chronic kidney disease on the waiting list for renal transplantation. Nephrol Dial Transplant. 2012;27(7):2979–84. https://doi.org/10.1093/ndt/gft770.

252. Foy A, Rier J, Kazak M. High numbers of false-positive stress tests are the result of inappropriate testing. Am J Med Qual. 2014(29):153–9. https://doi.org/10.1177/1062860613489726.

253. Holle SLK, Andersen MH, Klein CF, Bruun NE, Tonder N, Haarmark C, et al. Clinical usefulness of FDG-PET/CT for identification of abnormal extra-cardiac foci in patients with infective endocarditis. Int J Cardiovasc Imaging. 2020;36(5):939–46. https://doi.org/10.1007/s10554-020-01787-8.

254. Harris J, Yoon J, Salem M, Selim M, Kumar S, Liotau VA. Utility of transhthoracic echocardiography in diagnostic evaluation of ischemic stroke. Front Neurol. 2020;11:103. https://doi.org/10.3389/fneur.2020.00103.

255. Patel MR, Peterson ED, Dai D, Brennan JM, Redberg RF, Anderson HV, et al. Low diagnostic yield of elective coronary angiography. N Engl J Med. 2013;362(10):886–95. https://doi.org/10.1056/NEJMoa0907227.

256. Witteles RM, Knowles JW, Perez M, Morris WM, Spettell CM, Brennan TA, et al. Use and overuse of left ventriculography. Am Heart J. 2012;163(4):617-23.e1. https://doi.org/10.1016/j.ahj.2012.12.018.

257. Haymart MR, Banerjee M, Reyes-Gastelum D, Caoili E, Norton EC. Thyroid ultrasound and the increase in diagnosis of low-risk thyroid cancer. J Clin Endocrinol Metab. 2019;104(3):785–92. https://doi.org/10.1210/jc.2018-01933.

258. Mohammadi M, Betel C, Burton KR, Higgins GM, Ghobar Z, Halperin U. Follow-up of benign thyroid nodules—can we do less? Can Assoc Radiol J. 2019;70(1):62–7. https://doi.org/10.1016/j.carj.2018.10.001.

259. Baek HJ, Kim DW, Lee CY, Huh JY, Sung JY, Choy YJ. Analysis of postoperative ultrasonography surveillance after hemithyroidectomy in patients with papillary thyroid microcarcinoma: a multicenter study. Endocr Pract. 2017;23(7):794–802. https://doi.org/10.4158/EP161723.OR.
273. Baek HJ, Kim DW, Lee S, Ryu I, Lee CY, Choi YJ, et al. Postoperative ultra-
sonography surveillance in patients with follicular thyroid carcinoma: a multicenter study. Radiol Med. 2017;122(7):530–7. https://doi.org/10.
1007/s11547-017-0753-7.

274. Panneerselvan R, Schneider DF, Sippel RS, Chen H. Radioactive iodine
scanning is not beneficial but its use persists for euthyroid patients: J Surg
Res. 2013;184(1):269–73. https://doi.org/10.1016/j.jsr.2013.03.092.

275. Kim DW. Long-term follow-up ultrasonography after lobectomy in pap-
ilary thyroid microcarcinoma patients: a single-center study. Endocr
Res. 2016;41(3):213–7. https://doi.org/10.1007/s12030-015-1173-583.

276. Jones BA, Lindeman B, Chen H. Are Tc-99m-sestamibi scans in patients
with secondary hyperparathyroidism and renal failure needed? J Surg
Res. 2019;243:380–3. https://doi.org/10.1016/j.jss.2019.04.084.

277. Jaune F, Quinto L, Alodib I, Mollot J. Overuse of diagnostic tools and
medications in acute rhinosinusitis in Spain: a population-based study
(the PROSINUS study). BJM Open. 2018;8(1):e018788. https://doi.org/10.
1136/bmjopen-2017-018788.

278. Huang LK, Tu HF, Jiang LD, Chen YY, Fu CY. Evaluation of concomitant
radioactive iodine. J Surg Res. 2019;253:269–75. https://doi.org/10.1016/j.
jss.2019.05.084.

279. Sener MT, Kok AN, Kara C, Anci Y, Sahingoz S, Emet M. Diagnosis
of juvenile ossifying fibroma? A comparison of 2 imaging modalities (computed tomography and magnetic resonance imaging). J Oral
Maxillofac Surg. 2015;73(7):1304–13. https://doi.org/10.4103/0222-
0391.141409.

280. Kenway B, Vlastarakos PV, Kasbekar AV, Axon PR, Donnelly N. Are routine
head CT scan: a retrospective study at a level II trauma center. J Clin
Nose Throat J. 2016;95(8):318–22.

281. Strait L, Sussman R, Ata A, Edwards MJ. Utilization of CT imaging in
maxillofacial trauma: sense or nonsense? Int J Oral Maxillofac Surg.
2015;73(7):1304–13. https://doi.org/10.1016/j.ijom.2015.03.001

282. Zulfiqar M, Kim S, Lai JP, Zhou Y. The role of computed tomography in
reduction and internal fixation of mandibular fractures: clinical need.
Contemp Clin Dent. 2014;5(2):166–9. https://doi.org/10.4103/0973-
2011;40(12):1373–6. https://doi.org/10.1016/j.ijom.2011.08.008.

283. Dawson EC, Montgomery CP, Frim D, Koogler T. Is repeat head
computed tomography necessary in children admitted with mild
head injury and normal neurological exam? Pediatr Neurosurg.
2012;48(8):221–4. https://doi.org/10.1159/000346697.

284. Howe J, Fitzpatrick CM, Lakam DR, Gleisner A, Vane DW. Routine repeat
brain computed tomography in all children with mild traumatic brain
injury may result in unnecessary radiation exposure. J Trauma Acute
Care Surg. 2014;76(2):292–5. https://doi.org/10.1097/TA.0b013e318
201119 (discussion 5-6).

285. Rho YJ, Chung HJ, Suh ES, Lee KH, Eun BL, Nam SO, et al. The role of
neuroimaging in children and adolescents with recurrent headaches—
multicenter study. Headache J Head Face Pain. 2011;51(3):403–8. https://doi.org/10.1111/j.1526-4610.2011.01845.x.

286. Ahmed M, Grossman S, Rafique B, Momoh OA. Site locked headaches
in pediatric patients do not require routine brain imaging and rarely
have a serious etiology. Acta Paediatr. 2017;106(3):791–5. https://doi.org/10.1111/apa.13743.

287. Gandhi R, Lewis EC, Evans JW, Sell E. Investigating the necessity of com-
tputed tomographic scans in children with headaches: a retrospective
review. CJEM. 2015;17(2):148–53. https://doi.org/10.2310/8000.2014.
014609.

288. Trofimova AV, Kishore D, Urquia L, Tewskebury G, Duszkak R Jr, Levy MD,
et al. Imaging utilization in children with headaches: current status and
opportunities for improvement. J Am Coll Radiol. 2020;17(5):574–83.
https://doi.org/10.1016/j.jacr.2020.01.008.

289. Zeechan M, Hamidi M, O'Keeffe T, Hanna K, Kuvatunyovu N, Tang A,
et al. Pediatric liver injury: physical examination, fast and serum transami
nases can serve as a guide. J Surg Res. 2019;242:151–6. https://doi.org/10.
1016/j.jss.2019.04.021.

290. Zeechan M, Hamidi M, O'Keeffe T, Hanna K, Kuvatunyovu N, Tang A,
et al. Pediatric liver injury: physical examination, fast and serum transami
nases can serve as a guide. J Surg Res. 2019;242:151–6. https://doi.org/10.
1016/j.jss.2019.04.021.

291. Biondi E, Macduff S, Capucilli P, Tsuboyama M, Wu S, Beck C, et al. Using
computed tomography and diffusion weighted imaging in children with
acute care setting—are we overdiagnosing constipation? Cureus.
2020;12(3):7283. https://doi.org/10.7759/cureus.7283.

292. Acker SN, Trinh BB, Partrick DA, Stewart CL, Bensard DD. Is Routine
ventricular shunt. Childs Nerv Syst. 2019;35(3):477–86. https://doi.org/
10.1007/s00381-018-04046-3.

293. Abdullah S, Shet N, Watkins R, Kim JS. Is the scout out? The utility of scout
radiographs in the pediatric upper gastrointestinal examination. J Pediatr
Gastroenterol Nutr. 2018;67(5):576–9. https://doi.org/10.1097/MPG.
0000000000002117.

294. Ul Haq MMA, Lyons H, Halim M. Pediatric abdominal X-rays in the
acute care setting—are we overdiagnosing constipation? Cureus.
2020;12(3):7283. https://doi.org/10.7759/cureus.7283.

295. El‑Maadawy SM, El‑Atawi KM, Elhalik MS. Role of bedside ultrasound in
determining the position of umbilical venous catheters. J Clin Neonatol.
2016;26(1):29–33. https://doi.org/10.1055/s-0035-1563675.
381. Peterson T, Askew JW, Bell M, Crusan D, Hodge D, Gibbons RJ. Low yield of stress imaging in a population-based study of asymptomatic patients after percutaneous coronary intervention. Circ Cardiovasc Imaging. 2014;7(3):438–45. https://doi.org/10.1161/CIRCIMAGING.113.000833.

382. Prasad SM, Gu X, Lipsitz SR, Nguyen PL, Hu JC. Inappropriate utilization of radiographic imaging in men with newly diagnosed prostate cancer in the United States. Cancer. 2012;118(5):1260–7. https://doi.org/10.1002/cncr.26416.

383. Schumacher JR, Neuman HB, Chang GJ, Kozower BD, Edge SB, Yu M, et al. A national study of the use of asymptomatic systemic imaging for surveillance following breast cancer treatment (AFT-01). Ann Surg Oncol. 2018;25(9):2587–95. https://doi.org/10.1007/s10434-018-6496-4.

384. Thiriez C, Itri E, Fenelon G, Evangelista E, Meignan M, Cesaro P, et al. Clinical routine use of dopamine transporter imaging in 516 consecutive patients. J Neurol. 2015;262(4):909–15. https://doi.org/10.1007/s00415-014-7634-y.

385. Solivetti FM, Elia F, Guerini A, Desiderio F, Santaguida M, Sperduti I, et al. Cutaneous melanoma follow-up: appropriateness of requests for ultrasound tests—the S.Gallicano National Referral Centre Experience. J Exp Clin Cancer Res. 2013;32(1):73. https://doi.org/10.1186/1756-9966-32-73.

386. Remfry A, Abrams H, Dudzinski DM, Weiner RB, Bhatia RS. Assessment of inpatient multimodal cardiac imaging appropriateness at large academic medical centers. Cardiovasc Ultrasound. 2015. https://doi.org/10.1186/s12947-015-0037-0.

387. Wymer KM, Pearce SM, Harris KT, Pierrozzi PM, Daneshmand S, Eggener SE. Adherence to national comprehensive cancer network(R) guidelines for testicular cancer. J Urol. 2017;197(3 Pt 1):684–9. https://doi.org/10.1016/j.juro.2016.09.073.

388. Gulsen I, Ak H, Karadas S, Demir I, Bulut MD, Yacioglu S. Indications of brain computed tomography scan in children younger than 3 years of age with minor head trauma. Emerg Med Int. 2014;2014:248967. https://doi.org/10.1155/2014/248967.

389. Weiss AR, Lyden ER, Anderson JR, Hawkins DS, Spunt SL, Walterhouse DO, et al. Histologic and clinical characteristics can guide staging evaluations for children and adolescents with rhabdomyosarcoma: a report from the Children’s Oncology Group Soft Tissue Sarcoma Committee. J Clin Oncol. 2013;31(26):3226–32. https://doi.org/10.1200/JCO.2012.44.6475.

390. Levin DC, Rao VM. Reducing Inappropriate use of diagnostic imaging through the choosing wisely initiative. J Am Coll Radiol. 2017;14(9):1245–52. https://doi.org/10.1016/j.jacr.2017.03.012.

391. Brady AP, Bello JA, Derchi LE, Fuchsjaeger M, Goergen S, Krestin GP, et al. Radiology in the era of value-based healthcare: a multi-society expert statement from the ACR, CAR, ESR, ISMRM, RANZCR, and RSNA. Radiology. 2021;298(3):846–91. https://doi.org/10.1148/radiol.2020209027.

392. Munn Z, Peters MDJ, Sterne JA, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol. 2018;18(1):143. https://doi.org/10.1186/s12874-018-0611-x.

Publisher’s Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.