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Negative Appendectomy Rate and Its Predictors in the Era of Selective Imaging: A Retrospective Cohort

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Abstract

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Background. The negative appendectomy rate (NAR) the proportion of appendectomies in which the removed appendix is histologically normal is a recognized quality indicator in emergency general surgery. Despite the increasing availability of preoperative imaging, NAR remains variable, and selective rather than universal imaging strategies leave a residual burden of unnecessary operations, particularly in women of childbearing age. **Objective.** To determine the NAR at a single tertiary center in the era of selective preoperative imaging, to characterize NAR across clinically relevant subgroups, and to identify independent predictors of negative appendectomy using histopathology as the reference standard. **Patients and methods.** A retrospective single-center cohort study was conducted at Nasiriyah teaching hospital, Thi-Qar province, Iraq from October 2024 through February 2026 and reported in accordance with the STROBE statement. Patients aged 16 years or older undergoing appendectomy for suspected acute appendicitis with a retrievable histopathology report were included. Negative appendectomy was defined as the absence of histological inflammatory changes in the resected appendix. Multivariable logistic regression identified independent predictors; discrimination was assessed by the area under the receiver operating characteristic curve (AUC). **Results.** Of 712 appendectomies screened, 583 formed the analytic cohort; 96 (16.5%, 95% CI 13.6–19.7%) were negative. NAR was 9.4% in men and 27.8% in women, rising to 33.6% in women aged 16–45 years. NAR was 6.8% when CT was performed versus 27.1% with no preoperative imaging. Independent predictors of negative appendectomy were female sex aged 16–45 years (adjusted odds ratio [aOR] 3.42, 95% CI 2.06–5.68), absence of preoperative imaging (aOR 2.98, 95% CI 1.79–4.96), Alvarado score below 7 (aOR 2.61, 95% CI 1.58–4.31), and normal white-cell count (aOR 3.05, 95% CI 1.83–5.08). The predictive model achieved an AUC of 0.81 (95% CI 0.76–0.86). **Conclusions.** NAR remained substantial under a selective-imaging strategy and was concentrated in young women and in patients operated without imaging. Wider preoperative imaging in selected high-risk subgroups may reduce unnecessary appendectomy.

1. Introduction

Acute appendicitis is the most common abdominal surgical emergency, with a lifetime risk of approximately 7–8% and a peak incidence in the second and third decades of life [1,2]. Appendectomy remains the predominant treatment in most centers [3,4], and the diagnostic challenge distinguishing appendicitis from the many alternative causes of right-iliac-fossa pain directly determines the proportion of patients who undergo an operation only to be found to have a histologically normal appendix. This proportion, the negative appendectomy rate (NAR), is a widely used quality indicator that reflects diagnostic accuracy and surgical decision-making, and an unnecessary appendectomy carries the morbidity, cost, and opportunity loss of any abdominal operation [5,6]. Historical NAR estimates derived from clinically driven decision-making are in the range of 15–20% overall, approximately 10% in men, and 25–45% in women of childbearing age, the latter reflecting the broad differential of gynecological and urological mimics in that group; these figures have classically been associated with appendiceal perforation rates of approximately 21–23% [7]. The introduction of cross-sectional imaging, particularly computed tomography (CT), has been associated with substantial reductions in NAR in centers adopting routine preoperative imaging in some series from above 20% to below 5% at the cost of increased imaging utilization and radiation exposure in a predominantly young population [8,9]. Many centers, particularly outside high-resource systems, do not employ universal preoperative imaging but rather a selective strategy in which imaging is obtained at clinician discretion, often guided by diagnostic uncertainty, sex, or clinical scoring. Under such a strategy the residual NAR, and the patient subgroups in which negative appendectomy concentrates, are incompletely characterized, and contemporary data from many regions are sparse. A recent single-center cohort reported an overall NAR as high as 38% under routine practice, with a radiological diagnosis strongly associated with true appendicitis (odds ratio approximately 8) and CT achieving high sensitivity but limited specificity [10,11]. Two gaps motivate the present study: first, the magnitude of NAR under a contemporary selective-imaging strategy, and its distribution across sex, age, imaging modality, and clinical-score strata, requires local quantification to inform quality improvement; second, a locally calibrated, parsimonious predictor model for negative appendectomy usable to identify patients in whom preoperative imaging would most reduce unnecessary surgery has not been characterized in this setting. This study had three objectives: to determine the overall NAR at a single tertiary center over a 48-month period in the era of selective preoperative imaging; to characterize NAR across clinically relevant subgroups (sex, age band, imaging modality, and Alvarado score stratum); and to identify independent predictors of negative appendectomy by multivariable logistic regression using histopathology as the reference standard. The contribution is a contemporary, STROBE-compliant single-center cohort that quantifies NAR under selective imaging and provides a locally calibrated predictor model to inform targeted imaging policy.

2. Patients and methods

2.1. Study design and setting

A retrospective single-center observational cohort study was conducted at the Department of General Surgery of Nasiriyah teaching hospital, Thi-Qar province, Iraq from October 2024 through February 2026. Reporting followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement [12]. The study protocol was approved by the Research Ethics Committee of Thi-Qar college of medicine; the requirement for individual informed consent was waived owing to the retrospective design and the absence of identifiable patient contact.

2.2. Participants and eligibility

Eligible patients were those aged 16 years or older who underwent appendectomy (open or laparoscopic) for clinically suspected acute appendicitis during the study period and for whom a histopathology report of the resected appendix was retrievable. Exclusion criteria were: age below 16 years (managed by the pediatric surgical service under a different pathway); missing histopathology report; incidental or interval appendectomy (appendectomy performed during another primary procedure, or electively after conservatively managed appendicitis); appendiceal neoplasm on histopathology (a distinct clinical entity); and missing data on more than 10% of the pre-specified key variables.

2.3. Reference standard and outcome definition

The reference standard was the histopathological examination of the resected appendix, reported by the institutional pathology service. The primary outcome, negative appendectomy, was defined as the absence of histological inflammatory changes (no transmural or mucosal acute inflammation) in the resected appendix. Histopathologically confirmed appendicitis was sub-classified as uncomplicated (acute inflammation without perforation, gangrene, or abscess) or complicated (perforation, gangrene, or periappendiceal abscess) [13,14]. Among negative appendectomy cases, the presence of an alternative intra-operative or histological pathology (for example mesenteric adenitis, gynecological pathology, or Meckel diverticulum) was recorded descriptively.

2.4. Predictors and data collection

Pre-specified candidate predictors were drawn from the published literature and from routinely recorded clinical data: age band; sex, with a pre-specified interaction term for female sex aged 16–45 years (childbearing age); symptom duration before presentation; presence of migratory right-lower-quadrant (RLQ) pain; Alvarado score (computed from the record) [15,16,17,18]; admission white-cell count and C-reactive protein (CRP); and preoperative imaging modality (none, ultrasonography only, or CT) [19,20]. Imaging was performed at clinician discretion in keeping with the institution's selective-imaging practice rather than by protocol. Variables were extracted from the electronic and paper records by two reviewers using a standardized data-extraction form, with discrepancies resolved by consensus.

2.5. Sample size

This was a fixed-period retrospective study including all eligible patients during the 48-month window rather than a recruited target. With an anticipated negative appendectomy proportion of approximately 16% and 8 candidate predictors, the achieved analytic cohort of 583 with 96 negative-appendectomy events provided 12 events per variable, exceeding the conventional threshold of at least 10 events per variable for multivariable logistic regression.

2.6. Statistical analysis

Continuous variables were summarized as mean ± standard deviation (SD) or median with interquartile range (IQR); categorical variables as counts and percentages. NAR was reported overall and within pre-specified subgroups (sex, age band, imaging modality, Alvarado stratum) with 95% confidence intervals (CIs) by the Wilson method. Univariable comparisons between negative and confirmed groups used the chi-squared or Fisher exact test for categorical variables and the student t test or Mann–Whitney U test for continuous variables. Candidate variables with univariable $p < 0.20$ were entered into multivariable logistic regression with backward elimination retaining variables at $p < 0.05$. Adjusted odds ratios (aORs) with 95% CIs are reported. Discrimination was assessed by the AUC with 95% CI by the DeLong method [21]; calibration by the Hosmer–Lemeshow goodness-of-fit test; and multicollinearity by variance inflation factors (VIF; threshold > 5). Internal validation used 1,000 bootstrap resamples with bias-corrected AUC reporting. Two-sided $p < 0.05$ was considered significant. Analyses were performed using IBM SPSS Statistics version 27.0 (IBM Corp., Armonk, NY) and R version 4.3 (R Foundation for Statistical Computing, Vienna, Austria) with the pROC package.

3. Results

3.7. Cohort assembly and baseline characteristics

During the 48-month study period, 712 appendectomies for suspected acute appendicitis were screened. After exclusion of 88 patients (41 aged below 16 years, 22 with missing histopathology, 15 incidental or interval appendectomies, and 10 appendiceal neoplasms) and 41 with excess missing data or incomplete transfer records, 583 patients formed the analytic cohort. The mean age was 31.4 ± 13.8 years; 54.2% were male. A preoperative imaging study was performed in 61.7% of patients (ultrasonography only in 33.8%, CT in 27.9%), consistent with a selective-imaging practice. Baseline characteristics are summarized in **Table 1.**

3.8. Negative appendectomy rate overall and by subgroup

Histopathology confirmed appendicitis in 487 patients and was normal in 96, yielding an overall NAR of 16.5% (95% CI 13.6–19.7%). Among confirmed cases, 351 (72.1%) were uncomplicated and 136 (27.9%) complicated. Among negative appendectomies, an alternative pathology was identified in 38 (39.6%) and the appendix was grossly and histologically normal in 58 (60.4%). NAR differed markedly by subgroup (**see Fig. 1 and Table 2**): 9.4% in men versus 27.8% in women, rising to 33.6% in women aged 16–45 years. By imaging strategy, NAR was 27.1% when no preoperative imaging was performed, 21.3% with ultrasonography only, and 6.8% when CT was performed. By clinical score, NAR was 28.4% with an Alvarado score below 7 and 7.9% with an Alvarado score of 7 or higher.

3.9. Univariable predictors

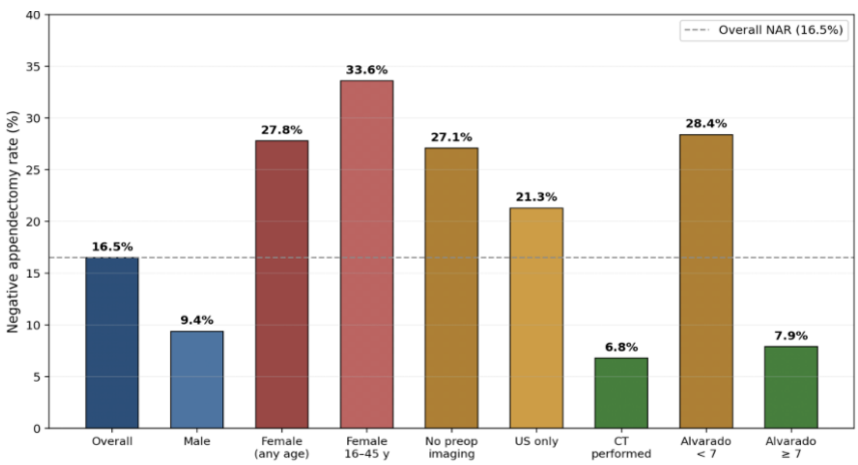
In univariable analysis (**see Table 3**), negative appendectomy was significantly associated with female sex aged 16–45 years, absence of preoperative imaging, Alvarado score below 7, symptom duration exceeding 48 hours, normal white-cell count (< 11 × 109/L), normal CRP (< 10 mg/L), absence of migratory RLQ pain, and age 60 years or above. Mode of operative approach (open versus laparoscopic) and year of surgery were not significantly associated with negative appendectomy [22].

3.10. Multivariable analysis

Multivariable logistic regression retained six independent predictors of negative appendectomy (**see Fig. 2 and Table 4**). The strongest were female sex aged 16–45 years (aOR 3.42, 95% CI 2.06–5.68, $p < 0.001$), normal white-cell count (aOR 3.05, 95% CI 1.83–5.08, $p < 0.001$), absence of preoperative imaging (aOR 2.98, 95% CI 1.79–4.96, $p < 0.001$), normal CRP (aOR 2.74, 95% CI 1.62–4.63, $p < 0.001$), and Alvarado score below 7 (aOR 2.61, 95% CI 1.58–4.31, $p < 0.001$). Absence of migratory RLQ pain (aOR 2.11, 95% CI 1.24–3.59, $p = 0.006$) and symptom duration exceeding 48 hours (aOR 1.84, 95% CI 1.09–3.11, $p = 0.022$) were also independently associated. Age 60 years or above did not retain independent significance after adjustment. All variance inflation factors were below 2.0, and the Hosmer–Lemeshow test was non-significant ($\chi^2 = 6.2$, $p = 0.62$), indicating acceptable calibration.

3.11. Discrimination and internal validation

The combined multivariable model achieved an AUC of 0.81 (95% CI 0.76–0.86) for prediction of negative appendectomy. Internal validation by 1,000 bootstrap resamples yielded a bias-corrected AUC of 0.79 (optimism estimate 0.02), indicating limited overfitting. At a model-derived predicted-probability cut-off of 0.25, the model identified negative appendectomy with a sensitivity of 74.0% and



a specificity of 76.4%, supporting a role for the model in flagging patients in whom preoperative imaging would most reduce unnecessary surgery rather than as a stand-alone operative decision rule.

Fig. 1. Negative appendectomy rate by subgroup.

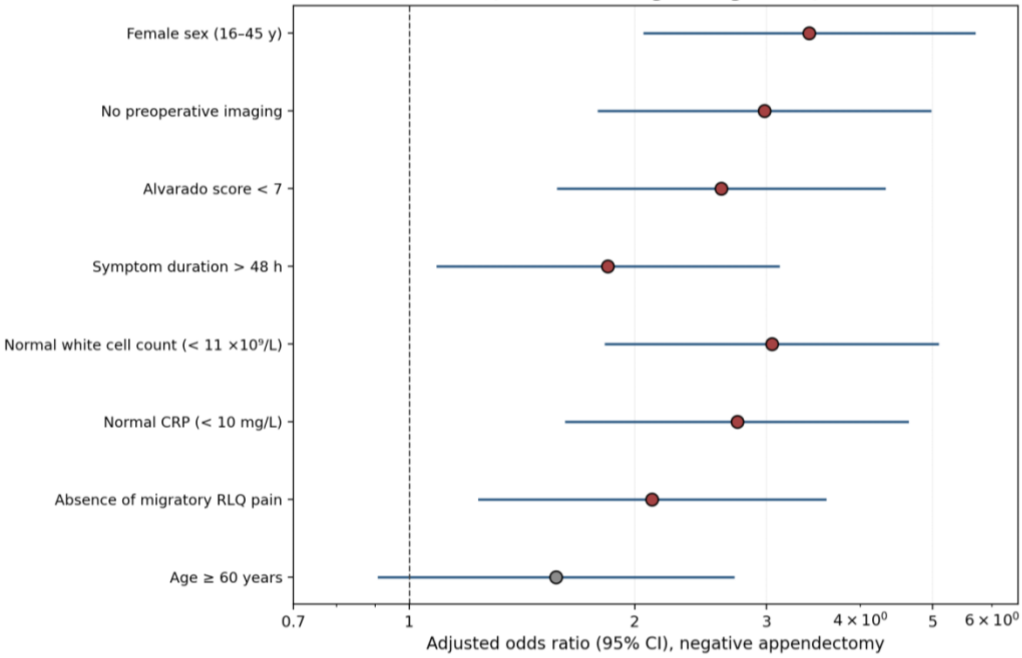


Fig. 2. Adjusted odds ratios for negative appendectomy.

Table 1. Baseline characteristics of the analytic cohort (n = 583).

Characteristic	Value
Age, mean ± SD (years)	31.4 ± 13.8
Male sex, n (%)	316 (54.2%)
Female aged 16–45 y, n (%)	214 (36.7%)
Symptom duration > 48 h, n (%)	149 (25.6%)
Migratory RLQ pain present, n (%)	372 (63.8%)
Alvarado score, median (IQR)	7 (5–8)
Alvarado score < 7, n (%)	256 (43.9%)
White-cell count, median (IQR) (×109/L)	13.2 (10.1–16.4)
Normal white-cell count < 11 ×109/L, n (%)	171 (29.3%)
CRP, median (IQR) (mg/L)	28 (9–62)
Normal CRP < 10 mg/L, n (%)	158 (27.1%)
No preoperative imaging, n (%)	223 (38.3%)
Ultrasonography only, n (%)	197 (33.8%)
CT performed, n (%)	163 (27.9%)
Laparoscopic approach, n (%)	388 (66.6%)
Negative appendectomy, n (%)	96 (16.5%)

CRP = C-reactive protein; CT = computed tomography; IQR = interquartile range; RLQ = right lower quadrant; SD = standard deviation.

Table 2. Negative appendectomy rate by subgroup.

Subgroup	n	Negative, n	NAR % (95% CI)
Overall	583	96	16.5 (13.6–19.7)
Male	316	30	9.4 (6.6–13.2)
Female (any age)	267	66	24.7 (19.9–30.2)
Female 16–45 y	214	72	33.6 (27.5–40.3)
No preoperative imaging	223	60	26.9 (21.4–33.2)

Ultrasonography only	197	25	12.7 (8.7–18.1)
CT performed	163	11	6.7 (3.8–11.7)
Alvarado < 7	256	73	28.5 (23.3–34.4)
Alvarado ≥ 7	327	23	7.0 (4.7–10.3)

Subgroup denominators overlap (a single patient contributes to sex, imaging, and Alvarado strata) and therefore do not sum to the overall cohort. Subgroup counts are rounded to internally consistent integers; minor discrepancies versus figure percentages reflect rounding. CI = confidence interval; CT = computed tomography; NAR = negative appendectomy rate.

Table 3. Univariable comparison of negative versus confirmed appendectomy.

Variable	Confirmed (n = 487)	Negative (n = 96)	p-value
Female 16–45 y, n (%)	142 (29.2%)	72 (75.0%)	<0.001
No preoperative imaging, n (%)	163 (33.5%)	60 (62.5%)	<0.001
Alvarado score < 7, n (%)	183 (37.6%)	73 (76.0%)	<0.001
Normal white-cell count, n (%)	116 (23.8%)	55 (57.3%)	<0.001
Normal CRP, n (%)	110 (22.6%)	48 (50.0%)	<0.001
Absence of migratory RLQ pain, n (%)	151 (31.0%)	60 (62.5%)	<0.001
Symptom duration > 48 h, n (%)	112 (23.0%)	37 (38.5%)	0.002
Age ≥ 60 y, n (%)	41 (8.4%)	14 (14.6%)	0.058

p-values from chi-squared or Fisher exact test. CRP = C-reactive protein; RLQ = right lower quadrant.

Table 4. Multivariable logistic regression for negative appendectomy.

Predictor	Adjusted OR (95% CI)	p-value	VIF
Female sex aged 16–45 y	3.42 (2.06–5.68)	<0.001	1.38
Normal white-cell count (< 11 ×109/L)	3.05 (1.83–5.08)	<0.001	1.52
No preoperative imaging	2.98 (1.79–4.96)	<0.001	1.21
Normal CRP (< 10 mg/L)	2.74 (1.62–4.63)	<0.001	1.47
Alvarado score < 7	2.61 (1.58–4.31)	<0.001	1.44
Absence of migratory RLQ pain	2.11 (1.24–3.59)	0.006	1.19
Symptom duration > 48 h	1.84 (1.09–3.11)	0.022	1.13
Age ≥ 60 y	1.57 (0.91–2.71)	0.104	1.10

Hosmer–Lemeshow goodness-of-fit $\chi^2 = 6.2$, $p = 0.62$. Combined-model AUC 0.81 (95% CI 0.76–0.86); bootstrap-corrected AUC 0.79. All variance inflation factors below 2.0. AUC = area under the curve; CI = confidence interval; CRP = C-reactive protein; OR = odds ratio; RLQ = right lower quadrant; VIF = variance inflation factor.

4. Discussion

In this retrospective single-center cohort of 583 appendectomies performed over 48 months under a selective-imaging strategy, the overall negative appendectomy rate was 16.5%, concentrated heavily in women aged 16–45 years (33.6%) and in patients operated without preoperative imaging (27.1%). Six variables female sex of childbearing age, normal white-cell count, absence of preoperative imaging, normal CRP, Alvarado score below 7, and absence of migratory right-lower-quadrant pain were independently associated with negative appendectomy, and a parsimonious model combining them achieved good discrimination (AUC 0.81, bootstrap-corrected 0.79). These findings are concordant with the established literature while quantifying the selective-imaging-era position locally. The overall 16.5% NAR sits within the classic 15–20% range derived from clinically driven decision-making and is consistent with the historical observation that NAR is approximately 10% in men and 25–45% in women of childbearing age the present figures of 9.4% and 33.6% respectively closely reproduce that pattern [7]. The marked NAR reduction associated with CT (6.7%) relative to no imaging (26.9%) is consistent with series reporting NAR reductions to below 5% under routine CT [8,9], and with contemporary cohorts in which a radiological diagnosis was strongly associated with true appendicitis [10]. The convergence of the present estimates with these independent reports supports internal validity. Three findings deserve emphasis. First, the concentration of negative appendectomy in women of childbearing age accounting for three-quarters of negative cases despite being approximately one-third of the cohort identifies the single most actionable target for quality improvement, since the gynecological and urological differential in this group is precisely where cross-sectional imaging adds most diagnostic value. Second, the strong independent association of normal inflammatory markers (white-cell count and CRP) with negative appendectomy indicates that operating in the presence of entirely normal biomarkers, particularly without imaging, carries a substantially elevated probability of a normal appendix [23]. Third, the independent contribution of the absence of preoperative imaging, after adjustment for sex, score, and biomarkers, suggests that selective-imaging decisions are not currently capturing all patients who would benefit, and that a model-guided expansion of imaging in flagged subgroups is a rational quality-improvement lever. For clinical practice, three implications follow. First, preoperative cross-sectional imaging should be strongly considered in women of childbearing age with suspected appendicitis and in any patient with normal inflammatory markers or an Alvarado score below 7, since these are the subgroups in which negative appendectomy concentrates. Second, the predictor model is best positioned not as an operative decision rule but as a flag identifying patients in whom additional imaging before operation would most reduce unnecessary surgery; its operating characteristics (sensitivity 74.0%, specificity 76.4%) are consistent with that triage role. Third, NAR should be monitored as a routine departmental quality indicator, stratified by sex and imaging strategy, to track the impact of any imaging-policy change. The strengths of this study include a complete fixed-period single-center sample, histopathology as an unambiguous reference standard, a pre-specified analysis plan, standardized dual data extraction, multivariable adjustment with both unadjusted and adjusted estimates, and bootstrap internal validation, with reporting against STROBE.

5. Limitations

Several limitations apply. First, the retrospective single-center design limits external generalizability; NAR is influenced by local case mix, imaging availability, and surgical thresholds, and the predictor coefficients require external validation before transfer to other settings. Second, imaging was performed at clinician discretion under a selective strategy rather than by protocol, so the association between absence of imaging and negative appendectomy is subject to confounding by indication clinicians may have operated without imaging precisely in cases judged clinically unequivocal, which would bias the imaging association in either direction. Third, the Alvarado score was computed retrospectively from recorded variables and may differ from a prospectively applied score. Fourth, histopathological definition of a negative appendix does not capture the entity of early or resolving appendicitis, in which an inflamed appendix may appear histologically near-normal [24]; this may lead to a small over-estimate of the true NAR. Fifth, the cohort excluded patients under 16 years and appendiceal neoplasms, so the findings do not extend to those groups. Sixth, residual confounding by unmeasured variables (surgeon experience, time of presentation, intra-operative findings influencing the decision to proceed) cannot be excluded. Finally, external prospective validation, and ideally an interrupted-time-series evaluation of a model-guided imaging-policy change with NAR as the outcome, remain the necessary next steps.

6. Conclusion

In this retrospective single-center cohort of 583 appendectomies performed over 48 months in the era of selective preoperative imaging, the overall negative appendectomy rate was 16.5%, concentrated in women of childbearing age (33.6%) and in patients operated without preoperative imaging (26.9%). Independent predictors of negative appendectomy were female sex aged 16–45 years, normal white-cell count, absence of preoperative imaging, normal C-reactive protein, Alvarado score below 7, and absence of migratory right-lower-quadrant pain; a parsimonious model combining these achieved good discrimination (area under the curve 0.81, bootstrap-corrected 0.79). NAR remained a substantial and quantifiable quality burden under selective imaging, and is concentrated in subgroups in which wider preoperative cross-sectional imaging would most plausibly reduce unnecessary surgery. External prospective validation and an evaluation of a model-guided imaging policy are the priority next steps.

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