

ORIGINAL ARTICLE

Knowledge of imaging appropriateness and image interpretation among medical students and interns in Riyadh, Saudi Arabia: a multi-institutional cross-sectional study

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ABSTRACT

Background: Radiology underpins diagnosis across specialties, yet remains underrepresented in many undergraduate curricula. This study assessed imaging appropriateness and image interpretation knowledge among medical students and interns in Riyadh, compared pre-clinical and clinical stages, and described awareness of appropriateness frameworks.

Methods: Analytical cross-sectional study conducted September 2025–January 2026 at universities in Riyadh, Saudi Arabia. A self-administered online questionnaire assessed perceptions of radiology education, awareness of appropriateness frameworks, and knowledge through six scenario-based and six image-based items. Participants were classified as pre-clinical (years 1–3) or clinical (year 4 to internship). Analyses used Welch's t-tests, chi-square tests, and mixed-effects regression with a random intercept for university.

Results: Of 495 responses, 493 were analyzed (257 pre-clinical, 236 clinical). Clinical-stage participants scored higher (7.14 ± 2.48 versus 4.38 ± 2.43 ; mean difference 2.76, 95% CI 2.33 to 3.20; Hedges' $g = 1.12$; $p < 0.001$), larger for image-based than scenario-based items ($g = 1.16$ versus 0.67). This persisted after adjusting for academic achievement and institution. Awareness of appropriateness frameworks was reported by 45 participants (9.1%) and did not differ by training stage ($p = 0.54$), academic year ($p = 0.27$), or institution ($p = 0.50$).

Conclusions: Applied imaging knowledge was substantially higher at the clinical stage, with gains concentrated in image interpretation. Awareness of appropriateness frameworks was near-absent and did not increase at any point in training, suggesting that clinical immersion develops pattern recognition while leaving explicit frameworks untaught. The study was confined to Riyadh, which may limit generalizability to other regions.

Keywords: Radiology/education, medical students, undergraduate medical education, diagnostic imaging, clinical competence, Saudi Arabia.

Introduction

Medical imaging is central to clinical practice and is a core competency for physicians across specialties. National competency specifications for Saudi medical graduates require the ability to select and interpret common diagnostic investigations, and physicians are expected both to request imaging appropriately and to recognize major abnormalities [1,2]. Inappropriate use exposes patients to avoidable radiation, incidental findings and cost, and can delay diagnosis.

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Radiology nonetheless remains underrepresented in many undergraduate curricula [3]. Pre-clinical students often encounter radiological images principally within anatomy teaching, where the emphasis falls on structural recognition rather than clinical application, and teaching is sometimes delivered by non-radiologists [4]. Students themselves prioritize the applied skills such teaching omits, ranking the ability to view radiographs and distinguish normal from abnormal above other content [5]. Many therefore reach the clinical years with limited understanding of imaging indications and modality selection [3,6].

Imaging appropriateness – the match between a clinical question and the study best able to answer it at acceptable risk and cost – is formalized in frameworks such as the American College of Radiology Appropriateness Criteria, and structured exposure to these improves trainees' knowledge of appropriate utilization [7]. Gispen and Magid found modality-selection knowledge limited before a radiology elective [8], and Parkoohi and colleagues reported that most Iranian externs and interns failed items on computed tomography, magnetic resonance imaging, and ultrasound indications, with 16.5% selecting cross-sectional imaging where ultrasound was indicated [9].

Comparable findings come from Saudi Arabia, where clinical-year students at one institution scored 4.10 of 10 on imaging modality knowledge [10]; a wider literature documents limited understanding of radiation dose and protection internationally [11,12] and regionally [13,14]. Few studies have examined imaging appropriateness specifically, and none to our knowledge has combined scenario- and image-based assessment across multiple institutions in a single Saudi city. Concerns that artificial intelligence may reduce demand for radiologists have also been reported to influence specialty choice, with reported magnitudes varying widely [15].

This study assessed knowledge of imaging appropriateness and image interpretation across universities in Riyadh; compared pre-clinical and clinical stages; determined whether any difference was independent of academic achievement and institution; described awareness of appropriateness frameworks and exposure to radiology attachments; and, among participants not considering radiology, described the influence of concerns about artificial intelligence.

Materials and Methods

Design, setting and participants

This analytical cross-sectional study is reported in accordance with the STROBE statement and the CHERRIES checklist for internet-based surveys. Participants were students enrolled in colleges of medicine at universities in Riyadh, Saudi Arabia, and graduates undertaking the internship year at those institutions. Data were collected between September 16, 2025 and January 4, 2026, following Institutional Review Board approval, using an online questionnaire. Individuals not enrolled at, or not graduates of, a college of medicine in Riyadh were excluded. Recruitment

used convenience sampling through social media and in-person distribution within medical colleges; because the number of students reached is unknown, a response rate cannot be calculated. The platform did not restrict repeat submissions, and no identifying information was collected. Assuming a between-group difference of 0.5 standard deviations, a two-sided alpha of 0.05 and 80% power, a minimum of 64 participants per group was required.

Questionnaire

The questionnaire was developed by the research team *de novo* rather than adapted from a previously validated instrument. All items were reviewed by one consultant radiologist for content relevance, clarity, and correctness of the designated answer, and revised accordingly; no second expert reviewed the items and no content validity index or comparable quantitative index was computed. The instrument was pilot tested with 34 medical students spanning all academic years at more than one university in Riyadh; the pilot identified no problems of comprehension or wording and no item was changed, so the instrument used in the main study was identical to the piloted version. Pilot responses were collected during instrument development, before ethical approval, and were not analyzed. Formal psychometric validation was therefore limited, and this is stated as a limitation.

The questionnaire recorded age, gender, university, academic year, and self-reported grade point average and assessed perceptions of radiology education, exposure to radiology teaching and clinical attachments, familiarity with decision-support tools for imaging appropriateness, and interest in radiology as a career. Participants who had not considered radiology were additionally asked, on a five-point Likert scale, the extent to which concerns about artificial intelligence influenced that decision.

Knowledge was assessed with twelve single-best-answer items: six vignettes requiring selection of the most appropriate modality and six requiring a diagnosis from a radiograph or computed tomography image. Each item offered four substantive options and an explicit "I don't know" option; one offered five. Items scored one for the designated correct response and zero otherwise, including "I don't know". Subscale scores were the sum of six items each (range 0–6) and the total their sum (range 0–12). Five images were unannotated; one carried arrows indicating the abnormality and therefore assessed recognition rather than detection. One item asked which modality best evaluates the urinary tract in chronic kidney disease while minimizing contrast-related risk: ultrasound was designated correct, though non-contrast magnetic resonance urography, selected by 17.0%, also avoids iodinated contrast; the pre-specified key was retained and a sensitivity analysis is reported. The full instrument, images, and answer key are available from the corresponding author on request.

Excluded items and training stage

Items on completion of a formal radiology course, timing of first teaching, and instructional hours were excluded for demonstrable unreliability: responses were internally

contradictory in 197 of 493 participants (40.0%), and agreement among students at the same institution ranged from 57% to 94% on whether a separate course existed. Participants were categorized as pre-clinical (years 1–3) or clinical (year 4 to internship). This boundary was supported empirically: scores did not differ between second- and third-year students (4.41 versus 4.77; $p = 0.32$) but differed substantially between third and fourth year (4.77 versus 6.72; Hedges' $g = 0.80$; $p < 0.001$).

Ethical considerations

The study was approved by the Institutional Review Board of King Saud University Medical City, Riyadh (approval number 25/0798/IRB; Research Project No. E-25-10074) on September 15, 2025, and the approval covered recruitment at all participating universities in Riyadh. Written informed consent was obtained electronically from every participant before questionnaire completion, and participation was voluntary and anonymous.

Statistical analysis

Analyses used R (version 4.3.2; R Foundation for Statistical Computing, Vienna, Austria). Categorical variables were compared with chi-square tests and continuous scores with Welch's t-tests, summarized as means with standard deviations and medians with interquartile ranges. Effect sizes are Hedges' g with 95% confidence intervals. The three knowledge outcomes

were pre-specified as co-primary and no adjustment for multiplicity was applied. Because participants were nested within institutions, mixed-effects linear regression with a random intercept for university examined predictors of score, with training stage, grade point average, gender, prior radiology attachment, and career interest as fixed effects. Grade point average was recorded in bands on a five-point scale while two institutions grade on four, and was therefore standardized within institution. Internal consistency was assessed with the Kuder–Richardson formula 20, with item difficulty and corrected item–total correlation computed for each item. Two-sided $p < 0.05$ was considered significant.

Results

Participants

Of 495 responses, one respondent declined consent, and one was enrolled outside Riyadh; both were excluded. No respondent left the knowledge section incomplete. The analyzed sample comprised 493 participants: 257 pre-clinical and 236 clinical, the latter including 19 interns (8.1%). Participants came from seven named medical schools, public and private, with one reporting an unlisted institution (Table 1). Representation was uneven across training stage – one institution supplied 31.8% of clinical but 6.2% of pre-clinical participants, another

Table 1. Participant characteristics, n (%).

Characteristic	Pre-clinical ($n = 257$)	Clinical ($n = 236$)	Total ($n = 493$)
Age 18–20	98 (38.1)	7 (3.0)	105 (21.3)
Age 20–25	152 (59.1)	215 (91.1)	367 (74.4)
Age 25–30	7 (2.7)	14 (5.9)	21 (4.3)
Female	130 (50.6)	116 (49.2)	246 (49.9)
Male	127 (49.4)	120 (50.8)	247 (50.1)
Year 1	51 (19.8)	—	51 (10.3)
Year 2	56 (21.8)	—	56 (11.4)
Year 3	150 (58.4)	—	150 (30.4)
Year 4	—	116 (49.2)	116 (23.5)
Year 5	—	101 (42.8)	101 (20.5)
Internship	—	19 (8.1)	19 (3.9)
King Saud University	82 (31.9)	30 (12.7)	112 (22.7)
Princess Nourah bint Abdulrahman University	66 (25.7)	45 (19.1)	111 (22.5)
Imam Mohammad Ibn Saud Islamic University	16 (6.2)	75 (31.8)	91 (18.5)
King Saud bin Abdulaziz University for Health Sciences	33 (12.8)	52 (22.0)	85 (17.2)
Almaarefa University	30 (11.7)	2 (0.8)	32 (6.5)
Dar Al Uloom University	13 (5.1)	18 (7.6)	31 (6.3)
Alfaisal University	17 (6.6)	13 (5.5)	30 (6.1)
Other	—	1 (0.4)	1 (0.2)
GPA 4.50–5.00	169 (65.8)	151 (64.0)	320 (64.9)
GPA 3.75–4.49	77 (30.0)	69 (29.2)	146 (29.6)
GPA 2.75–3.74	10 (3.9)	16 (6.8)	26 (5.3)
GPA below 2.00	1 (0.4)	—	1 (0.2)

Percentages are within column. GPA bands are defined on a five-point scale; two institutions grade on four. The response options contained no band spanning 2.00–2.74. Age categories are reproduced as administered and overlap at 20 and 25 years. GPA, grade point average.

11.7% of pre-clinical and two clinical participants – so stage comparisons partly reflect institutional differences.

Knowledge scores

Clinical-stage participants scored substantially higher across all three domains (Table 2, Figure 1). Total score was 7.14 ± 2.48 versus 4.38 ± 2.43 (mean difference 2.76, 95% CI 2.33 to 3.20; Hedges' $g = 1.12$; $p < 0.001$), with a larger difference for image-based items (1.91, 95% CI 1.61 to 2.20; $g = 1.16$) than scenario-based items (0.86, 95% CI 0.63 to 1.08; $g = 0.67$).

Performance varied sharply across items (Figure 2). Common, rule-based scenarios were answered well: radiography for suspected fracture by 85.2% of pre-clinical and 92.8% of clinical participants, and ultrasound in pregnancy by 77.0% and 90.3%. Performance fell on scenarios requiring imaging choice to be integrated with patient-specific risk. The lowest-scoring item concerned imaging the urinary tract in chronic kidney disease while minimizing contrast risk (18.7% and 24.6%) and was the only scenario item on which clinical participants did not perform significantly better ($p = 0.14$).

Instrument performance

Internal consistency was acceptable for the full scale (KR-20 = 0.745; standard error of measurement 1.42) and within each stage (0.683 and 0.665). Reliability differed by domain: 0.725 for image-based items but only 0.489 for scenario-based items, falling to 0.398 among clinical participants. Item difficulty ranged from 0.215 to 0.888 and corrected item–total correlations from 0.106 to 0.563. Eleven of twelve items met the 0.20 discrimination floor; the appendicitis item did not ($r = 0.106$) and was the only item whose removal would have raised reliability. Chance performance was 1.17 and 1.20 of 6 for scenario- and image-based items; pre-clinical performance exceeded chance on both ($p < 0.001$ and $p = 0.001$), though narrowly for images. Pre-clinical participants selected “I don't know” on 43.2% of image items versus 17.5% of clinical participants.

Multivariable analysis

Clinical training stage remained strongly associated with the total score after adjustment for grade point average, gender, prior radiology attachment, and career

Table 2. Knowledge scores by training stage.

Domain	Pre-clinical mean $\pm$ SD	Median (IQR)	Clinical mean $\pm$ SD	Median (IQR)	Mean difference (95% CI)	Hedges' g (95% CI)	p
Total (0–12)	4.38 ± 2.43	4 (3–6)	7.14 ± 2.48	8 (6–9)	2.76 (2.33 to 3.20)	1.12 (0.93 to 1.31)	<0.001
Scenario (0–6)	2.85 ± 1.34	3 (2–4)	3.71 ± 1.22	4 (3–5)	0.86 (0.63 to 1.08)	0.67 (0.48 to 0.85)	<0.001
Image (0–6)	1.53 ± 1.56	1 (0–2)	3.43 ± 1.73	4 (2–5)	1.91 (1.61 to 2.20)	1.16 (0.97 to 1.35)	<0.001

Welch's t -test. Total $t = 12.47$, $df = 486$; scenario $t = 7.43$, $df = 491$; image $t = 12.81$, $df = 475$. CI, confidence interval; IQR, interquartile range; SD, standard deviation.

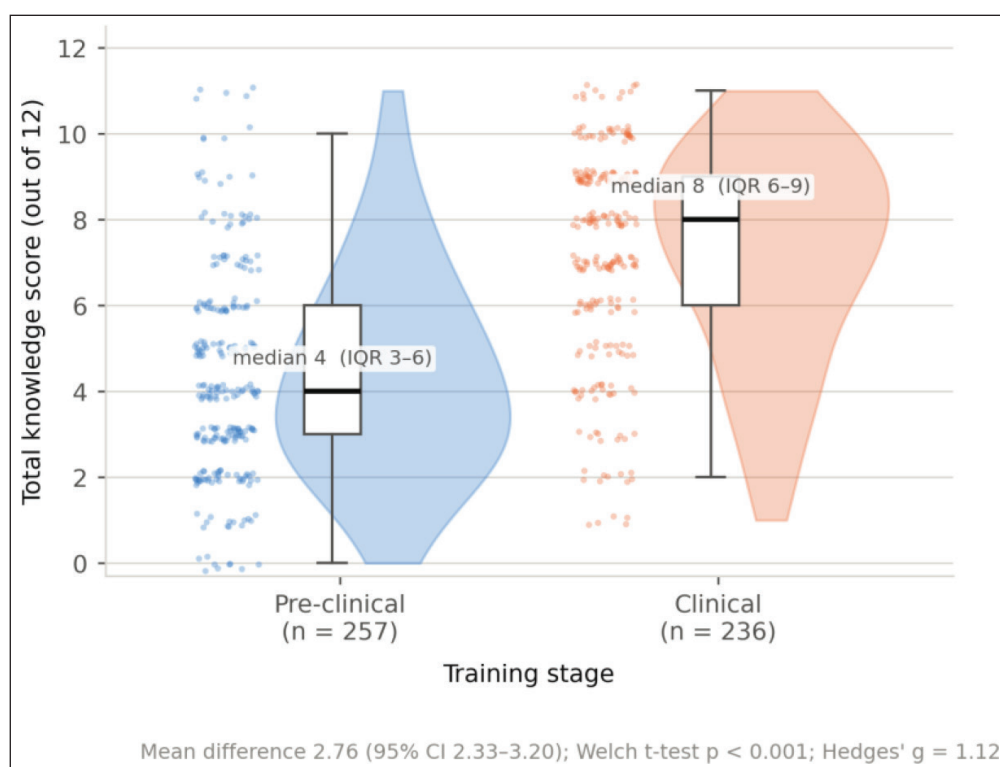


Figure 1. Total knowledge score by training stage. Violins show kernel density bounded to the possible range (0–12); boxes show median and interquartile range with whiskers to $1.5 \times$ IQR. Pre-clinical $n = 257$; clinical $n = 236$. Mean difference 2.76 (95% CI 2.33 to 3.20), $p < 0.001$.

interest ($\beta = 3.02$, 95% CI 2.57 to 3.47; $p < 0.001$) (Table 3). Grade point average was independently associated with score, whereas prior radiology attachment was not associated in any model or subscale. The intraclass correlation for university was 0.207, indicating that approximately 21% of variance lay between institutions; because verified curriculum documentation was unavailable, this could not be attributed to specific curricular features.

Perceptions, awareness and exposure

Around one-third (154; 31.2%) had considered radiology as a specialty, with no difference by stage ($p = 0.88$). Just over half (268; 54.4%) believed radiology was adequately covered and 346 (70.2%) that teaching had helped them clinically; neither differed by stage ($p = 0.22$ and $p = 0.82$) (Table 4). Awareness of decision-

support tools for imaging appropriateness was low and did not vary with training: 45 participants (9.1%) reported familiarity, 201 (40.8%) were unsure, and 247 (50.1%) had not heard of them, with no difference by stage (8.2% versus 10.2%; $p = 0.54$), academic year ($p = 0.27$), or institution ($p = 0.50$) (Figure 3). Radiology attachment was equally uncommon in both groups (7.0% versus 7.6%; $p = 0.93$), and those reporting familiarity with appropriateness tools did not score higher (6.27 versus 5.64; $p = 0.18$).

Artificial intelligence and career intention

Of the 339 participants who had not considered radiology, 323 (95.3%) answered the artificial intelligence item. Disagreement was most common: 127 (39.3% of those answering) disagreed or strongly disagreed that such concerns influenced their decision, against 101

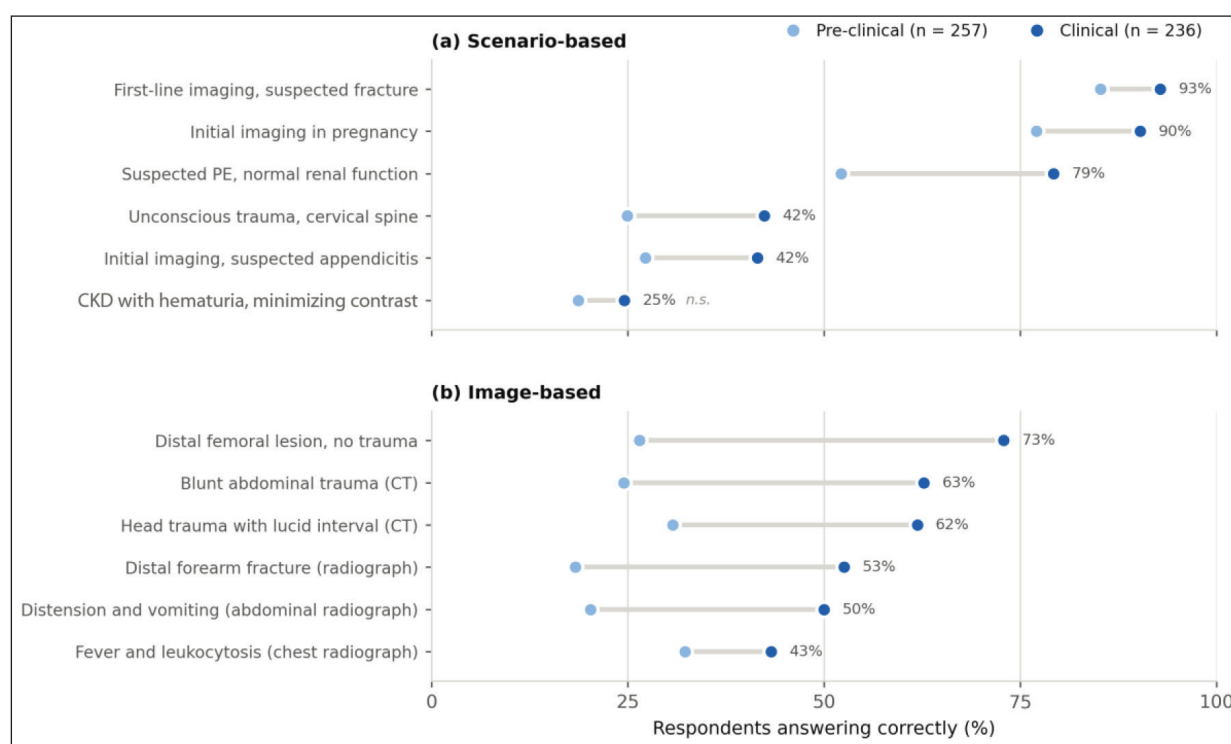


Figure 2. Percentage answering each item correctly, by training stage, ordered by clinical-stage performance within domain: (a) scenario-based items; (b) image-based items. All between-stage differences were significant at $p < 0.05$ except the chronic kidney disease item (n.s.). Chi-square test per item.

Table 3. Mixed-effects linear regression of knowledge score (random intercept for university; $n = 493$).

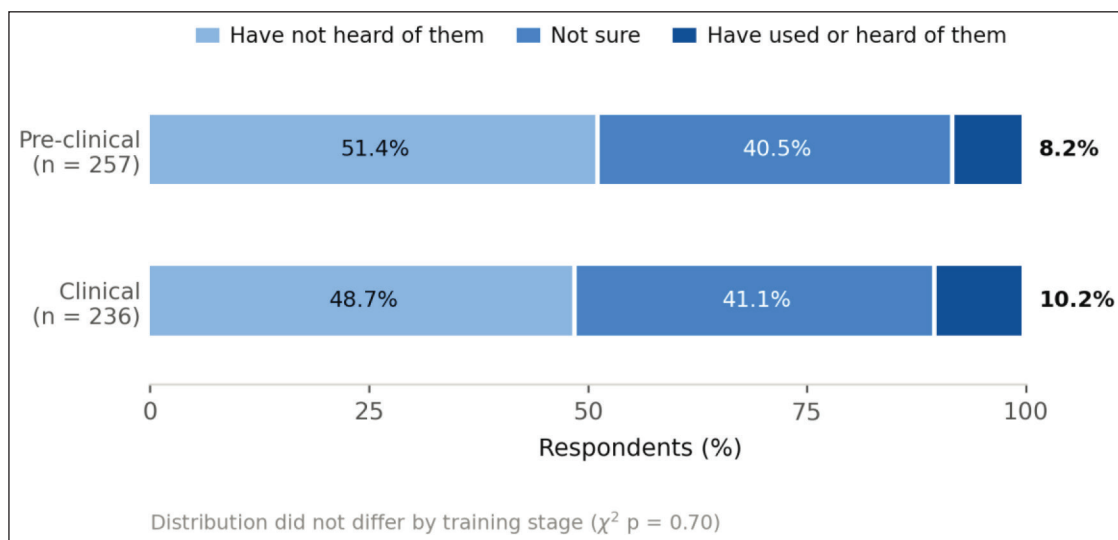
Predictor	Total β	Total 95% CI	Scenario β	Image β
Clinical training stage	3.02	2.57 to 3.47	0.99	2.02
GPA (per SD, within institution)	0.40	0.19 to 0.60	0.16	0.24
Female gender	0.22	-0.29 to 0.73	0.26	-0.04
Prior radiology attachment	-0.27	-1.06 to 0.51	-0.15	-0.13
Considered radiology as a career	0.38	-0.07 to 0.82	0.16	0.22
Between-university variance	1.38	—	—	—
Intraclass correlation	0.207	—	—	—

All three columns are mixed-effects models with a random intercept for university, fitted separately to each outcome. Gender was not significant in any model (scenario $\beta = 0.26$, $p = 0.06$). Ordinary least squares diagnostics: Breusch-Pagan $p = 0.98$; all variance inflation factors ≤ 1.02 . CI, confidence interval; GPA, grade point average; SD, standard deviation.

Table 4. Perceptions, awareness, and exposure, by training stage.

Variable	Pre-clinical (n = 257)	Clinical (n = 236)	Total (n = 493)	p
Considered radiology as a career	79 (30.7)	75 (31.8)	154 (31.2)	0.88
Radiology adequately covered	147 (57.2)	121 (51.3)	268 (54.4)	0.22
Teaching helped clinical practice	182 (70.8)	164 (69.5)	346 (70.2)	0.82
Appropriateness guidelines: aware	21 (8.2)	24 (10.2)	45 (9.1)	0.54
Appropriateness guidelines: not sure	104 (40.5)	97 (41.1)	201 (40.8)	0.96
Appropriateness guidelines: not heard of	132 (51.4)	115 (48.7)	247 (50.1)	0.62
Completed a radiology attachment	18 (7.0)	18 (7.6)	36 (7.3)	0.93

Values are n (%); chi-square tests. Across the full three-category awareness distribution, $p = 0.70$.

**Figure 3.** Awareness of decision-support tools for imaging appropriateness, such as the American College of Radiology Appropriateness Criteria, by training stage. Chi-square $p = 0.70$.**Table 5.** Influence of concerns about artificial intelligence on the decision not to pursue radiology (n = 339)

Response	n	% of eligible group	% of those answering
Strongly agree	30	8.8	9.3
Agree	71	20.9	22.0
Neutral	95	28.0	29.4
Disagree	73	21.5	22.6
Strongly disagree	54	15.9	16.7
No response	16	4.7	—
Total	339	100.0	100.0

Presented only to participants who had not considered radiology. Because conditional branching was not enforced, responses from those who had considered radiology (n = 98) were excluded; item non-response was not imputed. Column percentages may not sum to 100 owing to rounding.

(31.3%) who agreed and 95 (29.4%) neutral (Table 5). Endorsement did not differ by stage ($p = 0.42$) and was unrelated to knowledge score (Spearman $\rho = 0.002$), but was higher among male than female respondents (3.09 versus 2.63 on a five-point scale; $p = 0.001$).

Sensitivity analyses

The stage difference was robust to alternative scoring and sample definitions: accepting either ultrasound or non-

contrast magnetic resonance urography for the chronic kidney disease item gave a mean difference of 2.76 ($g = 1.11$); excluding interns gave 2.69 ($g = 1.08$); and excluding third-year participants gave 3.32 ($g = 1.32$).

Discussion

Across medical schools in Riyadh, participants at the clinical stage scored more than one standard deviation higher than pre-clinical participants, and the association persisted after adjustment for academic achievement and institution. Awareness of the frameworks governing imaging appropriateness, by contrast, did not increase at any point in training.

The largest difference lay in image-based items, where clinical participants scored more than twice as highly. Image interpretation relies on visual pattern recognition developed through repeated exposure to clinical material, which rotations plausibly provide [16]. The scenario-based difference was smaller, though attenuated by that subscale's lower reliability; correcting for attenuation raises its effect size from 0.67 to 0.95, so the contrast between domains is real but less pronounced than the raw figures suggest.

Performance fell markedly on scenarios requiring imaging choice to be weighed against patient-specific risk. The chronic kidney disease item was both the worst

performed and the only scenario item on which clinical participants did not improve, suggesting that reasoning about contrast-related harm in a specific patient is not acquired through clinical exposure alone. The appendicitis item showed a different pattern: 42.0% chose ultrasound and 34.1% contrast-enhanced computed tomography, yet the item barely correlated with overall performance ($r = 0.106$). The error was spread evenly across the ability range rather than concentrated among weaker students, which suggests a taught heuristic – generalizing the pediatric and obstetric preference for ultrasound to non-pregnant adults – rather than absent knowledge.

The most consistent finding was the near-absence of awareness of appropriateness frameworks. Only 9.1% reported familiarity, and this did not differ by training stage, academic year, or institution, nor did those reporting familiarity score higher. This closely matches the 11.3% familiarity reported among third-year students at a United States medical school [17], suggesting an international rather than a local deficiency. In that study, an intervention raised awareness to 82.4%, while usage among newly aware students remained 21.3%, paralleling the absence here of any advantage from reported familiarity. Clinical immersion appears to develop diagnostic pattern recognition while leaving the explicit rules of appropriate imaging selection untaught. Consistent with this, prior completion of a radiology attachment was not associated with knowledge in any model, although only 36 participants reported one.

Absolute scores compare favorably with published samples. Clinical participants answered 61.8% of scenario items correctly, against 41% on a modality scale among clinical-year students at another Saudi institution [10], a score classified as failing among Iranian externs and interns [9], and 35.6% on radiation knowledge among Norwegian final-year students [12]. Instruments differ, so these comparisons are indicative only. Measured and perceived competence also dissociated: scores were 2.76 points higher at the clinical stage, yet the proportion believing radiology adequately covered did not differ ($p = 0.22$). Perceived adequacy appears insensitive to cohort-level gains, so student demand is unlikely to surface this gap.

Limitations

The cross-sectional design prevents causal inference; clinical-stage participants also differ in age, cumulative knowledge, and examination familiarity. Instrument validation was limited to review by a single radiologist who was a member of the research team, without independent expert review or content validity indices, and the scenario-based subscale did not reach acceptable internal consistency, so those comparisons carry greater measurement error and likely understate the true difference. Convenience sampling precludes a response rate and invites self-selection, evidenced by the 31.2% reporting interest in radiology; this probably inflates absolute scores but is less likely to bias the stage comparison. The questionnaire was unsupervised and untimed, so consultation of external resources cannot be excluded. Curriculum documentation was unavailable,

so coursework exposure could not be characterized. Participants were nested within institutions (intraclass correlation 0.207) with unbalanced representation across stage, so residual confounding by institution remains possible. Grade point average, attachment, and perceptions were self-reported and are open to social desirability bias, which would tend to inflate reported familiarity with appropriateness tools, reported attachment, and perceived competence; the knowledge items, being objectively scored, are less exposed to it. Finally, knowledge was assessed by questionnaire rather than by observed imaging requests; twelve items cannot span the domain; one image was annotated, so the subscale mixed detection with recognition; and the study was confined to Riyadh.

Conclusion

Applied imaging knowledge was substantially higher among medical students and interns at the clinical stage than at the pre-clinical stage, by more than one standard deviation, and this persisted after adjustment for academic achievement and institution. The gain was concentrated in image interpretation rather than appropriateness reasoning, and performance remained poor on scenarios requiring imaging choice to be weighed against patient-specific risk. Awareness of imaging appropriateness frameworks was reported by fewer than one in ten participants, did not increase with training stage, academic year or institution, and conferred no measurable advantage – closely matching figures reported internationally. Clinical immersion appears to develop diagnostic pattern recognition while leaving explicit appropriateness frameworks untaught, and strengthening undergraduate radiology education may require their deliberate introduction during clinical training [18,19]. Because the study was confined to Riyadh, multicenter studies across Saudi Arabia are needed to establish whether these patterns hold elsewhere; prospective evaluation of such teaching is the necessary next step.

Conflict of interests

The authors declare that there is no conflict of interest regarding the publication of this article.

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None.

Ethical approval

Ethical approval was granted by the Institutional Review Board of King Saud University Medical City via reference number 25/0798/IRB (Research Project No. E-25-10074), dated September 15, 2025. The approval covered recruitment at all participating universities in Riyadh.

Consent for participation

Written informed consent was obtained electronically from all participants prior to questionnaire completion.

Consent for publication

Not applicable.

List of abbreviations

CI confidence interval
IQR interquartile range

KR-20 Kuder–Richardson formula 20
SD standard deviation.

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Supplementary content (if any) is available online.

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