

BMJ Open Appropriate use of medical imaging in two Spanish public hospitals: a cross-sectional analysis

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ABSTRACT

Objectives To determine the appropriateness of medical imaging examinations involving radiation and to estimate the effective radiation dose and costs associated.

Design Cross-sectional retrospective study.

Setting Two Spanish public tertiary hospitals.

Participants 2022 medical imaging tests were extracted from the radiology information system in February and March of 2014. MRI and ultrasound examinations were excluded.

Primary and secondary outcome measures Five outcomes were set independently by at least two researchers according to four guidelines: (1) appropriate; (2) inappropriate; (3) inappropriate due to repetition, if the timing to carry out next diagnostic tests was incorrect according to guidelines; (4) not adequately justified, if the referral form did not include enough clinical information to allow us to understand the patient's clinical condition; and (5) not included in the guidelines, if the referral could not be matched to a clinical scenario described in the guidelines. We estimated the prevalence of the five categories according to relevant clinical and sociodemographic variables and the effective radiation dose and costs for each category.

Results Approximately half of the imaging tests were deemed as appropriate (967, 47.8%) while one-third (634, 31.4%) were considered inappropriate. 19.6% of the effective dose and 25.2% of the cost were associated with inappropriate tests. Women were less likely than men to have an imaging test classified as appropriate (adjusted OR 0.70, 95% CI 0.57 to 0.86). Imaging tests requested by general practitioners were less likely to be considered appropriate than those requested by central services (adjusted OR 0.60, 95% CI 0.38 to 0.93). Mammography and CT were more likely to be appropriate than conventional X-rays.

Conclusion There was a significant frequency of inappropriateness, which resulted in a high percentage of associated effective radiation dose. Percentage of inappropriateness depends on sociodemographic and clinical characteristics such as sex, age, referral physician and medical imaging test.

INTRODUCTION

In 1998, Chassin and Galvin¹ defined overuse as ‘*the provision of medical services that are more likely to cause harm than good*’. Since then,

Strengths and limitations of this study

- This is the first study to investigate the appropriateness of medical imaging test in a clinical general context according to available evidence and to estimate the associated effective dose and costs.
- One of the strengths of this study lies in including all imaging tests performed in routine clinical practice. The only criterion for exclusion was not using radiation. Such a wide approach is basic from a public health perspective, as well as to approach the problem of appropriateness in daily clinical practice.
- The available guidelines do not cover the whole spectrum of clinical situations in a general practice context, such as the appropriate timing for follow-up imaging test studies in different situations such as patients with cancer under treatment or follow-up trauma patients.

there has been increasing concern about the problem of ‘too much medicine’² and its medical, social and economic consequences.³ Diagnostic imaging is not an exception, and there are indications that many imaging tests could be inappropriate.⁴ Some studies that focused on a limited set of imaging tests found rates of inappropriate examinations between 15% and 35%.^{5–7}

Overuse can be measured directly using medical records, comparing the appropriateness of the referrals against evidence-based guidelines.⁸ However, in the case of imaging tests, several aspects could be missed if we based our judgement solely on these guidelines. For instance, repeating the same or a similar imaging test (with the same diagnostic value) is an incorrect practice that has not usually been analysed in the clinical practice.⁹ It is also important to acknowledge that sometimes the guidelines used do not include the information needed to comprehend the whole spectrum of the clinical condition for which the imaging test is required.¹⁰ Moreover, on other occasions, the appropriateness of some referral forms cannot be assessed

properly using the guidelines because medical records do not include enough clinical information to understand the diagnostic reasoning on which they are based.^{6,11}

There are other clinical situations where referring physicians ask for a medical imaging to reassure patients, although there is no real suspicion of a disease. Although these situations are usual in clinical practice, they are inappropriate. The consequences of the overuse of imaging tests range from increased costs and waiting lists to overdiagnosis and medical clinical cascades.^{12,13} Radiation imaging tests, additionally, imply radiation exposure, which is associated with stochastic health effects, such as cancer.¹⁴ The International Commission for Radiological Protection (ICRP), along with the legislation in most countries, requires medical radiation exposures to be justified or, in other words, do more good than harm.¹⁵

In our setting, the European Union (EU) has put out a framework of legislation regarding radiation protection that includes the principle of justification for all clinical practices involving radiation exposure. The first step towards justification is the appropriateness of the medical tests. In particular, the revised 'Basic Safety Standards Directive', adopted in 2013 by all member states,¹⁶ requires the measurement of overuse for medical radiation exposures. Thus, although the overuse of other imaging tests such as MRI and ultrasound (US) is also associated with financial and clinical harms, given the European scenario, we focused on radiation exposure medical imaging tests.

Advances in imaging and information technology have increased the importance of the radiologist by increasing utilisation of diagnostic imaging and by moving the radiologist into a more central role in integrated patient care. Radiologists and also radiological technicians should have a role in insuring that medical imaging tests are used efficiently and appropriately. However, it is difficult for radiologists to guarantee that all tests are ordered appropriately for several reasons. Clinical information is important to correlate with the imaging findings, especially to avoid false-positive imaging diagnoses. Unfortunately, radiologists are rarely consulted, and they often perform and interpret the imaging reports without enough clinical information. Radiologists and other specialists should closely cooperate to try to balance the potential to diagnose a disease that may cause morbidity and mortality against unnecessary testing, which carry their own risks, together with patient anxiety and the cost to society. Moreover, while radiological services are essential to the care of patients, radiologists are relatively limited in their ability to refer patients to their own facilities.¹⁷ To the patients, radiological services may seem somewhat inopportune or alarming and typically are unaware which radiologist is reviewing the image. Therefore, it is important to have more contact with patients to share decisions when performing any medical imaging test.

To the best of our knowledge, the studies that analyse overuse through the appropriateness of medical imaging

test have mainly focused on high-dose and high-cost imaging techniques, such as CT and MRI.^{5,18} However, these techniques account for up to 20% of all imaging tests carried out in routine clinical practice.¹⁹ Conversely, although conventional X-rays deliver much lower radiation effective doses and are responsible for over 70% of the imaging tests referrals, they have been less studied in relation to overuse. Additionally, current evidence suggests that very few referrers and practitioners use referral guidelines to assist the process of justification.^{20,21} Regardless of the dose, the potential detriment effect of a high prevalence use of inadequate low-dose radiation imaging test has to be included in the studies estimating overuse of imaging tests.

In the present study, we assessed if referring physicians from two different Spanish hospitals chose the most appropriate ionising imaging test for a given clinical condition according to selected guidelines and estimated the radiation effective dose and costs associated. We also described the patient's clinical and sociodemographic profile associated with the appropriateness of the imaging tests.

METHODS

Study design

We carried out a cross-sectional study to analyse the appropriateness of ionising imaging tests and their associated radiological exposure in two Spanish public tertiary hospitals.

Setting

The target population of the study were the residents of the catchment area of the two participating hospitals: Sant Joan (population of 234 424) and Dr Peset (population of 377 780), both in the Valencian Community (south-east Spain). These are referral hospitals for all individuals living in their catchment areas and belong to the National Health Care System. The majority of the population in Spain uses the National Health System (NHS) as the main medical service (the publicly funded insurance scheme covers 98.5% of the Spanish population). The NHS healthcare delivery system is structured into two healthcare levels: (1) primary healthcare, which makes basic healthcare services available within a 15 min radius from any place of residence, and the main facilities are the healthcare centres; and (2) specialised care, which is provided in specialist care centres and hospitals in the form of outpatient and inpatient care. Healthcare services are distributed following a region-based organisation of health areas and basic health zones where primary healthcare centres are based. Each health area is assigned a general hospital where patients are referred to for specialised care and for imaging examinations. In Spain, as in other European countries such as England, Finland and others, primary care is the preferred entrance to healthcare

services. Hence, general practitioners (GPs) can request imaging tests or refer patients to specialty care if they considered necessary according to their suspicious diagnosis without any restriction. However, the radiologist can assist the primary care physician in their gatekeeping role by recommending appropriate imaging follow-up and sometimes by recommending the appropriate referrals to specialists.

Participants

We retrospectively collected from the radiology information system (RIS) of both hospitals all consecutive referrals that were requested during the first week of February and March of 2014 until the target of 1000 referrals per hospital was reached. Imaging tests that did not imply radiation exposure (ie, MRI and US) were excluded because they are not affected by the

requirements of justification in radiation protection legislation. A list of the radiological examinations included in the study, along with their characteristics and classification, can be found in [table 1](#). All the medical imaging tests carried out in these centres are included in the radiology information system (RIS/PACS, Picture Archiving and Communication System). Once all the reports were collected, two researchers (BL and MP-V) performed the retrospective data collection through patients' medical records.

Study size

We estimated that, for a precision of 2% with 95% CIs and an expected frequency of at least 20% of inappropriate imaging tests,⁵ a sample size of 1537 imaging tests was required. To allow for analysis by subgroups, we increased this number to 2000 tests with at least 1000 from each hospital.

Table 1 Categorisation of imaging tests included in the study and their associated characteristics

Classification for the statistical analysis	Standardised name	Common names	Associated effective dose*	Cost (in €)†
Chest/Thorax	Chest/Thorax	XR thorax, XR plain thorax, XR thorax portable...	0.05	9.8
Other XR	XR musculoskeletal	XR foot, XR both feet, XR hand and wrist, XR lower extremities, XR clavicle	0.0034	9.8
	XR cervical spine	XR cervical spine, XR neck	0.08	12.6
	XR abdomen	XR plain abdomen, XR abdomen, XR occlusive series	0.5	9.8
	XR thoracic spine	XR dorsal spine, XR thoracic spine	0.5	12.6
	Miscellaneous XR	XR paranasal sinuses, orthopantomography, head radiography and others	0.4	9.8
Mammography	Mammography	Mammography	0.64	28.1
CT body	CT thorax-abdomen-pelvis	CT thorax-abdomen-pelvis, CT TAP	12.3	109.7
	CT abdomen-pelvis	CT abdomen-pelvis, CT urology	10.9	105.3
	CT thorax-abdomen	CT thorax-abdomen, CTA	10.4	98.0
CT chest	CT chest	HRCT, CT pulmonary embolism, CT thorax and others	7	84.7
Other CT	CT head	CT cranial, CT orbits, CT face, CT brain and others	1.7	72.6
	CT musculoskeletal	Musculoskeletal CT, CT feet, CT knee, CT hip and others	0.8	
	CT abdomen	CT abdomen, angiorenal CT, adrenal CT	6.8	85.0
	CT neck	CT neck, CT cervical spine	3	89.3
	CT spine	CT spine, CT lumbar spine, CT column, CT dorsal...	6.7	37.0
XR/Fluor	Ba follow	Upper gastrointestinal series, barium meal, barium follow	4.5	33.7
	Intravenous urogram	Intravenous urography, intravenous pyelography, urography	2.1	42.8
	Ba enema	Barium enema, enema	2.9	67.9
	Hysterosalpingography	Hysterosalpingography	1.2	96.3

*From a previous study by the authors.²¹

†Of the most common examination in the group, obtained from the analytical accounting system of both health departments.

Ba, Barium; CTA, Computed Tomography Angiography; HRCT, High-resolution Computed Tomography; TAP, TAP test; XR, X-ray.

Data collection

Both hospitals have a digital RIS from where data were extracted. We recorded the following variables from the medical records for each referral: demographic characteristics, setting (inpatient, outpatient, emergency room (ER)), type of department (clinical, surgical, general practice, and central departments including radiology and the ER), and the information on clinical suspicion which was then grouped into different categories, based on the 10th Revision of the International Statistical Classification of Diseases, Injuries and Causes of Death, that is, preoperative, neoplasm, diseases of the musculoskeletal system, digestive system diseases, respiratory system diseases and others. We also collected information about the imaging test, estimated the associated radiation effective dose using previous published evidence²² and the costs according to the established prices in the National Health Care System. All the information about the imaging tests carried out in the last 12 months was also collected from the medical records. **Table 1** summarises the information associated with the imaging tests.

The appropriateness of the 2022 imaging tests reviewed was determined by five expert researchers who were trained in the use of the following four guidelines:

- ▶ Radiation Protection 118: Referral Guidelines for Imaging²³: document published in 2000 by the European Commission for use by health professionals referring patients for medical imaging
- ▶ The American College of Radiologists (ACR) Appropriateness Criteria²⁴: evidence-based expert consensus guidelines to assist referring physicians and other providers in choosing the most appropriate imaging test or interventional radiology treatment decision for a specific clinical condition
- ▶ 'Do not do'²⁵: a guideline published by the Spanish Radiological Society aiming to describe a series of medical imaging tests that should not be done according to available evidence
- ▶ Guidelines by the National Institute for Health and Care Excellence (NICE)²⁶: guidance, advice, quality standards and information services for health, public health and social care based on available evidence.

Our study protocol established that Radiation Protection 118 (RP118) should be the referral guideline, and the other three could be consulted in those cases in which RP118 did not include recommendations for the clinical scenario based on which the imaging tests were requested. The RP118 guideline is grouped into five classifications: indicated, specialised investigation, not indicated initially, indicated only in specific circumstances and not indicated. In order to compare RP118 with ACR's Appropriateness Criteria (given that ACR uses a numerical rating to indicate when a test is appropriate), we established the following comparison according to previous bibliography²⁷:

1. indicated: usually appropriate (score 7–9) (request the most appropriate imaging study first)

2. specialised investigation and not indicated initially: might be appropriate (score 4–6) (avoid ordering; consider specialist referral or radiology consultation)
3. not indicated: not usually appropriate (score 1–3) (avoid ordering)
4. indicated only in specific circumstances: not applicable (follow specific recommendations).

Thus, a clinical situation defined with a score 7–9 was classified as appropriate, and it was classified as inappropriate with a score 1–6.

For the present study, we defined appropriateness or not of the imaging tests examined as follows:

1. appropriate, if the imaging test requested is the recommended option by the guideline given the clinical scenario described in the referral
2. inappropriate according to the selected guidelines, if the clinical scenario described in the referral is included in the guidelines but the imaging test is not recommended for that specific clinical condition
3. inappropriate due to repetition, if the timing to carry out next diagnostic tests was incorrect according to guidelines, that is, the same or an equivalent imaging test had already been performed with the same aim and/or performed before the recommended time interval
4. not adequately justified, if the referral form did not include enough clinical information to allow to understand the patient's clinical condition and hence to evaluate the appropriateness of tests according to the selected guidelines
5. not included in the guidelines, if the referral could not be matched to any clinical scenario described in the guidelines; given that the guidelines are limited, some clinical conditions are missed.

Each imaging test was analysed separately by at least two researchers. All the researchers have a wide experience in analysing appropriateness of medical tests. Moreover, JV and IG-A are both radiologists and board-certified, each with 30+ years of clinical experience and with 20+ years of experience in management of radiology departments (both have been the head of the radiology departments of the two hospitals included in the study). Moreover, JV is currently the scientific director of the European Diploma in Radiology and a member of the panel of the European Society of Radiology (ESR)-ACR iGuide Project of the European Board of Radiology. One of the researchers (JV-P) evaluated the 2022 imaging tests and the other four analysed around 500 imaging tests each. The researchers classified each imaging test in one of the previously described five categories and were required to add a brief description of the process carried out, including which guideline had been used and any concern regarding the classification.

In the first phase, a pilot study of a sample of 20 imaging tests was independently evaluated by the five researchers to test the study protocol. Through a discussion of each individual case, we reached consensus and established a protocol for the remaining cases. Next, we analysed

the rest of the imaging tests: of the 2002 imaging tests, 1114 (55.6%) had agreement between two researchers; 579 (28.9%) were solved by consensus between two researchers, recording disagreements; and 309 (15.4%) where there was no consensus were analysed by a third reviewer. If the third reviewer did not agree with the other two reviewers, the case was discussed in a final meeting with the five researchers (9, 0.45%).

Statistical analysis

We estimated the prevalence of the five outcome categories and the associated effective radiation dose in the whole population, as well as the prevalence according to relevant variables. Age was transformed in quartiles because the equal variance and normal distribution test was rejected. To compare each category with selected patients' characteristics, χ^2 test or Fisher's exact test was used.

Finally, we estimated the relationship (OR and 95% CIs) between a synthetic binary outcome (appropriate vs non-appropriate, which included inadequate according to guidelines, inadequate due to repetition and not adequately justified) and the variables included in the study through an unconditional logistic regression. After evaluating for possible interactions between variables and performing all possible two-way tests, the final multivariable model considered all variables that were significant in univariate analyses ($P < 0.05$) and used a stepwise forward selection.

We measured the correlation between each researcher and the outcome through the Cohen's kappa. Additionally, we performed the multivariate analysis on the original ratings of the reviewers and the results were very similar.

All the analyses were carried out with the statistical software Stata V.11.

RESULTS

Application of guidelines

Guidelines were used in different degrees. RP118, which our study protocol recommended as the first source of information when analysing each referral, was used 49.1% of the times. ACR's Appropriateness Criteria, on the other hand, was a vital source of information in 31.2% of the referrals. 'Do not do', the guideline of the Spanish Medical Society, was employed in 16.1% of the cases, and finally the guidelines published by NICE were used for 3.6% of the cases.

Characterisation of the imaging test according to their appropriateness

We included 2022 image tests from 1853 patients (1060, 57.2% women), with a median age of 62 years (IQR 47–75). The majority of referrals were from outpatients (1221, 60.4%), compared with 546 (27.0%) from patients in the ER and 255 (12.6%) from inpatients. The most common indication was neoplasm (476, 23.5%), followed

by diseases of the musculoskeletal system (446, 22.1%) and diseases of the respiratory system (300, 14.8%). Plain radiographs accounted for 1417 (70%) of the imaging tests, and of these 733 (36.3%) were chest/thorax radiographs and 175 (8.7%) were mammographies. Among the 515 (25.5%) CT scans, 217 (10.7%) were chest-abdomen-pelvis CT and 107 (5.3%) were chest CT. Seventy-nine (3.9%) imaging tests were contrast-enhanced procedures (table 2).

According to the guidelines used, almost half of the 2022 imaging tests reviewed were deemed as appropriate (967, 47.8%), 634 (31.4%) were considered inappropriate, 94 (4.6%) inappropriate due to repetition, 169 (8.4%) not adequately justified, and for 158 imaging tests (7.8%) the clinical scenario was not included in the guidelines. The frequency of appropriateness according to relevant variables is shown in table 2.

Women (527/1149, 45.9%) were less likely to have a test considered as appropriate than men (440/873, 50.4%) ($P = 0.006$). Patients older than 75 years (261/481, 54.3%) were more likely to have a test deemed as appropriate than those younger than 47 years (232/519, 44.7%) ($P < 0.001$). Inpatients (152/255, 59.6%) were more likely to have a test classified as appropriate than those outpatients (567/1221, 46.4%) and those in the ER (248/546, 45.4%); however, they were more likely to have a test inappropriate due to repetition (34/225, 13.3%) ($P < 0.001$). Patients with a disease in the respiratory system were more likely to have a test classified as appropriate (213/300, 70.8%) ($P < 0.001$). Patients having a mammography or a CT were more likely to have a test considered as appropriate than those having a radiograph ($P < 0.001$).

Multivariable analysis

In multivariable analysis (table 3), women were less likely than men to have an imaging test classified as appropriate (adjusted OR 0.70, 95% CI 0.57 to 0.86) ($P = 0.001$). Patients with an age in the upper quartile were 1.80 times more likely to have an imaging test classified as appropriate than patients in the lowest quartile (adjusted OR 1.80, 95% CI 1.35 to 2.39) ($P < 0.001$).

Imaging tests requested by GPs were less likely to be considered appropriate than those requested by central services (adjusted OR 0.60, 95% CI 0.38 to 0.93) ($P = 0.023$). Patients with a suspected disease of the respiratory system were 18.29 times more likely to have imaging tests considered appropriate than patients who received a preoperative chest X-ray test (adjusted OR 18.29, 95% CI 10.45 to 32.03) ($P < 0.001$).

According to the type of imaging test, mammography and CT were more likely to be appropriate than conventional X-rays (adjusted OR 1.94, 95% CI 1.16 to 3.23, and adjusted OR 1.79, 95% CI 1.29 to 2.48, respectively).

Despite the similar populations, and the use of similar protocols to request for imaging tests, we observed differences in disease prevalence and demographics between the two populations in the univariate analysis; there were no differences in multivariate analysis.

Table 2 Characteristics of the imaging radiation tests according to their appropriateness

Variables	All imaging tests	Appropriate	Inappropriate according to the guidelines	Inappropriate due to repetition	Not adequately justified	Not included in the guidelines	P value*
Total, n (%)	2022 (100)	967 (47.8)	634 (31.4)	94 (4.6)	169 (8.4)	158 (7.8)	
Gender							
Male	873 (43.2)	440 (50.4)	248 (28.4)	40 (4.6)	63 (7.2)	82 (9.4)	0.006
Female	1149 (56.8)	527 (45.9)	386 (33.6)	54 (4.7)	106 (9.2)	76 (6.6)	
Age							
≤47	519 (25.7)	232 (44.7)	205 (39.5)	9 (1.7)	42 (8.1)	31 (6.0)	<0.001
>47 to ≤63	513 (25.4)	220 (42.9)	182 (35.5)	28 (5.5)	37 (7.2)	46 (9.0)	
>63 to ≤75	508 (25.1)	254 (50.0)	134 (26.4)	24 (4.7)	41 (8.1)	55 (10.8)	
>75	481 (23.8)	261 (54.3)	112 (23.3)	33 (6.9)	49 (10.2)	26 (5.4)	
Health department†							
HD1	1005 (49.7)	536 (53.3)	288 (28.7)	35 (3.5)	35 (3.5)	111 (11.0)	<0.001
HD2	1017 (50.3)	431 (42.4)	346 (34.0)	59 (5.8)	134 (13.2)	47 (4.6)	
Patient setting							
Outpatient	1221 (60.4)	567 (46.4)	412 (33.7)	41 (3.4)	74 (6.1)	127 (10.4)	<0.001
Emergency room	546 (27.0)	248 (45.4)	197 (36.1)	19 (3.5)	78 (14.3)	4 (0.7)	
Inpatient	255 (12.6)	152 (59.6)	25 (9.8)	34 (13.3)	17 (6.7)	27 (10.6)	
Type of department							
Clinical specialties	713 (35.3)	385 (54)	135 (18.9)	49 (6.9)	53 (7.4)	91 (12.8)	<0.001
Surgical specialties	605 (29.9)	255 (42.1)	240 (39.7)	24 (4.0)	32 (5.3)	54 (8.9)	
Central services	506 (25)	227 (44.9)	179 (35.4)	16 (3.2)	76 (15.0)	8 (1.6)	
General practice	198 (9.8)	100 (50.5)	80 (40.4)	5 (2.5)	8 (4.0)	5 (2.5)	
Indication (according to category in the International Diseases Classification)							
Neoplasm	476 (23.5)	258 (54.0)	104 (21.8)	25 (5.2)	17 (3.6)	74 (15.5)	
Musculoskeletal system	446 (22.1)	197 (44.1)	148 (33.1)	18 (4.0)	37 (8.3)	47 (10.5)	
Respiratory system	300 (14.8)	213 (70.8)	46 (15.3)	22 (7.3)	13 (4.3)	7 (2.3)	
Digestive system	214 (10.6)	69 (32.2)	112 (52.3)	3 (1.4)	22 (10.3)	8 (3.7)	
Preoperative	167 (8.3)	32 (19.6)	113 (69.3)	8 (4.9)	10 (6.1)	0 (0)	<0.001
Other	419 (20.7)	198 (47.3)	111 (26.5)	18 (4.3)	70 (16.7)	22 (5.3)	
Imaging test							
Chest/Thorax	733 (36.3)	315 (43.0)	262 (35.7)	49 (6.7)	95 (13.0)	12 (1.6)	<0.001
Other XR	516 (25.5)	218 (42.2)	198 (38.4)	18 (3.5)	41 (7.9)	41 (7.9)	
Mammography	175 (8.7)	108 (61.7)	54 (30.9)	5 (2.9)	5 (2.9)	3 (1.7)	
CT body	217 (10.7)	113 (52.1)	41 (18.9)	11 (5.1)	7 (3.2)	45 (20.7)	
CT chest	110 (5.4)	71 (64.5)	12 (10.9)	7 (6.4)	7 (6.4)	13 (11.8)	
Other CT	192 (9.5)	110 (57.3)	31 (16.1)	3 (1.6)	10 (5.2)	38 (19.8)	
XR/Fluor	79 (3.9)	32 (40.5)	36 (45.6)	1 (1.3)	4 (5.1)	6 (7.6)	

*P values were obtained by χ^2 test of homogeneity.

†HD1 and HD2 stand for health departments 1 and 2, respectively.

XR, X-ray.

Effective dose associated

The cumulative effective dose associated with the 2022 imaging tests was 4482.8 mSv. [Figure 1](#) compares the relative contribution of each category with the total number of examinations and with the total collective effective dose.

More than half of the effective dose (2446.1 mSv, 54.2%) was associated with appropriate imaging tests and 19.6% (884.9 mSv) with those inappropriate according to the guidelines. Two categories accounted for less than 5% of the effective dose each (inappropriate to repetition: 4.8%,

Table 3 Multivariable analysis: variables significantly associated with imaging tests classified as appropriate*

	Multivariate OR	95% CI	P value
Gender			
Male	1.00		
Female	0.70	0.57 to 0.86	0.001
Age			
≤47	1.00		
>47 to ≤63	1.03	0.78 to 1.35	0.855
>63 to ≤75	1.55	1.17 to 2.07	0.002
>75	1.80	1.35 to 2.39	<0.001
Type of department			
Central services	1.00		
Clinical specialties	1.02	0.76 to 1.38	0.882
General practice	0.60	0.38 to 0.93	0.023
Surgical specialties	1.10	0.78 to 1.54	0.590
Indication (according to category in the International Diseases Classification)			
Preoperative	1.00		
Neoplasm	6.10	3.41 to 10.92	<0.001
Musculoskeletal system	5.82	3.60 to 9.39	<0.001
Digestive system	3.34	1.85 to 6.05	<0.001
Respiratory system	18.29	10.45 to 32.03	<0.001
Other	5.38	3.19 to 9.07	<0.001
Type of imaging test			
Conventional X-rays	1.00		
XR/Fluor†	0.94	0.54 to 1.64	0.834
Mammography	1.94	1.16 to 3.23	0.011
All CT	1.79	1.29 to 2.48	0.001

*Imaging tests for which the outcome was 'Not included in the guidelines' were excluded from this analysis.

†Contrast-enhanced procedures.

214.8 mSv; not adequately justified: 4.7%, 210.7 mSv), and not included in the guidelines accounted for 16.7% of the effective dose (754.1 mSv).

Costs associated

The total cost associated with the 2022 imaging tests was €61 695.9. Figure 2 compares the relative contribution of each category with the total number of examinations and with the total cost. Half of the cost (€3139.8, 50.9%) was associated with appropriate imaging tests, and 25.2% (€15 571.1) with those inappropriate according to the guidelines. Two categories accounted for less than 6% of the cost each (inappropriate to repetition: 3.8%, €2355.6; not adequately justified: 5.4%, €3305.5), and not included in the guidelines accounted for 14.7% of the cost (€9065.7).

DISCUSSION

Our results show that less than 50% of the evaluated imaging tests were considered appropriate according to the available recommendations in the guidelines selected, and the percentage of tests classified as inappropriate was significant (31.4%). Moreover, 4.6% of the imaging tests were incorrectly timed and 8.4% of the referrals did not include enough clinical information to enable a proper evaluation. The remaining 7.8% of clinical scenarios were not included in the guidelines we used. Of the collective effective dose, 29.1% was associated with inappropriate imaging tests (19.6% due to inappropriate according to the guidelines, 4.8% due to repetition and 4.7% due to inadequately justified tests) and 34.4% of the total cost.

Few studies have analysed the appropriateness of imaging tests in clinical situations, and most of them only focused on CT examinations. Almén *et al*⁵ observed that 19.3% of the CT referrals were not justified, and Lehnert and Bree¹⁸ found that 26% of the CTs and MRIs were considered inappropriate. Our study showed a similar result; if we combine all CT imaging tests, 24.9% (129 of the total 519) were considered inappropriate (84, 16.19% inadequate according to guidelines; 21, 4.0% inadequate due to repetition; and 24, 4.6% not adequately justified).

In multivariable analysis, tests were more likely to be appropriate for men than for women and for older patients than for younger ones. The differences in use of healthcare services between genders have been previously evaluated²⁸: women tend to visit more often the GP and use diagnostic services more extensively. Moreover, other studies have shown that gender affects the presentation of disease, the risk of testing and the diagnostic yield of a test.²⁹ Providers in general practice were less likely to order appropriate imaging test than those in central departments, something that Almén *et al*⁵ already discussed. They argued that patients in general practice were prone to have more diffuse symptoms, which could lead to more inappropriate imaging tests compared with follow-up tests ordered by a specialist. Additionally, it is possible that some imaging tests requested in general practice are included in the referral protocols in order to meet the scheduling requirements of specialists. Mammography and CTs were more likely to be appropriate than conventional X-rays and contrast-enhanced procedures, indicating the greater effort made to justify the imaging tests that are either part of a screening or associated with a higher radiation exposure.

There were also differences according to the suspected disease; those imaging tests for patients with a respiratory system disease were more likely to be appropriate than those who had a preoperative chest X-ray. Despite the number of guidelines advising against having a preoperative chest X-ray without a proper justification,^{23–26} 69.3% out of the 167 preoperative chest X-rays analysed were inadequate. Diseases of the gastrointestinal system were also associated with a high percentage of inappropriate examinations (52.3%), a result that is owed in part to abdominal radiographs performed on non-trauma

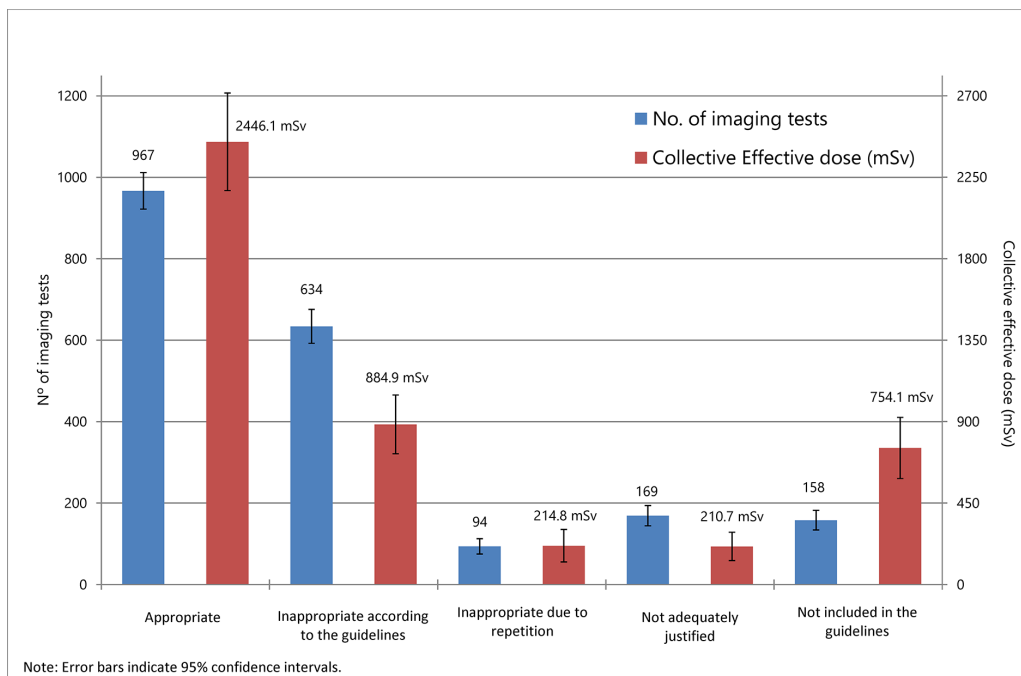


Figure 1 Relative weight of each of the categories of appropriateness, according to number of imaging tests and collective effective dose.

emergency patients, a practice that is not recommended because it rarely affects patient management.³⁰ These results reflect the difficulty of changing attitudes and common practices in clinical practice. Interventions to enhance the knowledge of the recommendations for some very common clinical scenarios in specific departments could reduce referrals that are inappropriate according to the guidelines significantly.³¹

The same can be argued for the imaging tests that were ‘not adequately justified’, which amount to 8.4% of the tests and 4.7% of the effective dose and 5.4% of the cost in our study. Justification, including referral form completion, is a legal requirement for all radiological exposures,³² as an incomplete referral form can have multiple negative consequences, including legal issues, the hospital’s functioning and, above all, the patient’s

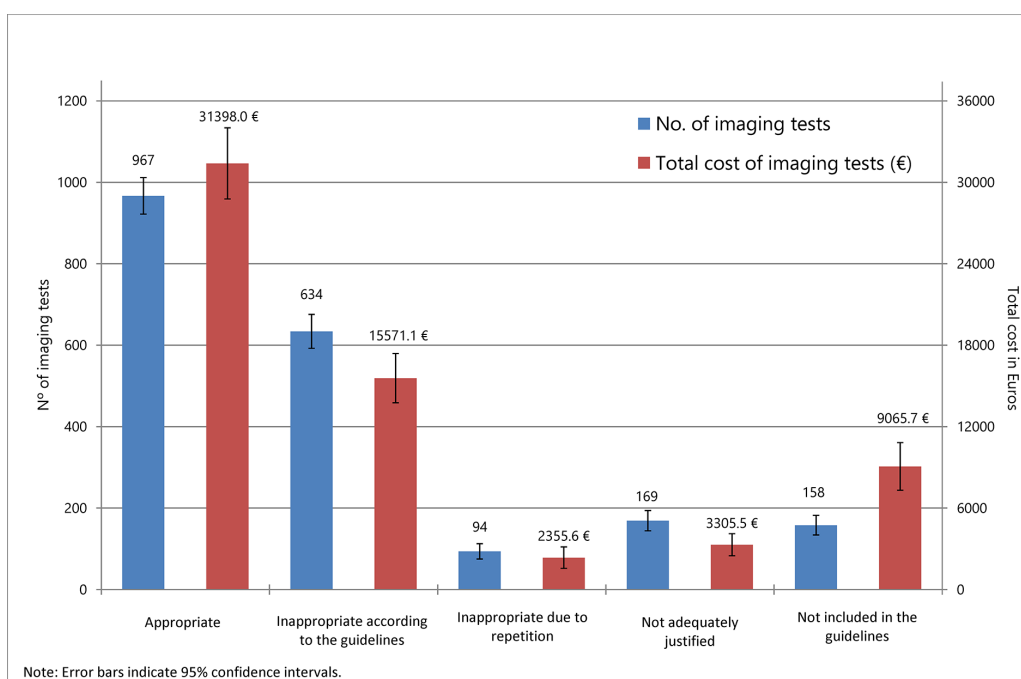


Figure 2 Relative weight of each of the categories of appropriateness, according to number of imaging tests and total costs of tests.

health. The referral is the most important piece of information available to the radiographer, and its quality determines often how optimal the imaging test will be. It has also been shown this can be improved in the clinical setting through several strategies such as education, guideline implementation and clinical audits.³³

There was also a relevant percentage of imaging tests inappropriate due to repetition (4.6% of imaging test, 4.8% of the effective dose and 3.4% of the cost). Both the referring clinician and the radiologist should have easy access and request the complete medical and radiological history to be aware of all the previous imaging tests which have already been performed before requesting a new one. Nevertheless, the available guidelines do not always explicitly state the appropriate timing for imaging, including when it would be clinically relevant to repeat a test, for instance, repetition of a chest X-ray in a patient with documented asthma and where a pneumonia or a new pathological process is not suspected. In such situations, local protocols and consensus should be adopted and followed.³⁴ Previous studies assessing the appropriateness of imaging tests relied on expert opinion in those cases where evidence was lacking or equivocal.³⁵ However, we wanted to examine the frequency and characteristics of such situations in relation to the guidelines consulted. We found 158 imaging tests (7.8%) and 754.1 mSv (16.7% of the collective effective dose) not included in the guidelines, fewer than in previous studies. In 1995, Martin *et al*¹⁰ showed that 24% of the referrals did not meet any clinical scenario in ACR's Appropriateness Criteria. This discrepancy with our results is probably due to the use of four different guidelines and by the increasing number of scenarios that are nowadays covered by the guidelines.

Requests of imaging tests from patients with neoplasm showed the highest rate of cases classified as not included in the selected guidelines (15.5%). The guidelines include many recommendations on imaging tests to be performed regarding the diagnosis of cancer, and often include recommendations for the follow-up of free-of-disease cancer patients, but there are no recommendations regarding timing for imaging tests to be performed for patients during treatment. The most widely used recommendations for evaluation of tumour response, such as Response Evaluation Criteria in Solid Tumors (RECIST),³⁶ were included in our study. However, RECIST does not include a recommended timing for the follow-up scans, which is considered an important feature, and advises clinicians to adhere to local or regional protocols. Therefore, since investigating whether local protocols were followed was beyond the scope of the present study, we decided to classify those cases as 'Not included in the guidelines' so that they would not be counted either as 'Appropriate' or as 'Inappropriate'. The number of RECIST tests in the data set is less than 50, in any case, and has not significantly influenced the overall results of the study. Follow-up of trauma patients is in a similar situation, and the percentage of clinical scenarios not covered by the guidelines was higher than average (10.5%).

Strengths and limitations

This study was a retrospective analysis of medical records and is subject to certain limitations. We based our classification in the available data and there may be some data missing in the medical history that could have helped to make a better classification. Moreover, we included published guidelines as the only possible gold standard against which to assess appropriateness. The approach to define appropriateness from guidelines is simple, but it is limited since this process does not allow to discriminate each particular patient's situation. Therefore our results could underestimate the percentage of appropriateness, particularly because we were strict about the appropriateness of the imaging tests because of the requirement for justification of all radiation exposures according to the justification, as defined in the most recent recommendations by the ICRP (Report 103). Thus, considering appropriate a test with an ACR score lower than 7 without meeting the special circumstances that are stated in the guideline would not agree with the definition of justification by the ICRP. Nevertheless it should be underlined that each imaging test was reviewed independently by two or three researchers with experience in this type of evaluations, and when disagreement occurred a single solution was reached by consensus.

We selected RP118 guidelines as the referral ones. There are two guidelines, to the best of our knowledge, that are published in Spanish and were available at the time the referrals were made: RP118 (published in all the major languages of the EU) and the book published by the Spanish Medical Radiology Society ('Do not do'), which is more up to date but covers only a small amount of clinical scenarios. Both have been distributed in Spanish hospitals, to varying degrees of success, and are known to Spanish radiologists. However, we also included the ACR's Appropriateness Criteria and NICE in the analysis for those cases in which RP118 did not include recommendations. Finally, we did not analyse the underutilisation of imaging tests, which is also a very important concern,³⁷ neither the impact of the inappropriate tests on the patient.

Our results may differ from those of studies in different settings. Nevertheless, we included two general hospitals and their respective catchment areas (with a total population over 600 000 people) and included over 2000 consecutive referrals. Even though our results could have some limited generalisability in other settings, analysing these populations provides important insight, showing that despite the different efforts made by specialist societies, inappropriate ordering of imaging tests is still a substantial problem.

CONCLUSION AND RECOMMENDATIONS

This study contributes important insights to the issue of appropriateness of imaging tests in clinical practice and its association with radiation exposure and cost. Our results showed an overview of the use of ionising

radiation imaging tests in a clinical setting, highlighting a significant percentage of inappropriateness, especially those imaging tests ordered by GPs, preoperative chest X-rays, conventional X-rays and contrast-enhanced procedures. It is essential that the available guidelines should include specific timing for follow-up imaging tests and references to a wider range of clinical situations in order to guide clinicians in the appropriate use of imaging tests. Furthermore, radiologists are presented with new opportunities to expand their role as public health providers. One of the methods that radiologists can use to facilitate the appropriateness of imaging tests is clinician education and to enhance the collaboration between radiologists and clinicians to jointly implementing guidelines for imaging. At this point, the ESR has recently lead a proposal of value-based radiology in which appropriateness and radiation protection are main issues.³⁸

We are at a point in time where clinical decision systems (CDS) are becoming more and more common in daily practice, and some are already working with diagnostic referrals. This will improve greatly the appropriateness in some instances, especially for GPs who are the primary targets of such systems. There is a danger underlying this, however, and that is the 'number' of appropriate testing could improve without any change in the frequency of testing (or with the frequency going up, as it tends to go). While we support the clinical use of CDS and think they are very good tools, the fact remains that awareness and education about the risks of inappropriate tests are necessary for any strategy to work. In this sense, it is probably a good idea for hospital management to support consensus protocols between specialties and workgroups that periodically review and update them. This gives clinicians a reliable tool to respond to common situations with a valid justification and at the same time can change attitudes over time. Finally, auditing referrals, in a similar way as our study, and periodically publishing or distributing the results, even anonymised, like a benchmark of different specialties/hospitals/regions and others would be a very powerful tool for awareness.

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Disclaimer The authors affirm that the manuscript is an honest, accurate and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

Competing interests None declared.

Patient consent Not required.

Ethics approval Institutional Review Board approval for the study was obtained from Miguel Hernández University (2014.37.E.OEP), Hospital San Juan Alicante (14/301) and Hospital Dr Peset, Valencia (2/14).

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