Requests for radiologic imaging

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Research article

Requests for radiologic imaging: Prevalence and determinants of inadequate quality according to RI-RADS

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ABSTRACT

Purpose: To determine the prevalence and determinants of radiologic imaging requests that are of inadequate quality according to the Reason for exam Imaging Reporting and Data System (RI-RADS).

Methods: This study included a random sample of 673 radiologic examinations performed at a tertiary care center. The quality of each imaging request was graded according to RI-RADS. Ordinal regression analysis was performed to determine the association of RI-RADS grade with patient age, gender, and hospital status, indication for imaging, requesting specialty, imaging modality, body region, time of examination, and relationship with previous imaging within the past one year.

Results: RI-RADS grades A (adequate request), B (barely adequate request), C (considerably limited request), and D (deficient request) were assigned to 159 (23.6 %), 166 (24.7 %), 214 (31.8 %), and 134 (19.9 %) of cases, respectively. Indication for imaging, requesting specialty, and body region were independently significantly associated with RI-RADS grades. Specifically, routine preoperative imaging (odds ratio [OR]: 3.422, $P = 0.030$) and transplantation imaging requests (OR: 8.710, $P = 0.000$) had a higher risk of poorer RI-RADS grades, whereas infection/inflammation as indication for imaging (OR: 0.411, $P = 0.002$), pediatrics as requesting specialty (OR: 0.400, $P = 0.007$), and head (OR: 0.384, $P = 0.017$), spine (OR: 0.346, $P = 0.016$), and upper extremity (OR: 0.208, $P = 0.000$) as body regions had a lower risk of poorer RI-RADS grades.

Conclusion: The quality of radiologic imaging requests is inadequate in >75 % of cases, and is affected by several factors. The data from this study can be used as a baseline and benchmark for further investigation and improvement.

1. Introduction

The quality of a request for a radiologic procedure is regarded important for a radiologist to accurately and efficiently interpret the imaging examination, to establish a correct (differential) diagnosis, and to provide appropriate advice to the referring physician for further patient management [1–3]. Recently, the Reason for exam Imaging Reporting and Data System (RI-RADS) was introduced [4]. RI-RADS uses a four-point grading system to determine the quality of a request for an imaging procedure, based on aspects such as the adequate description of the medical history, working or differential diagnoses, and location of signs and symptoms [4]. RI-RADS scores allow for a systematic assessment of the quality of imaging requests. RI-RADS found broad support among a panel of 87 radiologists with diverse levels of experience from various settings [5]. It can be regarded as an improvement to non-standardized systems that were used in previous studies [6–12].

There have not been any studies yet that have investigated the prevalence of imaging requests of inadequate quality according to RI-RADS. This information may be useful to establish a benchmark for interinstitutional comparison and as a baseline to improve upon. Furthermore, identification of factors that are associated with imaging requests of poor quality may be helpful to prioritize targets for improvement. Patient characteristics such as age, gender, and hospital status (inpatient, outpatient, or emergency), indication for imaging, requesting specialty, imaging modality, time of imaging, and relationship with any previous imaging may potentially affect the quality of an imaging request. The determinants of poor quality imaging requests are currently unknown because previous studies on this topic did not

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perform a comprehensive analysis taking into account multiple variables [6–12].

The purpose of this study was therefore to determine the prevalence and determinants of radiologic imaging requests that are of inadequate quality according to RI-RADS.

2. Materials and methods

2.1. Study design

This retrospective study was approved by the institutional review board of the University Medical Center Groningen (IRB number: 202000601) and the requirement for informed consent was waived. All radiologic examinations that were made in a tertiary care center on any of the 52 Tuesdays in the year 2017, were collected. All conventional radiography (which also included mammography), ultrasonography (US) (which also included breast US), computed tomography (CT), and magnetic resonance imaging (MRI) examinations were exported to four different spreadsheets (Microsoft Corp., Redmond, WA). The "RAND" function was then used to generate a random number belonging to each imaging examination in each of these four spreadsheets. The imaging examinations with the 174 lowest random numbers from each of these four spreadsheets were selected for potential inclusion in our study. As such, a random sample of 174 conventional radiography, 174 US, 174 CT, and 174 MRI examinations was extracted. Note that Tuesday was chosen because on average most radiologic examinations are performed at our institution on this day of the week. Also note that there is no predilection for certain types of radiologic examinations on any of the weekdays including Tuesday. Therefore, the selection of radiologic examinations can be considered representative of clinical practice at our institution. Radiologic examinations were excluded when performed for research purposes only, when performed for imaging guidance during a radiologic intervention (e.g. biopsy, drainage, injection, radiofrequency or microwave ablation) or surgery, and when patient data were missing in the electronic medical records.

2.2. Data extraction

For each radiologic examination, the following variables were extracted: patient's age, gender, and hospital status (inpatient, outpatient, or emergency), indication for imaging (cardiac, congenital/developmental, infection, inflammation, oncology, routine preoperative imaging, routine postoperative imaging, transplantation, trauma, vascular, or miscellaneous), requesting specialty (cardiology, cardiothoracic surgery, family medicine, gastroenterology, hematology, intensive care medicine, internal medicine, medical oncology, neurology, neurosurgery, orthopedics, otorhinolaryngology, pediatrics, pulmonary medicine, radiation therapy, rheumatology, surgery, urology, or other), imaging modality (conventional radiography, US, CT, or MRI), body region (abdomen, breast, chest, head, heart, lower extremity, neck, pelvis, spine, upper extremity, other body region, or multiple body regions), time of examination (i.e. office hours [between 8.00 and 17.00] or duty hours), and relationship of the examination with any previous imaging performed within the past one year.

2.3. RI-RADS grading

A radiologist (Ö.K., with 2 years of post-residency working experience) reviewed the requests of all radiologic examinations that were included in this study, and assigned a RI-RADS grade to each imaging request. Only the requisition form, which was in unstructured digital format for in-hospital requests and in unstructured handwritten format for requests from healthcare professionals outside the hospital, was evaluated for this purpose. Information from other sources such as electronic medical records was excluded. Three key categories of information were used to determine the RI-RADS grade: 1) impression (i.e. working or differential diagnosis), 2) clinical information (i.e. signs and symptoms, chronicity of current episode, location of signs and symptoms, pertinent past medical/surgical history, pertinent laboratory findings, and previous imaging reports when available), and 3) diagnostic question (i.e. confirmation/exclusion of diagnosis, grading/staging, pre-operative planning, follow-up of progress or response to treatment, etc.) [4]. RI-RADS grade A (adequate request) corresponds to the presence of all three key categories of information, RI-RADS grade B (barely adequate request) corresponds to the presence of all three key categories of information although some clinical findings are missing, RI-RADS grade C (considerably limited request) corresponds to the presence of only two key categories of information, and RI-RADS grade D (deficient request) corresponds to the presence of only one or no key category of information [4]. A second radiologist (T.C.K., with 4 years of postresidency working experience), who was blinded to the RI-RADS grades that were assigned by the first radiologist, assigned RI-RADS grades to a random subsample of 100 imaging requests, to determine interobserver agreement.

2.4. Statistical analysis

Continuous variables were expressed as means with standard deviations (SDs) and ranges, while categorical and ordinal variables were expressed with absolute numbers and relative frequencies. Interobserver agreement was analyzed using weighted κ statistics, with $\kappa < 0.2$ indicating poor agreement, $\kappa > 0.2$ to $\kappa \leq 0.4$ indicating fair agreement, $\kappa > 0.4$ to $\kappa \leq 0.6$ indicating moderate agreement, $\kappa > 0.6$ to $\kappa \leq 0.8$ indicating substantial agreement, and $\kappa > 0.8$ to $\kappa \leq 1$ indicating almost perfect agreement. Ordinal regression analysis was performed to determine the association between RI-RADS grade and the variables patient's age, gender, and hospital status, indication for imaging, requesting specialty, imaging modality, body region, time of examination, and relationship with previous imaging within the past one year. Only variables that were significant on univariate analysis (according to the Chi-square statistic for the difference between the -2 log-likelihoods of the null model and the model with the variable added), that remained significant after adjustment for multiple testing (using the Benjamini-Hochberg method at a false discovery rate control of 0.05), and without collinearity (Cramér's V coefficient <0.6) were entered in a multivariate model. For nominal variables the category with the largest number of observations was set as reference category for the odds ratios (ORs) obtained from multivariate ordinal regression. The Nagelkerke pseudo R^2 was calculated to determine the proportion of the total variability in RI-RADS grades that could be explained by the multivariate model. *P*-values less than 0.05 were considered statistically significant. Statistical analyses were performed using IBM Statistical Package for the Social Sciences (SPSS) version 26 (SPSS, Chicago, IL, USA).

3. Results

3.1. Study population

Of the random sample of 696 radiologic examinations, 673 (171 conventional radiography, 165 US, 168 CT, and 169 MRI examinations), which were performed in 660 unique patients, were finally included (Fig. 1). At the time of the radiologic examination, mean age ± SD of patients was 46.2 ± 15.4 years (range: 0–97 years), of whom 357 (53 %) male and 316 (47 %) female. The distribution of requesting specialties and body regions of the 673 radiologic examinations are shown in Figs. 2 and 3, respectively. Other study population characteristics are shown in Table 1. There were no missing variables for any of the included patients.

3.2. RI-RADS grades

RI-RADS grade A (adequate request) was assigned to 159 (23.6 %) of

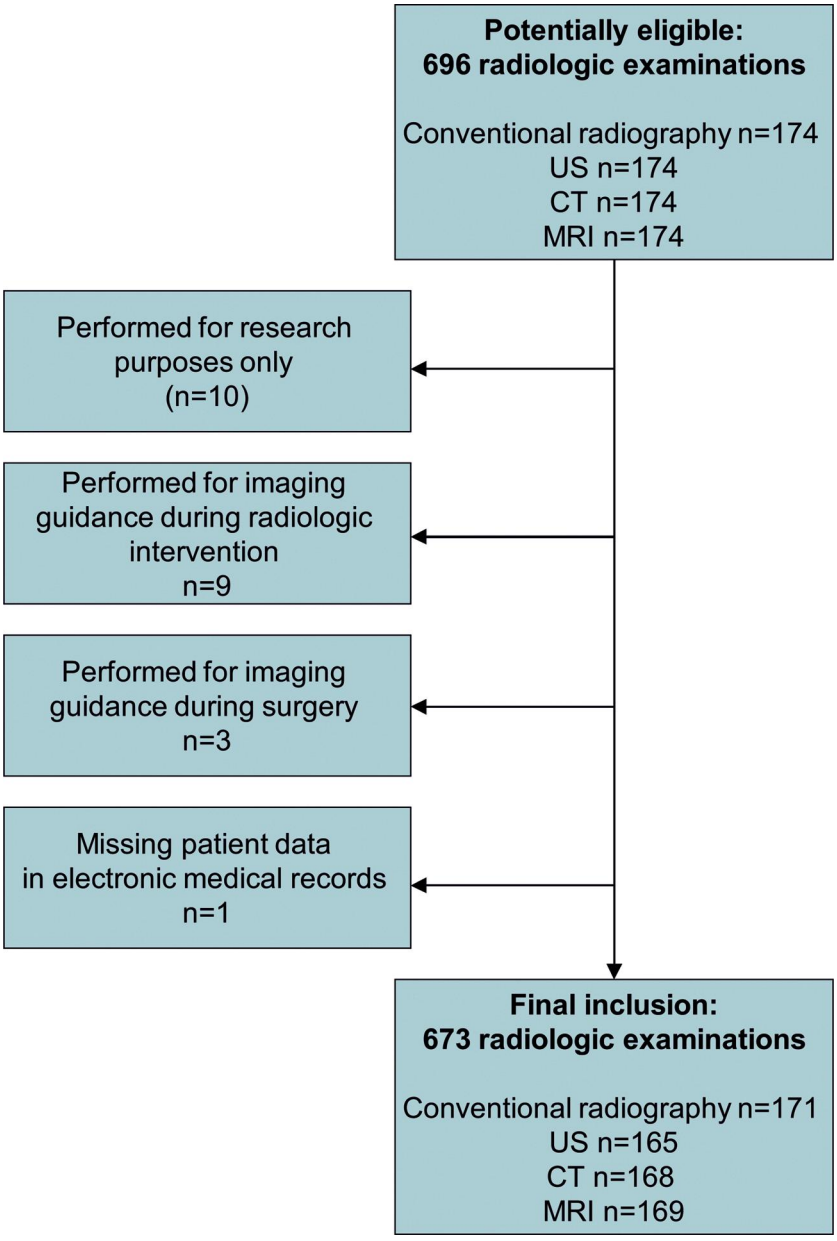

Fig. 1. Flowchart of patient inclusion.

radiologic examinations, whereas RI-RADS grades B (barely adequate request), C (considerably limited request), and D (deficient request) were assigned to 166 (24.7 %), 214 (31.8 %), and 134 (19.9 %) of cases, respectively. Representative examples of imaging requests in each of the four RI-RADS grade groups are shown in Table 2. Interobserver agreement was substantial with a κ value of 0.745 (95 % confidence interval: 0.658−0.831).

3.3. Association between RI-RADS grades and variables

On univariate analysis, there were significant associations between RI-RADS grades and indication for imaging ($P = 0.000$), requesting specialty ($P = 0.001$), imaging modality ($P = 0.001$), and body region ($P = 0.000$), which all remained significant after correction for multiple testing. However, there were no significant associations between RI-RADS grades and patient's age ($P = 0.194$), gender ($P = 0.144$), hospital status ($P = 0.589$), time of examination ($P = 0.194$), and relationship with any previous imaging performed within the past one year ($P = 0.870$). There was no collinearity between the variables that were significant on univariate analysis (Table 3). On multivariate analysis, indication for imaging, requesting specialty, and body region remained independently significantly associated with RI-RADS grades, whereas imaging modality did not. Specifically, routine preoperative imaging (OR: 3.422, $P = 0.030$) and transplantation imaging requests (OR: 8.710, $P = 0.000$) had a higher risk of poorer RI-RADS grades, whereas infection/inflammation as indication for imaging (OR: 0.411, $P = 0.002$), pediatrics as requesting specialty (OR: 0.400, $P = 0.007$), and head (OR: 0.384, $P = 0.017$), spine (OR: 0.346, $P = 0.016$), and upper extremity (OR: 0.208, $P = 0.000$) as body regions had a lower risk of poorer RI-RADS grades (Table 4). The Nagelkerke pseudo R^2 of the multivariate model was 0.185 (i.e. the multivariate model could explain 18.5 % of the variability in RI-RADS grades).

4. Discussion

The results of this study show that the majority of imaging requests

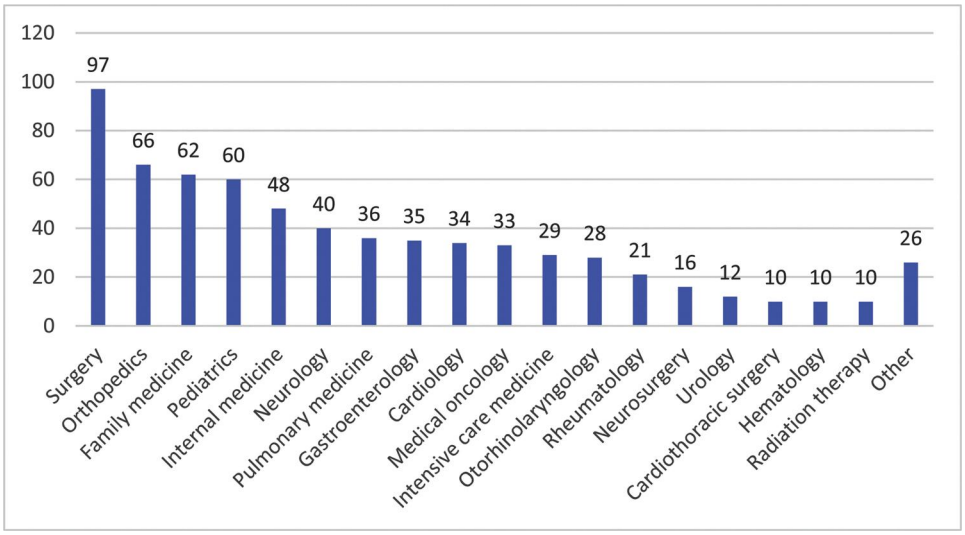

Fig. 2. Distribution of requesting specialties (absolute numbers) of the 673 radiologic examinations that were included in this study.

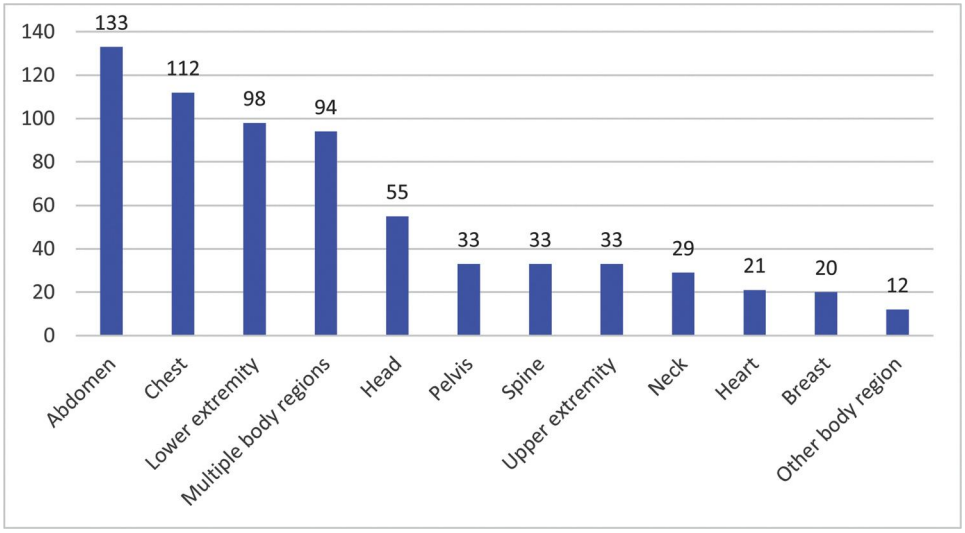

Fig. 3. Distribution of body regions (absolute numbers) of the 673 radiologic examinations that were included in this study.

(>75 %) are of insufficient quality, and that approximately 20 % is even considered a deficient request according to RI-RADS. RI-RADS was also demonstrated to be substantially reproducible. Indication for imaging, requesting specialty, and body region emerged as independent significant predictors of RI-RADS scores. The indications routine pre-operative imaging (e.g. chest radiography before cardiothoracic surgery or cross-sectional imaging to visualize anatomy before surgery) and transplantation imaging increased the odds of an unsatisfactory request. The purpose of many routine preoperative work-up and transplantation imaging examinations may appear self-evident, which may explain why these requests were more frequently of poor quality. However, even for seemingly routine procedures, it is crucial that referring physicians provide an adequate impression, clinical information, and diagnostic question to the imaging request, because the lack of this information has been recognized as a source of diagnostic errors [13]. In a recent survey among radiologists (the majority from the United States) 12.6 % indicated to have experienced at least one lawsuit potentially preventable with sufficient information in the imaging request [5]. In addition, if a radiologist frequently has to look up the missing information in the medical records or by contacting the requesting physician, this will slow down workflow and it might be a source of stress and frustration that may even refrain the radiologist from doing so in a busy practice. Altogether, patient care and safety may potentially be compromised when crucial information is missing from the imaging request and not available to the radiologist. Infection/inflammation as indication for imaging decreased the odds of a poor quality request. It can be speculated that patients with or suspected of an infection or inflammation are frequently acutely ill, and that the requesting physician needs an accurate imaging diagnosis to initiate an appropriate treatment in a timely manner, hence the relatively good quality of these imaging requests. Requests from pediatricians were also of higher quality than those of other types of physicians. Since an imaging procedure may generally be more burdensome to children than to adults, and radiation exposure plays a more important role in the pediatric population, pediatricians have to carefully outweigh the pros and cons and justify the need for imaging, which is probably reflected by the quality of their imaging requests. The strong interaction and frequent communication between pediatricians and pediatric radiologists in our hospital likely also plays an important role. Interestingly, imaging requests with the head, spine, or upper extremity were also of higher quality than those involving other body regions. The reason for this observation remains unclear. Furthermore, the multivariate model could only explain around 18.5 %

Table 1
Study population characteristics.

Variable	Category	Count	Percentage
Hospital status	Inpatient	81	12.0%
	Outpatient	553	82.2%
	Emergency	39	5.8%
Indication for imaging	Cardiac	16	2.4%
	Congenital/ developmental	35	5.2%
	Infection/ inflammation	58	10.0%
	Oncology	182	27.0%
	Routine preoperative imaging	15	2.2%
	Routine postoperative imaging	26	3.9%
	Transplantation	16	2.4%
	Trauma	62	9.2%
	Vascular	52	7.7%
	Miscellaneous	202	30.0%
Imaging modality	Conventional radiography	171	25.4%
	US	165	24.5%
	CT	168	25.0%
	MRI	169	25.1%
Time of examination	Office hours	604	89.7%
	Duty hours	69	10.3%
Relationship with any previous imaging performed within the past one year	Yes	351	52.2%
	No	322	47.8%

Abbreviations: CT: computed tomography; MRI: magnetic resonance imaging; US: ultrasonography.

Table 2
Representative examples of imaging requests in each of the four RI-RADS grade groups.

RI-RADS grade	Imaging request
A	Chest CT (requesting specialty: pediatrics): *"Fourteen-year-old girl with a history of osteosarcoma who underwent chemotherapy and surgery 9 years ago. One year after completion of treatment recurrent osteosarcoma in the other leg, again treated with chemotherapy and surgery. One year later metastasis in the left lung, which was resected. Are there any signs of lung metastases?"*
B	Abdominal ultrasonography (requesting specialty: internal medicine): *"Persistent cholestatic liver test abnormalities after pneumonia. History of cholecystectomy. Liver parenchyma abnormalities? Focal lesions? Size bile ducts? Obstruction?"*
C	Cerebellopontine angle MRI (requesting specialty: otorhinolaryngology) *"Cerebellopontine angle abnormality. Growth?"*
D	Chest radiography (requesting specialty: cardiology) *"Pre-CABG"*

Table 3
Cramér's V coefficients for the association between the variables indication for imaging, requesting specialty, imaging modality, and body region, with *P*-values between parentheses.

	Indication for imaging	Requesting specialty	Imaging modality
Requesting specialty	0.392 ($P = 0.000$)	–	–
Imaging modality	0.466 ($P = 0.000$)	0.487 ($P = 0.00$)	–
Body region	0.421 ($P = 0.000$)	0.481 ($P = 0.000$)	0.596 ($P<0.000$)

of the variability in RI-RADS grades. This indicates that there are still many unknown factors that affect the quality of an imaging request. The characteristics of the requesting physicians, including their clinical experience, skills in the interpretation of radiologic images, and clinical work pressure, may potentially be of influence. Further research is required to elucidate these factors.

The results of the present study underline the necessity to improve the overall quality of imaging requests. Providing feedback to individuals who submit imaging requests of insufficient quality, and acknowledging individuals who submit imaging requests of desired quality, may positively affect requesting physicians' behavior and increase the proportion of adequate imaging requests. This is in line with the radiologist's gatekeeper role to check the appropriateness of imaging and to optimize the diagnostic yield of an imaging examination [14].

Table 4
Association of variables with a poorer quality of the imaging request (based on RI-RADS grade) in multivariate ordinal regression analyses.

Variable	Category	Odds ratio[1]	95 % CI	*P*-value[2]
Indication for imaging	Cardiac	1.440	0.228–9.099	0.698
	Congenital/ developmental	2.143	0.955–4.811	0.065
	Infection/ inflammation	0.411	0.236–0.717	**0.002**
	Oncology	1.045	0.647–1.687	0.858
	Routine preoperative imaging	3.422	1.125–10.407	**0.030**
	Routine postoperative imaging	2.157	0.918–5.070	0.078
	Transplantation	8.710	3.025–25.083	**0.000**
	Trauma	1.291	0.696–2.393	0.418
	Vascular	1.170	0.614–2.230	0.634
	Miscellaneous	1 (reference)	–	–
Requesting specialty	Cardiology	0.519	0.196–1.375	0.187
	Cardiothoracic surgery	2.685	0.622–11.601	0.186
	Family medicine	1.549	0.781–3.071	0.210
	Gastroenterology	0.755	0.344–1.656	0.483
	Hematology	0.815	0.242–2.752	0.742
	Intensive care medicine	0.615	0.259–1.457	0.269
	Internal medicine	0.525	0.264–1.043	0.066
	Medical oncology	1.012	0.455–2.251	0.976
	Neurology	0.785	0.355–1.735	0.549
	Neurosurgery	1.202	0.414–3.486	0.735
	Orthopedics	1.504	0.752–3.008	0.248
	Otorhinolaryngology	1.064	0.398–2.844	0.902
	Pediatrics	0.400	0.206–0.777	**0.007**
	Pulmonary medicine	0.887	0.411–1.915	0.761
	Radiation therapy	2.700	0.729–10.000	0.137
	Rheumatology	1.510	0.577–3.952	0.401
	Urology	0.494	0.159–1.532	0.222
	Other	1.339	0.588–3.051	0.487
	Surgery	1 (reference)	–	–
Imaging modality	US	0.594	0.334–1.056	0.076
	CT	0.620	0.359–1.070	0.086
	MRI	0.833	0.483–1.436	0.510
	Conventional radiography	1 (reference)	–	–
Body region	Breast	0.411	0.151–1.120	0.082
	Chest	1.460	0.735–2.898	0.280
	Head	0.384	0.175–0.843	**0.017**
	Heart	1.913	0.282–12.973	0.507
	Lower extremity	0.624	0.302–1.289	0.203
	Neck	0.620	0.246–1.561	0.310
	Pelvis	0.768	0.354–1.668	0.505
	Spine	0.346	0.146–0.822	**0.016**
	Upper extremity	0.208	0.086–0.503	**0.000**
	Other body region	2.002	0.534–7.510	0.303
	Multiple body regions	0.598	0.298–1.203	0.149
	Abdomen	1 (reference)	–	–

Abbreviations: CI: confidence interval; CT: computed tomography; MRI: magnetic resonance imaging; US: ultrasonography.
Notes: [1]The category with the largest number of observations was used as reference; [2]Significant values ($P<0.05$) are marked in bold.

Standardization of radiology requisition forms according to RI-RADS may also reduce the proportion of missing data [10]. A perhaps even more effective approach is to reject to perform any imaging when the request is inadequate. Its feasibility was shown in a previous study on chest radiography [6]. However, manually checking all imaging requests may be a daunting, virtually impossible task in a high-volume radiology department. A natural language processing and machine learning algorithm, with RI-RADS scores as output, and implemented in the hospital's electronic ordering system for diagnostic imaging, may potentially be an efficient solution. This should be the topic of future research.

There are no previous studies that have applied RI-RADS to clinical data. Therefore, it is difficult to compare the present results to those of other studies on this topic [6–12]. Nevertheless, our results resonate with previous literature that generally reported poor imaging requests to be common [6–12]. They are also in line with the results of a recent survey in which the majority of radiologists (56.3 %) indicated that they encounter requisitions with incomplete or inaccurate data that make the interpretation challenging in more than half of the time [5]. Comprehensive studies on the determinants of poor quality imaging requests have also been lacking so far. One study by Davies et al. [12] investigated 1548 acute imaging requests for emergency department patients and inpatients, and reported that emergency department requests more frequently included the localization of signs and symptoms but tended to neglect the clinical history. Inpatient requests were the converse, localizing signs and symptoms less, but more often mentioning relevant clinical history [12]. Furthermore, it was reported that weekend requests were of higher overall quality than weekday requests, and that requests for US, CT, and MRI, were generally better than those of conventional radiography [12]. However, because Davies et al. [12] only included acute imaging requests, did not apply RI-RADS, and investigated only a few number of variables, the applicability of their results is limited and not comparable to those of the present study.

The present study had some limitations. First, the imaging request may not contain all information that has been communicated from the referring physician to the radiologist. Information could also have been transferred by means of oral communication. Nevertheless, it can be argued that the imaging request should always contain all necessary information to avoid the risk of miscommunication and errors. Second, this study was performed at a single tertiary care center in which more than 200,000 radiologic procedures are performed on an annual basis. However, imaging requests may differ between institutions and between countries. For example, is unclear if the results would be the same in centers with different volumes of examinations and with a non-academic profile. Third, RI-RADS was recently updated with the addition of a fifth category (RI-RADS grade X, which is assigned when no key category of information is included in the imaging request) [5]. Twenty-one of 134 RI-RADS grade D cases would have been reclassified as RI-RADS grade X if the updated RI-RADS was used. However, this would not change the overall results of our study. Fourth, the RI-RADS classification may need further refinement before it can be used in an official audit for quality improvement with a closed loop. For example, verbal information is inherently not captured when only analyzing written imaging requests, and some requests may require more in-depth clinical information than others. The standards of imaging requests ideally need to be agreed with those requesting prior to an audit.

5. Conclusion

The quality of radiologic imaging requests is inadequate in >75 % of cases according to the Reason for exam Imaging Reporting and Data System (RI-RADS) in our tertiary care center. Indication for imaging, requesting specialty, and body region were independently significantly associated with RI-RADS grades. The data from this study can be used as a baseline and benchmark for further investigation and improvement.

Funding

None.

IRB statement

The institutional review board of the University Medical Center Groningen approved this retrospective study (registered in the UMCG research register with number 202000601) and waived the requirement for written informed consent (see attached letter).

This study has been performed in accordance with the ethical standards in the 1964 Declaration of Helsinki.

This study has been carried out in accordance with relevant regulations of the US Health Insurance Portability and Accountability Act (HIPAA).

CRediT authorship contribution statement

Ömer Kasalak: Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization, Supervision. **Haider A.A. Alnahwi:** Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization. **Rudi A.J.O. Dierckx:** Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization, Supervision. **Derya Yakar:** Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization, Supervision. **Thomas C. Kwee:** Conceptualization, Methodology, Formal analysis, Investigation, Writing - original draft, Writing - review & editing, Visualization, Supervision.

Declaration of Competing Interest

The authors report no declarations of interest.

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