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To what extent do hospitalised patients receive appropriate CT and MRI scans? Results of a cross-sectional study in Southern Italy

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ABSTRACT

Objectives The aim of this study was to assess the frequency of appropriateness of inpatient CT and MRI scans performed in Southern Italy.

Methods The study was carried out by retrospectively reviewing medical records of adult patients admitted between 1 January and 31 December 2012 in two hospitals. The evaluation of appropriateness was performed according to the American College of Radiology Appropriateness Criteria, which assigns a score between 1 and 9.

Results Eight hundred and fifty-three medical records were reviewed. Six hundred and thirty-nine patients received CT examinations and 256 received MRI examinations. Four hundred and ninety-six (77.6%) of the patient population had appropriate CT and 202 (78.9%) received appropriate MRI examinations. The appropriateness was associated with: a confirmation of the diagnostic hypothesis, only one examination performed during hospital stay, the anatomical scan region, with musculoskeletal system being the least appropriate anatomical scan region. Moreover, for CT examinations, appropriateness was also associated with no use of contrast agent.

Conclusions Our findings highlight the need to reduce inappropriate use of CT and MRI. The study showed that the tool used is reliable to measure the extent of appropriateness of diagnostic imaging for inpatient examinations.

Strengths and limitations of this study

- ► Most prior studies focused on outpatient requests referred to diagnostic imaging departments. This is the first study exploring a large sample of imaging examinations requested during hospital stay.
- ► In this study, appropriateness was exclusively evaluated through the American College of Radiology Appropriateness Criteria guidelines, which allow an objective appropriateness assessment.
- ► Data were collected through a retrospective review of medical records. Therefore, the validity of results is influenced by the accuracy of clinical documentation.
- ► Generalisability of results to all Italian hospitals is somewhat limited, since the data were collected from two hospitals in Southern Italy.

INTRODUCTION

The use of diagnostic imaging has increased significantly over the past decade, and expensive technologies such as CT and MRI have been extensively introduced into several diagnostic procedures. The clinical information acquired from their use, the decrease in time needed to perform them and greater accessibility to imaging facilities have benefited patients with significant improvements in diagnostic capabilities but at the same time have resulted in a substantial increase in healthcare costs.[1 2]

In addition, the increasing complexity of imaging has often been accompanied by inefficient use of diagnostic facilities, which has led to inappropriate patient management and unnecessary radiation exposure.[3] CT delivers much higher doses of ionising radiation than conventional radiographs, and previous research has linked exposure to radiation levels in this range to the development of radiation-induced cancers.[4 5]

The increased utilisation of high-cost imaging examinations has motivated health systems worldwide to implement control mechanisms aimed at appropriate utilisation of imaging examinations.[3 6 7]

Assessing the appropriateness of individual medical imaging procedures is a complex issue involving several factors and may vary with the age, gender and physical limitations of the patient as well as with the condition and symptoms being investigated.[8] The American College of Radiology (ACR) developed for the first time in 1993 an evidence-based set of appropriateness criteria (AC), which was revised in 2008, 2015 and 2017 and intended to guide physicians to the appropriate use of diagnostic and interventional radiology for given clinical situations.[9]

Previous studies have been conducted to estimate the proportion of outpatient examinations improperly prescribed and performed by using ACR-AC or other similar guidelines, and they showed a CT and MRI inappropriateness rate ranging from 26% to 44%.[10 11] The causes of inappropriate utilisation include medical liability fears, patients' demands, regional differences in practice style and physician experience and training in the appropriate use of newer imaging modalities.[9] To the best of our knowledge, very limited research has targeted appropriate use of CT and MRI performed within the hospital healthcare setting.[12–15]

The primary aim of this study was to assess the frequency of appropriateness of inpatient CT and MRI scans performed in Southern Italy. The secondary aim was to identify possible variables that could affect the appropriateness, since we hypothesised that patient's and examination's characteristics, such as the investigated anatomical scan region, might be related to the appropriateness of CT and MRI scans performed in the hospital setting.

MATERIALS AND METHODS

Data collection was carried out from May 2013 to September 2014. Two trained physicians, who had experience in clinical documentation and were not involved in patient care, retrospectively reviewed medical records of patients aged 18 or more admitted between 1 January and 31 December 2012 to medical and surgical wards of a teaching hospital and a non-teaching acute care hospital located in Catanzaro (Italy). All medical records related to patients who received at least one CT or MRI examination were identified from an administrative database and were considered eligible for the study. Among these eligible medical records, we included in the study those reporting at least one clinical condition that matched with the list drawn up by the ACR-AC.

The sample size was determined prior to commencement of the study. It was calculated assuming an appropriateness rate of 50%, a margin of error of 5% and a 95% confidence level. Consequently, we sought to obtain a sample of 385 medical records. Anticipating an unavailability of clinical documentation in 30% of cases, a total sample size of 550 records was therefore needed. We decided to include an additional 300 medical records in case the clinical documentation was not complete.

To determine the sample size needed to evaluate the inter-rater agreement, we anticipated that there would be a 50% agreement and a relative error of 25%; thus, we calculated that less than 100 sample size was needed.

The following data were recorded for each patient: (1) sociodemographic characteristics (gender, age, marital status, education level and working activity); (2) characteristics of hospitalisation (date, diagnosis, mode and ward of admission and discharge); (3) clinical data (previous hospitalisations for the same disease, CT and MRI examinations for the same disease performed before admission and other diagnostic imaging examinations performed during hospital stay). To assess the clinical conditions of patients, we used the Charlson Comorbidity Index[16] that predicts the 10-year mortality for a patient who may have a range of several comorbid conditions. Each condition is assigned a score of 1, 2, 3 or 6, depending on the risk of dying associated with each one. Scores are added up to provide a total score to predict mortality; and (4) additional information about CT and MRI examinations performed during hospitalisation (type, date, diagnostic question and its eventual confirmation, contrast agent use, radiation exposure dose and appropriateness).

For each clinical record, the available clinical and imaging data were retrieved to identify all the clinical and demographic factors that could contribute to the justification for the use of diagnostic imaging examinations. The ACR-AC addresses a large number of clinical conditions and their variants and assigns an appropriateness score to the radiological procedures performed for each clinical condition (online supplementary appendix 1), then the two physicians reviewed the ACR-AC to identify a match between the indication of the examination and a variant of a clinical condition reported in the ACR-AC, and the appropriateness score for the performed imaging examination was recorded. The rating of appropriateness was determined by ACR-AC on the basis of type and anatomical site of radiological procedure, use of intravenous contrast, setting of performing and so on. Therefore, there could not be any possibility for the physicians who reviewed the medical records to arbitrarily decide on the appropriateness in a way that would override the ACR-AC.

The appropriateness is represented on an ordinal scale that uses integers from 1 to 9, which are grouped into three categories: if a radiological procedure is assigned a score from 1 to 3, it is classified as 'usually not appropriate'; if from 4 to 6, it is classified as 'may be appropriate'; if from 7 to 9, it is classified as 'usually appropriate'.[9] The application of ACR-AC assumes that the ultimate decision about the appropriateness of CT/MRI examinations is made in light of all the circumstances presented in an individual examination, including whether the examination is performed with the aim to confirm or exclude other pathology/conditions. When an examination received a score from 4 to 6, then physicians conservatively reclassified it as appropriate.

If a patient had received more than one diagnostic imaging examination, the judgement of appropriateness was carried out for each examination. If all examinations were judged appropriate, the patient was classified as being among those who received appropriate examinations. If at least one examination was inappropriate, we classified the patient as being among those who received an inappropriate examination.

At the time of writing the manuscript, the ACR-AC was revised. The latest release includes 11 new and 21 revised topics.[9] However, since the main changes have involved imaging procedures other than CT and MRI that were included in this study, this update has not substantially

modified the assignment of the appropriateness score in our study.

The two physicians concurrently and independently reviewed 85 medical records with the aim of evaluating the inter-rater reliability. Eventual disagreement in determining clinical conditions and variants that could affect the classification of the patients and, subsequently, the appropriateness rating of their examination, was resolved by discussion or if necessary by consensus in consultation with a third author (AB).

Statistical analysis

The overall agreement and the *k* statistic were used to assess the inter-rater reliability regarding the appropriateness of CT and MRI examinations. Multivariable stepwise logistic regression models were performed to determine the independent association of the several characteristics with the following outcomes of interest: appropriateness of CT examination (0=at least one inappropriate, 1=all appropriate or potentially appropriate) (model 1) and appropriateness of MRI examination (0=at least one inappropriate, 1=all appropriate or potentially appropriate) (model 2). The following explanatory variables were potentially included in all models: patient's age (five categories: 18–45 years=1, 46–55 years=2, 56–65 years=3, 66–75 years=4, >75 years=5), Charlson Comorbidity Index (0=0 and ≥1=1), previous outpatient diagnostic examinations (no=0, yes=1), previous hospitalisations for the same admission disease (no=0, yes=1), ward of admission (medical=0, surgical=1), admission type (programmed=0, urgent=1), length of hospital stay (continuous), contrast agent use (no=0, yes=1) and diagnostic hypothesis confirmed (no=0, yes=1). For model 1, the following variables were also included: more than one CT examination performed (no=0, yes=1), anatomical scan region (abdomen/pelvis=1, chest=2, head=3, whole body=4, musculoskeletal system=5, vascular system=6). For model 2, more than one MRI examination performed (no=0, yes=1), anatomical scan region (abdomen/pelvis=1, chest=2, head=3, musculoskeletal system/spine/extremities=4, vascular system=5). If multiple diagnostic imaging procedures were performed, we chose the anatomical scan region of the first performed examination when all procedures were appropriate and of the first inappropriate examination if at least one examination was considered inappropriate.

The model building strategy included the following steps: (1) univariate analysis of each variable considered, using the appropriate statistic test (χ^2 test, Fisher's exact test or t-test) and (2) inclusion of any variable whose univariate test showed a P value lower than 0.25. The significance level for including variables in the two models was set at P=0.2, and P=0.4 for dropping variables from the models. The results of the logistic regression analysis are presented as ORs and 95% CIs.

Stata V.14 statistical software package was used in conducting all data analysis.[17]

According to the design of the present study, researchers were exempted from obtaining written consent by the patients who are requested during the hospitalisation to give permission for their personal data to be used for research, as detailed by the Italian rules (Legislative Decree 196/2003).

RESULTS

One thousand eight hundred and seventy-four medical records of patients who received at least one CT or MRI were considered eligible; 937 of them reported at least one clinical condition included in the ACR-AC list and were included in the study. Eighty-four medical records were not available or did not report essential data for the appropriateness judgement. Therefore, 853 medical records were reviewed. In terms of test–retest reliability of the tool, the overall inter-rater agreement was excellent between the two reviewers, since the agreement and the *k* statistic for the assessment of the appropriateness of CT and MRI examinations were 92.5% and 0.84%, respectively. Indeed, only for six medical records the physicians had to discuss and to resolve the disagreement about the appropriateness classification. Six hundred and thirty-nine patients received at least one CT examination, and 256 received at least one MRI examination. Patient mean age was 62.7 years, the majority of the admissions were urgent, median length of stay was 11.3 days (range: 1–65 days) and the majority of the study population was admitted to medical wards (73.2%).

Overall, 751 CT examinations were reviewed, since 99 patients (15.5%) received more than one CT examination during the hospital stay. Among all CT performed, 596 (79.4%) were considered appropriate and 496 (77.6%) of 639 patients had all appropriate CT. Table 1 illustrates CT examinations by anatomical scan region and indications with relative appropriateness rates.

Three anatomical areas presented consistently higher CT scan rates: head (38.1%), abdomen/pelvis (22.9%) and chest (21.8%). In particular, a total of 286 brain, head and neck CT were performed during the study period.

More than half (55.3%) of head CT were requested for cerebrovascular disease; abdominal pain accounted for 34.9% of the CT scans of the abdomen/pelvis, whereas cancer, including screening purposes, staging and follow-up examinations, was the most frequent reason for performing a whole body CT.

Total body CT represented the least appropriate examination (62.3%). Other less appropriate site-related scans included musculoskeletal system CT (64.7%) and abdomen/pelvis CT (80.8%). The most frequent clinical conditions for which CT scans were deemed less appropriate included: abdomen/pelvis CT for kidney and urinary tract disease (61.4%); head CT for sensory loss (62.5%) and cerebrovascular disease (87.3%); and chest CT for acute respiratory illness (77.3%).

Table 1 Inpatient CT-specific indications and relative appropriate rates

Anatomical scan region	n	%	Appropriate n	Appropriate %
Head	286	38.1	236	92.2
Cerebrovascular disease	158	55.3	138	87.3
Head/spinal trauma	36	12.6	32	88.9
Dementia and movement disorders	29	10.1	27	93.1
Sensory loss	16	5.6	10	62.5
Headache	12	4.2	11	91.7
Seizures and epilepsy	11	3.8	11	100
Other	24	8.4	7	29.2
Abdomen/pelvis	172	22.9	139	80.8
Abdominal pain	60	34.9	56	93.3
Kidney and urinary tract disease	44	25.6	27	61.4
Cancer*	34	19.8	32	94.1
Jaundice	19	11	18	94.7
Other	15	8.7	6	40
Chest	164	21.8	133	81.1
Chronic dyspnoea–pulmonary/cardiac origin	51	31.1	44	86.3
Acute respiratory illness	44	26.8	34	77.3
Acute chest pain	30	18.3	24	80
Cancer*	18	11	17	94.4
Haemoptysis	10	6.1	10	100
Other	11	6.7	4	36.4
Whole body	77	10.3	48	62.3
Cancer*	44	57.1	36	81.8
Abdominal/chest pain	11	14.3	4	36.4
Cardiac/pulmonary disease	10	13	4	40
Other	12	15.6	4	33.3
Vascular system	35	4.6	29	82.8
Acute chest pain	13	37.1	12	92.3
Abdominal aortic aneurysm	12	34.3	10	83.3
Other	10	28.6	7	70
Musculoskeletal system	17	2.3	11	64.7
Neuropathy	9	53	7	77.8
Chronic neck/upper limb pain	4	23.5	2	50
Other	4	23.5	2	50
Overall	751		596	79.4

*Cancer included screening, staging and follow-up examinations.

Three hundred and seventy-one MRI examinations were reviewed, since 92 patients (35.9%) received more than one MRI examination during hospital stay. Overall, 310 MRI examinations (83.6%) were considered appropriate, and 202 (78.9%) patients received appropriate MRI examinations. As shown in table 2, head MRI was the most requested examination (65.2%), primarily prescribed for suspected dementia (39.3%). Movement disorders accounted for 45.6% of spine MRI, whereas cancer and jaundice were the most frequent reasons for prescribing an abdomen/pelvis MRI.

The lowest percentage of appropriate examinations (37.9%) was found to be for vascular system MRI. Indications for less appropriate MRI examinations included a broad array of clinical conditions, such as headache for vascular system (29.4%) and head MRI (86.4%), acute back pain for spine MRI (28.6%) and abdominal pain for abdomen/pelvis MRI (87.5%).

Table 2 Inpatient MRI-specific indications and relative appropriate rates

Anatomical scan region	n	%	Appropriate n	Appropriate %
Head	242	65.2	222	91.7
Dementia and movement disorders	95	39.3	93	97.9
Headache	44	18.2	38	86.4
Seizures and epilepsy	40	16.5	38	95
Cerebrovascular disease	24	9.9	22	91.7
Neuropathy	17	7	15	88.2
Sensory loss	14	5.8	12	85.7
Other	8	3.3	4	50
Spine/extremities	57	15.4	38	66.7
Dementia and movement disorders	26	45.6	22	84.6
Neuropathy	15	26.5	11	73.3
Spinal trauma	6	10.5	3	50
Acute back pain	7	12.4	2	28.6
Other	3	5	0	0
Abdomen/pelvis	39	10.5	36	92.4
Cancer*	13	33.3	13	100
Jaundice	13	33.3	13	100
Abdominal pain	8	20.6	7	87.5
Other	5	12.8	3	60
Vascular system	29	7.8	11	37.9
Headache	17	58.6	5	29.4
Cerebrovascular disease	4	13.8	3	75
Other	8	27.6	3	37.5
Chest	4	1.1	3	75
Cardiac disease	2	50	2	100
Cancer*	1	25	0	0
Chest pain	1	25	1	100
Overall	371		310	83.6

*Cancer included screening, staging and follow-up examinations.

Table 3 shows the distribution of the appropriateness of diagnostic examinations (CT/MRI) according to various explanatory variables.

After univariate analysis, appropriate CT examinations were significantly more likely in subjects with an urgent admission (χ^2=6.36, 1 df, P=0.012), with a shorter hospital stay (t=−1.98, 637 df, P=0.047), in those who received CT examinations without contrast agent (χ^2=48.49, 1 df, P<0.001), or only one CT examination (χ^2=27.09, 1 df, P<0.001), whereas they were significantly less likely in those whose musculoskeletal system or whole body were investigated compared with other sites (Fisher's exact test: P=0.038). Appropriateness of CT examinations was also associated with a confirmation of the diagnostic hypothesis (χ^2=87.41, 1 df, P<0.001). Results of the multiple logistic regression analysis partially confirmed those of the univariate analysis, except for length of stay and admission type that were not significantly associated with appropriateness of CT (table 4).

Appropriateness of MRI examinations, after univariate analysis, was associated with the diagnostic hypothesis confirmation (χ^2=7.62, 1 df, P=0.006), and MRI scan region, with vascular and musculoskeletal system/spine/extremities being the least appropriate anatomical scan regions (Fisher's exact test: P<0.001) (table 3). Appropriate MRI examinations were also significantly more likely among patients who received only one MRI examination during hospital stay (χ^2=35.24, 1 df, P<0.001). These findings were completely confirmed after multivariate analysis (table 4).

DISCUSSION

To the best of our knowledge, this study represents the first attempt to assess the appropriateness of inpatient

Table 3 Descriptive characteristics of study population and distribution of appropriateness of diagnostic examination (CT/MRI) according to various explanatory variables

	Patients who received at least one CT		Appropriate CT examinations		Patients who received at least one MRI		Appropriate MRI examinations	
Characteristic	**n**	**%**	**n**	**%**	**n**	**%**	**n**	**%**
Overall	639*	74.9	496*	77.6	256*	30	202*	78.9
Age (years)								
<46	69	10.80	58	84.06	101	39.45	75	74.26
46–55	65	10.17	50	76.92	51	19.92	41	80.39
56–65	110	17.21	83	75.45	49	19.14	41	83.67
66–75	146	22.85	111	76.03	38	14.84	30	78.95
>75	249	38.97	194	77.91	17	6.64	15	88.24
			χ^2=2.18, 4 df, P=0.701				Fisher's exact test: P=0.634	
Previous hospitalisations								
No	427	67.89	334	78.22	131	52.19	102	77.86
Yes	202	32.11	156	77.23	120	47.81	95	79.17
			χ^2=0.08, 1 df, P=0.779				χ^2=0.06, 1 df, P=0.802	
Charlson Comorbidity Index								
0	260	42.41	201	77.3	174	69.32	137	78.74
≥1	353	57.59	277	78.5	77	30.68	60	77.92
			χ^2=0.12, 1 df, P=0.731				χ^2=0.021, 1 df, P=0.885	
Length of stay, days, mean (SD)	11.62 (8.24)				11.04 (7.04)			
Appropriate group			11.2 (9.0)				10.8 (7.2)	
Inappropriate group			12.9 (9.9)				11.9 (6.4)	
			T=−1.98, 637 df, P=0.047				T=−1.01, 254 df, P=0.31	
Admission type								
Urgent	404	63.62	327	80.94	51	20.4	44	86.27
Planned	231	36.38	167	72.29	199	79.6	154	77.39
			χ^2=6.36, 1 df, P=0.012				Fisher's exact test: P=0.181	
Admission ward								
Medical	425	66.51	329	77.41	237	92.58	187	78.90
Surgical	214	33.49	167	78.04	19	7.42	15	78.95
			χ^2= 0.03, 1 df, P=0.858				Fisher's exact test: P=1.000	
Previous outpatient CT/MRI examinations								
No	474	76.82	366	77.22	140	55.12	112	80
Yes	143	23.18	116	81.12	114	44.88	88	77.19
			χ^2=0.98, 1 df, P=0.322				χ^2=0.29, 1 df, P=0.587	
Contrast agent use								
No	388	60.72	337	86.86	146	57.03	112	76.71
Yes	251	39.28	159	63.35	110	42.97	90	81.82
			χ^2=48.49, 1 df, P<0.001				χ^2=0.98, 1 df, P=0.322	
Diagnostic confirmation of the clinical hypothesis								
No	105	16.43	45	42.86	33	12.89	20	60.61
Yes	534	87.57	451	84.46	223	87.11	182	81.61
			χ^2=87.41, 1 df, P<0.001				χ^2=7.62, 1 df, P=0.006	

Continued

Table 3 Continued

Characteristic	Patients who received at least one CT		Appropriate CT examinations		Patients who received at least one MRI		Appropriate MRI examinations	
	n	%	n	%	n	%	n	%
Anatomical scan region								
Abdomen/pelvis	148	24.07	118	79.73	34	14.11	32	94.12
Chest	140	22.76	112	80	1	0.41	1	100
Head	218	35.45	173	79.36	164	68.05	143	87.20
Whole body	64	10.41	40	62.5	–	–	–	–
Musculoskeletal system/ spine/extremities	13	2.11	8	61.54	28	11.62	13	46.43
Vascular system	32	5.20	27	84.38	14	5.81	0	0
			Fisher's exact test: P=0.038				Fisher's exact test: P<0.001	
More than one examination performed during hospital stay								
No	540	84.51	439	81.30	164	64.06	148	90.24
Yes	99	15.49	57.58	57.58	92	35.94	54	58.70
			χ^2=27.09, 1 df, P<0.001				χ^2=35.24, 1 df, P<0.001	

*Total may not always sum to *n* because of missing data.

CT and MRI examinations in Italy, using the ACR-AC as reference. Indeed, prior studies comprised only outpatient requests referred to diagnostic imaging departments, whereas our sample is the first study exploring examinations requested during hospital stay. Appropriate use of MRI and CT is very important both medically and economically. There have been suggestions of various factors influencing overutilisation in many countries, including defensive medicine.[10 18]

This study showed an overall higher appropriateness than previous studies,[10 11] and it is not completely surprising since in Italy the provision of inpatient care, free of charge for all, is properly addressed by a specialist who clinically evaluates the patient. Nonetheless, a lower appropriateness rate compared with other hospital settings, such as the emergency department, was shown.[14]

However, comparisons with previous studies must be made with caution, since differences exist with respect to forms of care and methodology. First, as already stated, our data are from inpatient subjects. Moreover, in other studies, reference criteria were based on different recommendations or on the ACR-AC in combination with other guidelines.[10 11 19] Rosenkrantz *et al*[20] who, similarly to us, used exclusively ACR-AC, showed a higher percentage of appropriate investigations (almost 90%) that is close to our results. Regarding inpatient imaging, Moriarity *et al*[12] examined the effect of electronic clinical decision support (CDS) using ACR-AC for imaging requests and focused on the average AC score before and after CDS use.

As reported in previous studies,[10 21] inappropriate use of imaging services included head CT for chronic headache and cerebrovascular diseases, and lumbar spine MRI for acute back pain. These results also match with an analysis of utilisation trends among Medicare beneficiaries in the USA, showing that almost 30% of patients underwent imaging studies within the first 28 days of an episode of acute low back pain,[22] although appropriateness guidelines from many specialties, including those of the ACR, do not recommend any imaging 6 weeks before any episode of acute back pain without 'red flags' suggesting serious disease. Another reason for inappropriate imaging scans included whole body CT for cancer screening and recent indications provided by the American College of Preventive Medicine have strongly advised against this practice.[23]

Inappropriateness of CT and MRI was associated with multiple factors that warrant careful attention. We found that inappropriate CT and MRI were less likely to confirm the diagnostic hypothesis. This observation helps validate the value of the AC in mitigating the use of those imaging procedures likely to provide a negative result. Moreover, as reported in previous studies,[10 11 20] the correct orientation of the clinician and the use of an appropriate diagnostic technology contribute to confirm diagnostic hypothesis and, indeed, the AC were designed to ideally select for examinations expected to have maximal diagnostic yield, when balanced with cost and imaging-related risks.

We also found an association between inappropriateness of CT examinations and contrast agent use. This result has already been reported[24] and highlights the importance of a careful use of contrast agent, because this can result in unnecessary exposure of patients to the risk of adverse reactions or nephropathy induced by these agents.[25]

Table 4 Multiple logistic regression analysis results examining inappropriateness of CT and MRI according to several explanatory variables

Variable	OR	95% CI	P
Model 1: appropriate CT examinations Log likelihood=−237.60; χ^2=173.65 (6 df); P<0.0001, no of observations=613			
Contrast agent use			
No	1.00*		
Yes	0.17	0.10 to 0.28	<0.001
Clinical hypothesis confirmed by CT			
No	1.00*		
Yes	11.9	6.88 to 20.8	<0.001
More than one CT examination performed during hospital stay			
No	1.00*		
Yes	0.24	0.14 to 0.42	<0.001
Anatomical scan region			
Head	1.00*		
Whole body	0.69	0.35 to 1.32	0.268
Muscoloskeletal system	0.02	0.05 to 0.84	0.028
Vascular system	3.21	0.97 to 10.58	0.055
Model 2: inappropriate MRI examinations Log likelihood=−70.83; χ^2=54.41 (4 df); P<0.0001, no of observations=220			
Clinical hypothesis confirmed by MRI			
No	1.00*		
Yes	5.14	1.68 to 15.70	0.004
More than one MRI examination performed during hospital stay			
No	1.00*		
Yes	0.11	0.04 to 0.29	<0.001
Anatomical scan region			
Head	1.00*		
Muscoloskeletal system/spine/extremities MRI	0.08	0.02 to 0.25	<0.001
Admission type			
Planned	1.00*		
Urgent	0.57	0.17 to 1.90	0.368

*Reference category.

As expected, there was a correlation between the anatomical scan region and inappropriateness of radiological procedures, particularly for scans of the muscoloskeletal system and the spine/estremities. In these sites, CT and MRI are generally used as second-line examinations to solve specific diagnostic problems, whereas aspecific clinical conditions such as low back pain should be managed through proper clinical observation and first-line radiological examinations.

Our study showed that a relevant percentage of patients received multiple CT or MRI examinations, and repeated examinations were more likely to be inappropriate.[26–28] As reported in previous studies, repeated imaging is common, and an uncertain proportion of them likely represents an inappropriate use and overuse. For example, Ip *et al*[29] showed that the great majority of repeated abdominal imaging occurred contrary to radiologists' follow-up recommendations. Given the frequency and volume of repeat testing and its potential impact on quality of care and costs, future studies should evaluate strategies to improve the appropriateness of repeat testing and follow-up imaging recommendations.

Several strategies have been evaluated to reduce the overuse and inappropriate use of CT and MRI. Request for a consultation with a radiology specialist before the examination and evaluation of the requests using a computerised preauthorisation system[3] seems to have significantly reduced the number of inappropriate examinations. Moreover, early work on the impact of CDS in reducing redundant imaging is promising. O'Connor *et al*[30] showed that CDS led to the cancellation of 5% of repeat CT orders. Moriarity *et al*[12] reported a slight

increase in the average AC score after CDS introduction. Findings reported in these studies suggest the possible use of these strategies for inpatient radiological examinations.

The results of our study should be interpreted in light of few potential limitations. First, retrospective data collection may have distorted the actual rate of appropriateness, since it is influenced by the quality of medical records. Accuracy and completeness are two main characteristics that may affect data quality. In the present study, we are more prone to affirm that lack of data, instead of incorrect data, could have led to an alteration in the evaluation of the clinical condition, with a relative underestimation of appropriateness. Nevertheless, retrospective data collection is a common and accepted method for the evaluation of appropriateness and also to estimate wasteful imaging.[31 32] Second, collected data are referred to 2012. It is therefore possible that, in this 5-year period, the awareness campaigns, clinical decision support systems[33 34] and legislation may have resulted in an increase in the appropriateness rate of radiological procedures. In this context, the Council Directive 2013/59 Euratom, which stipulates procedures, roles and responsibilities that need to be observed by hospitals and professionals involved in medical radiation exposures,[35] has been introduced into Italian national legislation in 2015, with a possible positive impact on imaging examinations appropriateness.

Moreover, our cohort comprised imaging examinations performed in the inpatient setting at a teaching hospital and a non-teaching acute care hospital located in Southern Italy, and this cohort may not be representative of all Italian hospitals. However, we are confident that the findings of the study may be representative of at least the southern part of our country. Third, we evaluated the appropriateness exclusively through ACR-AC that is not commonly used in Italy. However, although European alternatives to ACR-AC, such as RCR iRefer, French or Italian guidelines for radiological examinations appropriateness evaluation were available,[36–38] we decided to apply ACR-AC, as we were interested to gain an objective evaluation of appropriateness, with the assignment of a numeric score, and none of these other alternatives would allow this approach. In addition, Italian guidelines for diagnostic imaging were published in 2004 and never updated.[38] Therefore, in light of our experience, it would be worth applying the ACR-AC to the Italian context. Finally, in those cases where multiple examinations were performed, we decided to classify a particular case as inappropriate if at least one examination was inappropriate, but we cannot exclude a possible bias in the findings, that could have reduced the extent of the gap between appropriate and inappropriate examinations. However, of the total 751 CT and 371 MRI performed, respectively 137 CT (18%) and 132 (35.6%) MRI were repeated imaging examinations. Thus, we may be confident that the impact of this bias on our results, if present, is probably marginal.

CONCLUSION

Our findings showed that there is a significant percentage of inpatient inappropriate imaging exams, and specific areas for improvement have been identified. The study shows that the tool used is reliable and has adequate validity to measure the extent of appropriateness of diagnostic imaging also in our context and for inpatient examinations. Further research is needed to expand appropriateness evaluation in this care setting, to investigate more thoroughly internal and external causes of inappropriate use of imaging examinations and also to evaluate the effectiveness of some strategies such as the use of a computerised preauthorisation system in order to reduce inappropriateness.

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