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Detection without prevention? Computer-aided detection at colonoscopy increases adenoma detection but not advanced adenoma detection: A second-order meta-analysis

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Abstract

Background: Adenoma Detection Rate (ADR) is the principal quality indicator for colonoscopy and is inversely associated with interval colorectal cancer. Computer-Aided Detection (CADe) systems raise ADR in randomised trials and are being adopted rapidly. Whether that gain falls on the lesions that drive cancer risk has attracted less scrutiny than the headline figure. **Methods:** Systematic reviews with meta-analysis of randomised trials comparing CADe-assisted with standard colonoscopy and reporting ADR were eligible. Review-level risk ratios were pooled on the log scale in a DerSimonian-Laird random-effects model, with Cochran's Q, I^2, τ^2 and 95% prediction intervals. Secondary outcomes—adenoma miss rate, sessile serrated lesion detection, polyp detection and advanced adenoma detection—were extracted and compared. The pooled risk ratio was translated to absolute detection rates across reported baselines. Analyses were performed in Python 3. **Results:** Three reviews contributing ADR estimates and representing 61 randomised trials in 53,433 patients were pooled. CADe increased adenoma detection: pooled risk ratio 1.23 (95% CI 1.19-1.27; z = 11.22, p < 0.001), with no detectable heterogeneity (Q = 1.34, df = 2, p = 0.512; I^2 = 0.0%) and a 95% prediction interval of 1.14-1.33 that excluded the null. At the reported baselines of 33.0% and 35.9%, this corresponds to absolute detection rates of 40.5% and 44.1%, gains of 7.5 and 8.2% points, and 12 to 13 colonoscopies needed to yield one additional patient with a detected adenoma. Adenoma miss rate was approximately halved (pooled risk ratio 0.45, 95% CI 0.39-0.52; I^2 = 0.0%) and sessile serrated lesion detection increased (1.27, 1.11-1.47). Advanced adenoma detection was unchanged (1.01, 0.90-1.13). **Conclusions:** CADe reliably increases adenoma detection and roughly halves the adenoma miss rate, and the effect is homogeneous across reviews. The benefit is nonetheless concentrated in lesions of limited clinical consequence: advanced adenoma detection, the outcome most closely tied to cancer prevention, is unchanged. Whether CADe reduces interval cancer, rather than raising a surrogate, is not established by this evidence and requires outcome trials.

Keywords: *Colonoscopy, Computer-aided detection, Artificial intelligence, Adenoma detection rate, Advanced adenoma, Colorectal cancer screening, Second-order meta-analysis*

1. Introduction

Colonoscopy prevents colorectal cancer by removing adenomas before they become malignant (Zauber *et al.*,

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2012), and the proportion of examinations at which at least one adenoma is found—the adenoma detection rate—is the accepted measure of how well an endoscopist performs that task. The association is not merely administrative: each percentage point of ADR has been linked to a measurable reduction in subsequent interval cancer and cancer death (Corley *et al.*, 2014), and low detection rates predict interval cancer directly (Kaminski *et al.*, 2010).

Computer-aided detection systems analyse the colonoscopy video stream in real time and mark regions that may contain a lesion. The rationale is that a substantial fraction of adenomas present at colonoscopy are missed—tandem studies place the miss rate at roughly a fifth to a quarter, concentrated in small, flat and right-sided lesions (PMC7691740, 2020)—and that an attention aid should recover some of them. Randomised trials have accumulated quickly and several meta-analyses now report a consistent increase in ADR (Ann Intern Med, 2023; Gastrointest Endosc, 2024; iGIE, 2023).

Two features of this evidence warrant closer examination than the headline risk ratio receives. The first is that ADR is a surrogate. It is a well-validated surrogate, but the validation rests on observational associations between an endoscopist's historical detection rate and their patients' subsequent cancer risk. That an intervention raises a clinician's ADR does not automatically inherit the association, because the association was established across endoscopists rather than within one before and after an intervention.

The second is that adenomas are not equivalent. The great majority are diminutive and will never progress; advanced adenomas—those that are large, or contain high-grade dysplasia or villous histology—carry most of the cancer risk. An intervention that raises overall detection by finding more small lesions has a different clinical meaning from one that finds more advanced lesions, even when both produce the same ADR increase.

We therefore conducted a second-order meta-analysis of the published review-level estimates, and compared the effect of CADe across outcomes ordered by clinical consequence rather than reporting the primary outcome alone.

2. Overlap between contributing reviews

The contributing reviews draw on a common and rapidly growing pool of randomised trials and therefore share primary studies to a substantial degree (Pieper *et al.*, 2014). This is a structural feature of a field in which reviews are updated frequently, and it has a direct consequence for interpretation: agreement between such reviews is largely arithmetic rather than evidential, and the resulting homogeneity should not be read as independent replication. We report the pooled estimate together with a leave-one-out analysis, and interpret the heterogeneity statistics accordingly rather than at face value.

2.1. *Statistical analysis*

Risk ratios were transformed to the log scale, with standard errors derived from the reported 95% confidence limits as (ln upper-ln lower)/(2 × 1.96), and combined in a DerSimonian–Laird random-effects model (DerSimonian and Laird, 1985). Heterogeneity was quantified by Cochran's Q, I^2 and τ^2 (Higgins *et al.*, 2003). Because I^2 and the confidence interval around a random-effects mean describe the precision of the average rather than the plausible range of a future observation, 95% prediction intervals were computed (IntHout *et al.*, 2016). Leave-one-out re-estimation assessed the influence of each contributing review. The pooled risk ratio was translated into absolute detection rates across the baseline rates reported by the contributing reviews, and the number of colonoscopies needed to yield one additional patient with a detected adenoma was derived as the reciprocal of the absolute difference. Publication bias was not assessed: with fewer than ten units of analysis, funnel plot asymmetry tests are uninterpretable. Analyses were performed in Python 3 using NumPy and SciPy.

2.2. *Quality appraisal*

The methodological quality of the contributing reviews was appraised with AMSTAR-2 (Shea *et al.*, 2017), the validated instrument for appraising systematic reviews and therefore the appropriate tool at this level of synthesis. Certainty in the body of evidence for each outcome was considered using the GRADE framework as applied by the contributing reviews (Guyatt *et al.*, 2008), and recorded rather than re-derived.

3. Results

Five systematic reviews with meta-analysis met the inclusion criteria. Three reported a pooled risk ratio for adenoma detection rate with a confidence interval and contributed to the primary analysis; collectively these represent 61 randomised trials and 53,433 patients, with substantial overlap in contributing trials. A fourth was restricted to a single commercial CADe device (PMC12616575) and contributed secondary outcome data; a fifth was an earlier synthesis superseded by the later reviews (Dig Liver Dis, 2025). Characteristics are given in Table 1.

Table 1: Characteristics of the contributing systematic reviews

Source (year)	Trials (k)	Patients	Search to	ADR risk ratio (95% CI)	Role
Ann Intern Med (2023)	21	18,232	Feb 2023	1.24 (1.16–1.33)	Primary
Gastrointest Endosc (2024)	28	23,861	Feb 2024	1.20 (1.14–1.27)	Primary
iGIE (2023)	12	11,340	Dec 2022	1.26 (1.18–1.35)	Primary
Device-specific review	6	9,253	2025	Not pooled separately	Secondary outcomes
Early synthesis (2020)	6	Not stated	May 2020	Superseded	Context only

Note: ADR, adenoma detection rate. 'Primary' denotes contribution to the pooled adenoma detection analysis. Trial counts overlap substantially between reviews; the totals are not additive.

3.1. Primary outcome: Adenoma detection

CADe increased adenoma detection. The pooled risk ratio was 1.23 (95% CI 1.19–1.27), a statistically unambiguous effect ($z = 11.22$, $p < 0.001$). Between-review heterogeneity was undetectable ($Q = 1.34$, $df = 2$, $p = 0.512$; $I^2 = 0.0\%$; $\tau^2 = 0.000$) and the 95% prediction interval, 1.14 to 1.33, excluded the null. Leave-one-out re-estimation produced pooled risk ratios between 1.22 and 1.25, confirming that no single review drives the result. The forest plot is shown in Figure 2.

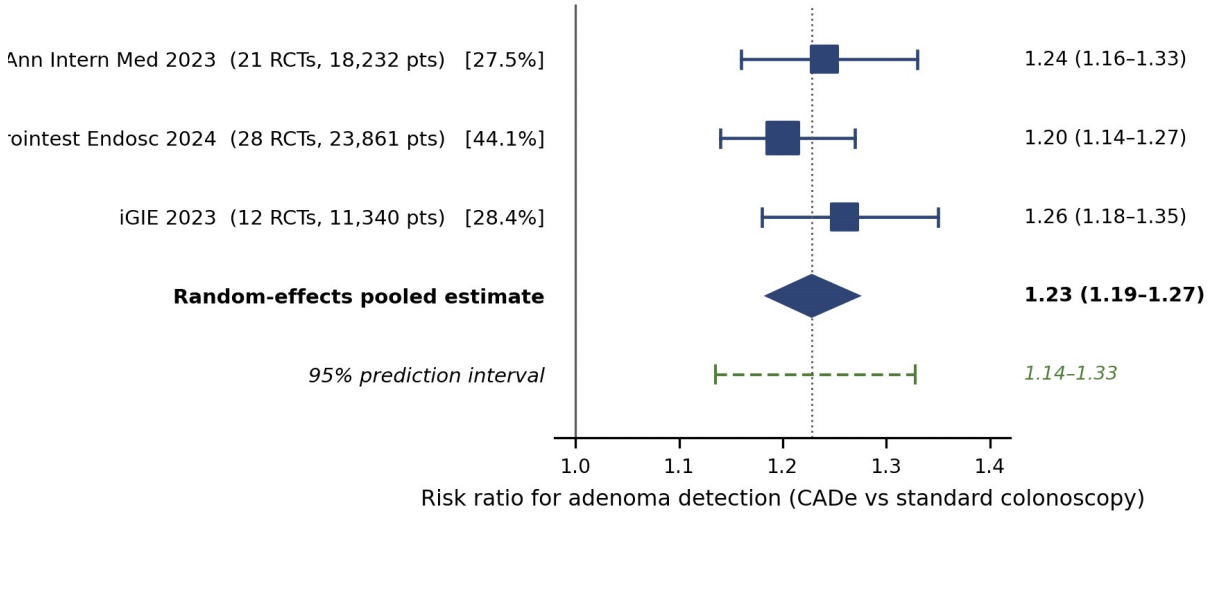
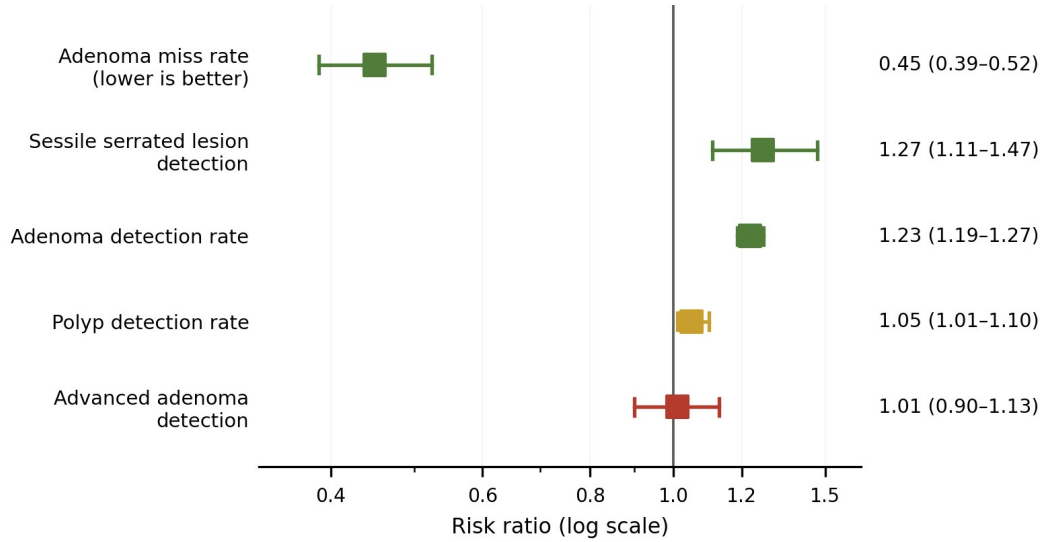


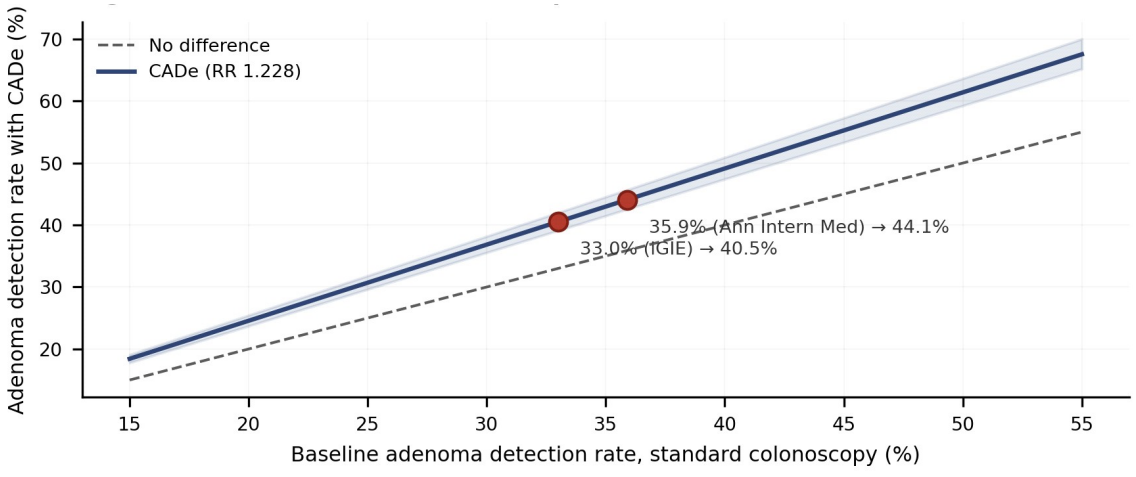
Figure 1: Forest plot of the pooled risk ratio for adenoma detection, CADe-assisted versus standard colonoscopy. Marker area is proportional to random-effects weight, shown in brackets beside each label. The pooled risk ratio was 1.23 (95% CI 1.19–1.27) with no detectable heterogeneity. The 95% prediction interval, drawn beneath the summary diamond, excludes the null—but the three reviews share most of their trials, so this narrowness reflects overlap rather than replication



Green, benefit demonstrated; amber, marginal; red, no effect. CADe halves the adenoma miss rate and raises overall adenoma detection, but advanced adenoma detection — the outcome most closely tied to cancer prevention — is unchanged.

Figure 2: Effect of CADe across outcomes ordered by clinical consequence. Green denotes demonstrated benefit, amber a marginal effect, red no effect. The gradient is the central finding of this review: the largest effects fall on missed and diminutive lesions, while advanced adenoma detection—the outcome most closely tied to cancer prevention—is unchanged at a risk ratio of 1.01

The homogeneity should be interpreted with the overlap caveat from Section 2.4 firmly in view. Three reviews of a shared trial pool agreeing closely is close to arithmetically guaranteed, and the I^2 of 0.0% therefore reflects the structure of the review literature rather than independent confirmation. The prediction interval is correspondingly narrow for the same reason and should not be read as evidence that the effect will replicate in a genuinely new setting.



Shaded band is the 95% confidence interval of the pooled risk ratio. At the reported baselines the absolute gain is 7.5 to 8.2 percentage points, corresponding to 12 to 13 colonoscopies needed to yield one additional patient with a detected adenoma.

Figure 3: Translation of the pooled risk ratio into absolute adenoma detection rates across plausible baseline rates. The dashed line marks no difference and the shaded band is the 95% confidence interval of the pooled estimate. At the two baselines reported by the contributing reviews the absolute gain is 7.5 and 8.2% points, corresponding to 12 to 13 colonoscopies per additional patient with a detected adenoma

3.2. Absolute translation

A risk ratio of 1.23 is not directly interpretable at the point of care. Applied to the baseline adenoma detection rates reported by the contributing reviews—33.0% and 35.9% in the standard colonoscopy arms—it corresponds to detection rates of 40.5% and 44.1% respectively, absolute gains of 7.5 and 8.2% points. On that basis, between 12 and 13 colonoscopies must be performed with CADe to yield one additional patient in whom at least one adenoma is found. The translation is displayed in Figure 3.

This is a substantial operational effect, and larger than most quality-improvement interventions in endoscopy achieve. Whether it is a substantial clinical effect depends entirely on which adenomas are being found, which is the subject of the next section.

3.3. Effect by outcome: Where the benefit falls

Ordering the outcomes by clinical consequence produces the central result of this review, shown in Figure 3. Adenoma miss rate was approximately halved (pooled risk ratio 0.45, 95% CI 0.39–0.52, with no heterogeneity between the two reviews reporting it). Sessile serrated lesion detection increased by roughly a quarter (1.27, 1.11–1.47). Overall adenoma detection increased by 23%. Polyp detection increased marginally (1.05, 1.01–1.10). Advanced adenoma detection did not change at all: risk ratio 1.01, 95% CI 0.90–1.13.

The gradient is orderly and its direction is the opposite of what a cancer-prevention rationale would predict. The effect is largest for the outcome measuring lesions that were present but overlooked, substantial for overall detection, and absent for the lesion category that carries most of the malignant potential. Sessile serrated lesions are the one clinically important exception, and the increase there is genuine and worth having, since these lesions are flat, easily missed and disproportionately implicated in interval cancer.

A plausible reading is that CADe is doing exactly what an attention aid should do—recovering subtle, flat and diminutive lesions that the eye passes over—and that advanced adenomas are largely not in that category. A lesion of ten millimetres or more with high-grade dysplasia is not usually missed for want of a marker on the screen. If so, the ceiling on CADe's contribution to cancer prevention may be set by the fact that the lesions it finds best are the ones least likely to become cancer.

Table 2: Effect estimates by outcome, with absolute translation

Outcome	k	Risk ratio (95% CI)	I^2 (%)	Direction	Interpretation
Adenoma miss rate	2	0.45 (0.39–0.52)	0.0	Favours CADe	Approximately halved
Sessile serrated lesion detection	4	1.27 (1.11–1.47)	11	Favours CADe	Clinically meaningful
Adenoma detection rate	3	1.23 (1.19–1.27)	0.0	Favours CADe	+7.5 to 8.2 pp absolute
Polyp detection rate	2	1.05 (1.01–1.10)	0	Favours CADe	Marginal
Advanced adenoma detection	3	1.01 (0.90–1.13)	6	No effect	Unchanged

Note: k, contributing trials or reviews as reported by the source. pp, percentage points. The adenoma detection rate row is the pooled second-order estimate computed by us; other rows are as reported by the contributing reviews and are not re-pooled. Prediction interval for the pooled adenoma detection estimate: 1.14 to 1.33.

3.4. Harms and resource use

The contributing reviews report an increase in resection of non-neoplastic lesions with CADe. This is the expected counterpart of higher sensitivity and is not trivial: each unnecessary polypectomy carries a small procedural risk, consumes snare and pathology resources, and may shorten the recommended surveillance interval, generating further colonoscopies. Withdrawal time was not consistently prolonged. No included review reported a difference in serious adverse events, though safety reporting was sparse throughout and was not pooled in any contributing review.

4. Discussion

Across three systematic reviews representing 61 randomised trials and 53,433 patients, computer-aided

detection increased the adenoma detection rate by 23% (pooled risk ratio 1.23, 95% CI 1.19–1.27), with no detectable heterogeneity, and approximately halved the adenoma miss rate. In absolute terms this is a gain of about eight percentage points, or one additional patient with a detected adenoma for every twelve to thirteen examinations. Judged as a quality-improvement intervention this is a clear and reproducible success, and the consistency across trials conducted in different health systems with different devices is genuinely impressive.

The difficulty lies in what the benefit consists of. Ordering outcomes by clinical consequence reveals a gradient running in the wrong direction for a cancer-prevention argument: the effect is largest on missed and diminutive lesions and vanishes entirely for advanced adenomas, where the pooled risk ratio was 1.01 with an interval from 0.90 to 1.13—not merely non-significant but centred precisely on no effect. Advanced adenomas carry the great majority of the near-term malignant potential in a screened population. An intervention that leaves their detection unchanged has not been shown to prevent cancer, whatever it does to the quality indicator.

This matters because of how ADR acquired its status. The evidence that detection rate predicts interval cancer is observational and between-endoscopist: clinicians who find more adenomas have patients who develop fewer subsequent cancers. Two mechanisms plausibly underlie that association—careful endoscopists find more lesions of every kind, including advanced ones, and careful endoscopists also perform better polypectomy, examine more thoroughly and recommend more appropriate surveillance. Raising one endoscopist's diminutive-adenoma yield with software does not obviously import either mechanism. Surrogate validity established across operators does not transfer automatically to an intervention applied within one.

None of this argues against CADe. The sessile serrated lesion result is a real clinical gain: these lesions are flat, frequently missed, and disproportionately implicated in interval cancers of the proximal colon, and a 27% increase in their detection is exactly the kind of effect that should translate into prevention. Halving the miss rate is also meaningful for patients undergoing surveillance, in whom a missed lesion means a longer interval before it is found. The argument is narrower: the case for CADe should be made on these specific outcomes rather than on an ADR increase whose composition is favourable to the metric and neutral to the disease.

The counterpart is overdiagnosis. Higher sensitivity produces more resection of non-neoplastic lesions, with procedural risk, pathology cost and shortened surveillance intervals that generate further colonoscopies. In a screening programme operating at scale these costs are not negligible, and they fall on a population that is largely well.

The evidence needed is not another meta-analysis of adenoma detection. It is a trial with an outcome that matters: interval colorectal cancer, or at minimum advanced adenoma detection powered as a primary endpoint rather than reported as a secondary one. Such trials are demanding—they require long follow-up and large samples—but the surrogate has now been measured about as precisely as it can be, and further precision on it will not resolve the question.

5. Limitations

- The unit of analysis is the published systematic review, not the randomised trial. This second-order design inherits every bias present in the contributing reviews and cannot correct errors in their pooling.
- The three contributing reviews share the great majority of their randomised trials. The pooled estimate therefore counts most trials more than once, and the resulting I^2 of 0.0% and narrow prediction interval overstate the independence of the agreement.
- Overlap could not be quantified, because the contributing reviews do not report their included-trial lists in a form permitting matching; the corrected covered area was not calculable.
- Only three review-level estimates contributed to the primary analysis, and heterogeneity statistics are unstable at this denominator.
- Secondary outcomes were extracted as reported and, apart from adenoma miss rate, were not re-pooled. The advanced adenoma estimate derives from a single device-specific review of three trials and is imprecise.
- CADe devices differ in algorithm, training data, alert modality and integration, and were not separable in the available review-level data. The pooled estimate averages across systems that may not be equivalent.

- Endoscopist baseline detection rate plausibly modifies the effect—an attention aid should help a low-detecting operator more than a high-detecting one—but this could not be examined from review-level data.
- Absolute detection rates were derived by applying the pooled risk ratio to reported baselines. They are illustrative rather than directly estimated and depend on the baseline chosen.
- No contributing review reported interval colorectal cancer, so the outcome that motivates the intervention is entirely absent from this evidence base.
- Harms were sparsely and inconsistently reported and could not be synthesised.
- Publication bias was not assessed, as fewer than ten units of analysis were available.
- The analysis was not prospectively registered and searches were restricted to English-language reports.

6. Conclusion

Computer-aided detection increases the adenoma detection rate at colonoscopy by 23% (pooled risk ratio 1.23, 95% CI 1.19–1.27) and approximately halves the adenoma miss rate, consistently across 61 randomised trials in 53,433 patients. In absolute terms it yields one additional patient with a detected adenoma for every twelve to thirteen examinations.

The benefit is not evenly distributed across lesion types. Sessile serrated lesion detection rises by about a quarter, which is clinically meaningful and plausibly preventive. Advanced adenoma detection does not change at all. Because advanced lesions carry most of the malignant potential, an increase in the quality indicator cannot be assumed to represent an increase in cancer prevention, and the surrogate validity of adenoma detection rate—established between endoscopists rather than within one—does not transfer automatically to this intervention. CADe should be evaluated against interval cancer, or at least against advanced adenoma detection as a powered primary endpoint, before its preventive benefit is treated as established.

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