Supplementary Information. Search strategy and search documentation

Search overview

The present spatial review was conducted as a task-specific secondary analysis of the evidence corpus identified in the prospectively registered parent systematic review (PROSPERO CRD420261476860). The parent search was designed to identify artificial-intelligence and machine-learning applications in upper gastrointestinal endoscopy for gastric premalignant lesions and early gastric cancer. No additional database search was performed for the present spatial analysis.

Searches combined four concepts: (1) artificial intelligence and machine learning; (2) upper gastrointestinal endoscopy; (3) gastric or stomach location; and (4) gastric premalignant lesions or early gastric cancer. Controlled vocabulary was used where supported and was combined with title, abstract, keyword, topic, or all-metadata free-text terms. No restrictions were applied by publication year, language, publication type, age, subject category, or open-access status.

PubMed/MEDLINE, Embase.com, Scopus, Web of Science Core Collection, Cochrane Library/CENTRAL, IEEE Xplore, and ClinicalTrials.gov were searched on 6 July 2026. The WHO International Clinical Trials Registry Platform (ICTRP) was searched on 9 July 2026. The exact strategies used and the corresponding retrieval counts are reproduced below.

PubMed/MEDLINE

Platform/fields: PubMed; MeSH and Title/Abstract. Search date: 6 July 2026. Records retrieved: 505. Filters: none.

```
(
 "Artificial Intelligence"[Mesh]
 OR "Machine Learning"[Mesh]
 OR "Deep Learning"[Mesh]
 OR "artificial intelligence"[Title/Abstract]
 OR AI[Title/Abstract]
 OR "machine learning"[Title/Abstract]
 OR "deep learning"[Title/Abstract]
 OR "neural network*"[Title/Abstract]
 OR "convolutional neural network*"[Title/Abstract]
 OR CNN[Title/Abstract]
 OR "computer-aided diagnosis"[Title/Abstract]
 OR "computer-aided detection"[Title/Abstract]
 OR "computer aided diagnosis"[Title/Abstract]
 OR "computer aided detection"[Title/Abstract]
 OR "computer-assisted diagnosis"[Title/Abstract]
 OR "computer-assisted detection"[Title/Abstract]
 OR CADe[Title/Abstract]
 OR CADx[Title/Abstract]
)
AND
(
 "Endoscopy, Gastrointestinal"[Mesh]
 OR "Gastroscopy"[Mesh]
 OR endoscop*[Title/Abstract]
 OR gastroscop*[Title/Abstract]
 OR "upper gastrointestinal endoscopy"[Title/Abstract]
 OR "upper GI endoscopy"[Title/Abstract]
 OR esophagogastroduodenoscopy[Title/Abstract]
 OR EGD[Title/Abstract]
)
AND
(
 "Stomach Neoplasms"[Mesh]
 OR "Precancerous Conditions"[Mesh]
 OR gastric[Title/Abstract]
 OR stomach[Title/Abstract]
)
AND
(
 "early gastric cancer"[Title/Abstract]
 OR "gastric cancer"[Title/Abstract]
 OR "gastric neoplasm*"[Title/Abstract]
 OR "gastric carcinoma"[Title/Abstract]
 OR "gastric tumor*"[Title/Abstract]
 OR "gastric tumour*"[Title/Abstract]
 OR "gastric premalignant lesion*"[Title/Abstract]
 OR "gastric precancerous lesion*"[Title/Abstract]
```

```
 OR "gastric precancerous condition*"[Title/Abstract]
 OR "gastric intestinal metaplasia"[Title/Abstract]
 OR "intestinal metaplasia"[Title/Abstract]
 OR "atrophic gastritis"[Title/Abstract]
 OR "chronic atrophic gastritis"[Title/Abstract]
 OR "gastric dysplasia"[Title/Abstract]
 OR "intraepithelial neoplasia"[Title/Abstract]
)
```

Embase.com

Platform/fields: Embase.com; Emtree plus title/abstract/keyword free text. Search date: 6 July 2026. Records retrieved: 1,476. Filters: none.

```
(
 'artificial intelligence'/exp
 OR 'machine learning'/exp
 OR 'deep learning'/exp
 OR 'artificial intelligence':ti,ab,kw
 OR ai:ti,ab,kw
 OR 'machine learning':ti,ab,kw
 OR 'deep learning':ti,ab,kw
 OR 'neural network*':ti,ab,kw
 OR 'convolutional neural network*':ti,ab,kw
 OR cnn:ti,ab,kw
 OR 'computer-aided diagnosis':ti,ab,kw
 OR 'computer-aided detection':ti,ab,kw
 OR 'computer aided diagnosis':ti,ab,kw
 OR 'computer aided detection':ti,ab,kw
 OR 'computer-assisted diagnosis':ti,ab,kw
 OR 'computer-assisted detection':ti,ab,kw
 OR cade:ti,ab,kw
 OR cadx:ti,ab,kw
)
AND
(
 'endoscopy'/exp
 OR 'gastroscopy'/exp
 OR endoscop*:ti,ab,kw
 OR gastroscop*:ti,ab,kw
 OR 'upper gastrointestinal endoscopy':ti,ab,kw
 OR 'upper gi endoscopy':ti,ab,kw
 OR esophagogastroduodenoscopy:ti,ab,kw
 OR egd:ti,ab,kw
)
AND
(
 'stomach'/exp
 OR gastric:ti,ab,kw
 OR stomach:ti,ab,kw
)
AND
(
 'stomach cancer'/exp
 OR 'stomach tumor'/exp
 OR 'precancerous condition'/exp
 OR 'intestinal metaplasia'/exp
 OR 'atrophic gastritis'/exp
 OR 'early gastric cancer':ti,ab,kw
 OR 'gastric cancer':ti,ab,kw
 OR 'gastric neoplasm*':ti,ab,kw
 OR 'gastric carcinoma':ti,ab,kw
 OR 'gastric tumor*':ti,ab,kw
 OR 'gastric tumour*':ti,ab,kw
 OR 'gastric premalignant lesion*':ti,ab,kw
 OR 'gastric precancerous lesion*':ti,ab,kw
 OR 'gastric precancerous condition*':ti,ab,kw
 OR 'gastric intestinal metaplasia':ti,ab,kw
 OR 'intestinal metaplasia':ti,ab,kw
 OR 'atrophic gastritis':ti,ab,kw
 OR 'chronic atrophic gastritis':ti,ab,kw
 OR 'gastric dysplasia':ti,ab,kw
 OR 'intraepithelial neoplasia':ti,ab,kw
)
```

Scopus

Field: TITLE-ABS-KEY. Search date: 6 July 2026. Records retrieved: 902. Filters: none. A sensitivity check excluding the standalone abbreviation AI retrieved 872 records; the broader 902-record strategy was retained because the additional yield was limited and improved sensitivity.

```
TITLE-ABS-KEY (
 "artificial intelligence" OR "AI" OR "machine learning" OR "deep learning"
 OR "neural network*" OR "convolutional neural network*" OR CNN
 OR "computer-aided diagnosis" OR "computer-aided detection"
 OR "computer aided diagnosis" OR "computer aided detection"
 OR "computer-assisted diagnosis" OR "computer-assisted detection"
 OR CADe OR CADx
)
AND TITLE-ABS-KEY (
 endoscop* OR gastroscop* OR "upper gastrointestinal endoscopy"
 OR "upper GI endoscopy" OR esophagogastroduodenoscopy OR EGD
)
AND TITLE-ABS-KEY ( gastric OR stomach )
AND TITLE-ABS-KEY (
 "early gastric cancer" OR "gastric cancer" OR "gastric neoplasm*"
 OR "gastric carcinoma" OR "gastric tumor*" OR "gastric tumour*"
 OR "gastric premalignant lesion*" OR "gastric precancerous lesion*"
 OR "gastric precancerous condition*" OR "gastric intestinal metaplasia"
 OR "intestinal metaplasia" OR "atrophic gastritis"
 OR "chronic atrophic gastritis" OR "gastric dysplasia"
 OR "intraepithelial neoplasia"
)
```

Web of Science Core Collection

Advanced Search; Topic (TS). Search date: 6 July 2026. Records retrieved: 732. Filters: none.

```
(((TS=("artificial intelligence" OR AI OR "machine learning" OR "deep learning" OR "neural network" OR "neural networks" OR
"convolutional neural network" OR "convolutional neural networks" OR CNN OR "computer-aided diagnosis" OR "computer-aided detection" OR
"computer assisted diagnosis" OR "computer assisted detection" OR CADe OR CADx))
AND TS=(endoscopy OR endoscopic OR gastroscopy OR gastroscopic OR "upper gastrointestinal endoscopy" OR "upper GI endoscopy"
OR esophagogastroduodenoscopy OR EGD))
AND TS=(gastric OR stomach))
AND TS=("early gastric cancer" OR "gastric cancer" OR "gastric neoplasm" OR "gastric neoplasms" OR "gastric carcinoma" OR
"gastric tumor" OR "gastric tumors" OR "gastric tumour" OR "gastric tumours" OR "gastric premalignant lesion" OR "gastric premalignant lesions" OR
"gastric precancerous lesion" OR "gastric precancerous lesions" OR "gastric intestinal metaplasia" OR "intestinal metaplasia" OR
"atrophic gastritis" OR "chronic atrophic gastritis" OR "gastric dysplasia" OR "intraepithelial neoplasia")
```

Cochrane Library/CENTRAL

Fielded search using four Title/Abstract/Keyword rows combined with AND; word variations searched. Search date: 6 July 2026. Records retrieved: 62 trials (0 reviews; 0 protocols). Filters: none. Direct citation export was not available from the displayed interface; the 62 CENTRAL records were manually captured in structured RIS format and retained in the search audit trail.

```
("artificial intelligence" OR AI OR "machine learning" OR "deep learning" OR "neural network" OR "neural networks" OR
"convolutional neural network" OR "convolutional neural networks" OR CNN OR "computer-aided diagnosis" OR "computer-aided detection" OR
"computer assisted diagnosis" OR "computer assisted detection" OR CADe OR CADx):ti,ab,kw
AND
(endoscopy OR endoscopic OR gastroscopy OR gastroscopic OR "upper gastrointestinal endoscopy" OR "upper GI endoscopy" OR
esophagogastroduodenoscopy OR EGD):ti,ab,kw
AND
(gastric OR stomach):ti,ab,kw
AND
("early gastric cancer" OR "gastric cancer" OR "gastric neoplasm" OR "gastric neoplasms" OR "gastric carcinoma" OR "gastric tumor" OR
"gastric tumors" OR "gastric tumour" OR "gastric tumours" OR "gastric premalignant lesion" OR "gastric premalignant lesions" OR
"gastric precancerous lesion" OR "gastric precancerous lesions" OR "gastric precancerous condition" OR "gastric precancerous conditions" OR
"gastric intestinal metaplasia" OR "intestinal metaplasia" OR "atrophic gastritis" OR "chronic atrophic gastritis" OR
"gastric dysplasia" OR "intraepithelial neoplasia"):ti,ab,kw
```

IEEE Xplore

Advanced Search; All Metadata. Search date: 6 July 2026. Records retrieved: 164. Filters: none. The standalone abbreviation AI was omitted because of expected engineering-database noise; formal AI terms and the phrase AI-assisted were retained.

("All Metadata":"artificial intelligence" OR "All Metadata":"machine learning" OR "All Metadata":"deep learning" OR
"All Metadata":"neural network" OR "All Metadata":"neural networks" OR "All Metadata":"convolutional neural network" OR
"All Metadata":"convolutional neural networks" OR "All Metadata":CNN OR "All Metadata":"computer-aided diagnosis" OR
"All Metadata":"computer-aided detection" OR "All Metadata":"computer assisted diagnosis" OR "All Metadata":"computer assisted detection" OR
"All Metadata":"computer-assisted diagnosis" OR "All Metadata":"computer-assisted detection" OR "All Metadata":CADe OR
"All Metadata":CADx OR "All Metadata":"AI-assisted")
AND
("All Metadata":endoscopy OR "All Metadata":endoscopic OR "All Metadata":gastroscopy OR "All Metadata":gastroscopic OR
"All Metadata":"upper gastrointestinal endoscopy" OR "All Metadata":"upper GI endoscopy" OR
"All Metadata":esophagogastroduodenoscopy OR "All Metadata":EGD)
AND
("All Metadata":gastric OR "All Metadata":stomach)
AND
("All Metadata":"early gastric cancer" OR "All Metadata":"gastric cancer" OR "All Metadata":"gastric neoplasm" OR
"All Metadata":"gastric neoplasms" OR "All Metadata":"gastric carcinoma" OR "All Metadata":"gastric tumor" OR
"All Metadata":"gastric tumors" OR "All Metadata":"gastric tumour" OR "All Metadata":"gastric tumours" OR
"All Metadata":"gastric premalignant lesion" OR "All Metadata":"gastric premalignant lesions" OR
"All Metadata":"gastric precancerous lesion" OR "All Metadata":"gastric precancerous lesions" OR
"All Metadata":"gastric intestinal metaplasia" OR "All Metadata":"intestinal metaplasia" OR "All Metadata":"atrophic gastritis" OR
"All Metadata":"chronic atrophic gastritis" OR "All Metadata":"gastric dysplasia" OR "All Metadata":"intraepithelial neoplasia")

ClinicalTrials.gov

Advanced Search. Search date: 6 July 2026. Records retrieved: 37 studies. All recruitment statuses and study types were retained.

Condition or disease: gastric cancer OR stomach cancer OR gastric neoplasm OR early gastric cancer OR gastric precancerous lesion OR gastric premalignant lesion OR intestinal metaplasia OR atrophic gastritis OR gastric dysplasia

Other terms: artificial intelligence OR machine learning OR deep learning OR computer-aided OR computer assisted OR AI-assisted OR CADe OR CADx OR EndoAngel OR WISENSE

Additional endoscopy/intervention terms: endoscopy OR gastroscopy OR upper gastrointestinal endoscopy OR esophagogastroduodenoscopy

WHO International Clinical Trials Registry Platform (ICTRP)

Three complementary Advanced Search strategies were used because the portal did not reliably retrieve the complete concept set as a single long Boolean query. All registry statuses, countries, and dates were retained. Search date: 9 July 2026. The searches returned 14 raw records and 13 unique records after removal of one duplicate retrieved by more than one ICTRP strategy.

Search A - Gastric cancer / early gastric cancer (Records retrieved: 4)

Condition: gastric cancer OR stomach cancer OR early gastric cancer

Intervention: endoscopy OR gastroscopy OR upper gastrointestinal endoscopy OR esophagogastroduodenoscopy

Title / free text: artificial intelligence OR machine learning OR deep learning OR computer-aided OR computer assisted OR AI-assisted OR CADe OR CADx OR EndoAngel OR WISENSE

Search B - Gastric neoplasm / dysplasia (Records retrieved: 8)

Condition: gastric neoplasm OR gastric neoplasms OR gastric tumor OR gastric tumors OR gastric tumour OR gastric tumours OR gastric dysplasia

Intervention: endoscopy OR gastroscopy OR upper gastrointestinal endoscopy OR esophagogastroduodenoscopy

Title / free text: artificial intelligence OR machine learning OR deep learning OR computer-aided OR computer assisted OR AI-assisted OR CADe OR CADx OR EndoAngel OR WISENSE

Search C - Gastric premalignant lesions (Records retrieved: 2)

Condition: gastric precancerous lesion OR gastric precancerous lesions OR gastric premalignant lesion OR gastric premalignant lesions OR intestinal metaplasia OR atrophic gastritis OR chronic atrophic gastritis

Intervention: endoscopy OR gastroscopy OR upper gastrointestinal endoscopy OR esophagogastroduodenoscopy

Title / free text: artificial intelligence OR machine learning OR deep learning OR computer-aided OR computer assisted OR AI-assisted OR CADe OR CADx OR EndoAngel OR WISENSE

Supplementary Table 1. Methodological assessment of study families included in the spatial AI review (**Part A.** Data independence and validation design)

Study	Patient-disjoint internal split	External validation	Multicenter validation	Prospective component	Live spatial evaluation	Spatial evaluation format
Ishida 2017 (1)	Unclear/NR	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Kanesaka, 2018 (2)	Unclear; possible overlap	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Takemoto, S., 2019 (3)	Unclear; block/patch split, patient-level separation not reported	No	No	No	No	Offline block/patch validation plus independent image-level localization evaluation.
Yoon HJ 2019 (4)	Yes	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
An P 2020 (5)	Unclear/NR	No	No	No	No	Stored-image segmentation plus ESD-video and pathology-mapping validation.
Du, W., 2021 (6)	Yes	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Ling T 2021 (7)	Unclear/NR	Yes	Yes	No	No	Independent image validation plus technical real-time margin delineation on unprocessed videos; not a live patient procedure.
Teramoto/Fujita 2021 (8)	Unclear; multiple images per patient	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Zhang L 2021 (9)	Unclear/NR	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Cui, 2022 (10)	Unclear; image-level split	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Jin J 2022 (11)	Unclear/NR	No	No	Yes	No	Primary spatial metrics from stored still images; prospective positive-video feasibility component, not live spatial deployment.
Liu 2023 (12)	Unclear/NR	Yes	Yes	No	No	Predominantly offline/stored endoscopic image evaluation.
Okumura S 2022 (13)	Unclear/NR	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Qiu, 2022 (14)	Unclear/NR	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.

Supplementary Table 1. Methodological assessment of study families included in the spatial AI review (**Part A.** Data independence and validation design)

Study	Patient-disjoint internal split	External validation	Multicenter validation	Prospective component	Live spatial evaluation	Spatial evaluation format
Teramoto A 2022 (15)	Unclear/NR	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Yamashita T 2022 (16)	Unclear/NR	No	No	Yes	No	Mixed prospective/retrospective feasibility evaluation; lesion/image spatial assessment.
Du W 2023 (17)	Unclear/NR	Yes	Yes	No	No	Predominantly offline/stored endoscopic image evaluation.
Ma, L., 2023 (18)	No / image-level random split	No	No	No	No	Stored-image localization/segmentation; pilot/video demonstration not treated as formal live evaluation.
Shibata 2023 (19)	Unclear; cross-validation unit not fully patient-defined	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Takemoto S 2023 (20)	Unclear/NR	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Zhang K 2024 (21)	Unclear/NR	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Hong K 2025 (22)	Unclear/NR	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Wang, B., 2025 (23)	Yes	Yes	Yes	No	No	Predominantly offline/stored endoscopic image evaluation.
Huang, C.-T., 2026 (24)	Unclear; patient-level split not reported	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Menaga, K., 2026 (25)	Unclear; patient-level split not reported	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Wang, 2019 (26)	Unclear; image/pixel development	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Siripoppohn, 2021 (27)	Unclear; image/pixel development	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Siripoppohn V 2022 (28)	Unclear/NR	No	No	No	No	Offline still-image segmentation with reported real-time-capable inference; no live clinical spatial evaluation.
Tiankanon 2022 (29)	Unclear; image-level train/validation/test split	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.

Supplementary Table 1. Methodological assessment of study families included in the spatial AI review (**Part A.** Data independence and validation design)

Study	Patient-disjoint internal split	External validation	Multicenter validation	Prospective component	Live spatial evaluation	Spatial evaluation format
Pornvoraphat P 2023 (30)	Unclear; internal image/pixel evaluation	No	No	No	No	Offline still-image segmentation with reported real-time-capable inference; no live clinical spatial evaluation.
Chen, Y.-T., 2024 (31)	Unclear; published image-level split	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Pornvoraphat, P. 2024 (32)	Unclear/NR	No	No	No	No	Held-out offline spatial evaluation with real-time technical capability; no live patient deployment.
Tiankanon 2024 (33)	Not applicable to development split (prospective clinical cohort)	No	No	Yes	Yes	Prospective live real-time diagnostic/segmentation assistance with site-level biopsy reference.
Obukhova 2025 (34)	Unclear; image-level train/test split	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Yu 2026 (35)	Unclear; few-shot episodic/internal split	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Zhang, M., 2026 (36)	Unclear; five-fold image evaluation, patient-level fold assignment not established in locked extraction	No	No	Yes	No	Prospectively acquired patient-sourced image dataset; spatial evaluation remained internal/offline.
Zhao Q 2023 (37)	Not applicable to development split (prospective clinical cohort)	Yes	Yes	Yes	Yes	Prospective live real-time video evaluation; AI-marked atrophy sites directly informed additional biopsy.
Chen H 2025 (38)	Unclear/NR	No	No	No	No	Predominantly offline/stored endoscopic image evaluation.
Gong EJ 2023 (39)	Unclear/NR	Yes	Yes	Yes	No	Spatial segmentation evaluated internally; separate external and prospective screening-endoscopy components assessed broader clinical classification.

Supplementary Table 1. Methodological assessment of study families included in the spatial AI review (**Part B.** Spatial reference annotation and unit-level considerations)

Study	Reference annotation	Annotator process	Pathology–spatial linkage	Primary unit	Unit / clustering considerations
Ishida 2017 (1)	Expert-drawn lesion/demarcation regions	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	No direct histopathologic linkage to the spatial reference was established in the locked extraction.	Image/superpixel/ lesion area	Patch/block/superpixel-level analysis creates correlated observations within source images and patients; clustering was not shown to be fully accounted for.
Kanesaka, 2018 (2)	Histopathology	Spatial annotator procedure not separately specified in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Takemoto, S., 2019 (3)	ESD histopathology and expert annotation	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image block/patch	Patch/block/superpixel-level analysis creates correlated observations within source images and patients; clustering was not shown to be fully accounted for.
Yoon HJ 2019 (4)	Histopathology of resection specimens	Spatial annotator procedure not separately specified in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image	Patient-disjoint partition was reported, but performance remained image/pixel-level and repeated observations within patients may still be correlated.
An P 2020 (5)	Expert masks and post-ESD histopathology	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Direct/strong endoscopy–pathology mapping for the resection margin.	Patient/image/ video/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Du, W., 2021 (6)	Expert pixel masks; pathology confirmation not clearly described	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathologic linkage limited or incompletely reported.	Image/pixel	Patient-disjoint partition was reported, but performance remained image/pixel-level and repeated observations within patients may still be correlated.
Ling T 2021 (7)	Postresection histopathology and expert masks	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Strong postresection histopathology linkage for EGC margin evaluation, with expert spatial masks.	Patient/image/ pixel-reader	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.

Supplementary Table 1. Methodological assessment of study families included in the spatial AI review (**Part B.** Spatial reference annotation and unit-level considerations)

Study	Reference annotation	Annotator process	Pathology–spatial linkage	Primary unit	Unit / clustering considerations
Teramoto/Fujita 2021 (8)	Histopathology	Spatial annotator procedure not separately specified in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Zhang L 2021 (9)	Histopathology	Spatial annotator procedure not separately specified in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Cui, 2022 (10)	Pathology/expert labels	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Jin J 2022 (11)	Histopathology/expert lesion masks	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image, frame, and video	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Liu 2023 (12)	Histopathology and expert lesion masks	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Patient/image/ pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Okumura S 2022 (13)	Expert demarcation and histopathology in one case	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Case/image boundary	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Qiu, 2022 (14)	Expert/pathology labels as reported	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.

Supplementary Table 1. Methodological assessment of study families included in the spatial AI review (**Part B.** Spatial reference annotation and unit-level considerations)

Study	Reference annotation	Annotator process	Pathology–spatial linkage	Primary unit	Unit / clustering considerations
Teramoto A 2022 (15)	Clinical/pathologic diagnosis and expert invasion masks	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image and case	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Yamashita T 2022 (16)	Histopathology/endoscopic resection findings	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Lesion/image	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Du W 2023 (17)	Expert lesion masks with histopathologic diagnosis	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Ma, L., 2023 (18)	Histopathology for EGC and expert review	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image	Random image-level splitting did not establish patient independence; repeated observations per patient may cross data partitions.
Shibata 2023 (19)	Clinical/pathologic diagnosis; details limited in abstract	Annotator procedure not clearly reported in the locked extraction.	Histopathologic linkage limited or incompletely reported.	Image and case	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Takemoto S 2023 (20)	ESD histopathology-defined lesion extent	Spatial annotator procedure not separately specified in the locked extraction.	Direct lesion-extent linkage to ESD histopathology.	Image and lesion/case	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Zhang K 2024 (21)	Expert lesion masks/clinical diagnosis	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	No direct histopathologic linkage to the spatial reference was established in the locked extraction.	Image/lesion mask	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.

Supplementary Table 1. Methodological assessment of study families included in the spatial AI review (**Part B.** Spatial reference annotation and unit-level considerations)

Study	Reference annotation	Annotator process	Pathology–spatial linkage	Primary unit	Unit / clustering considerations
Hong K 2025 (22)	Expert endoscopic/pathologic lesion masks	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Wang, B., 2025 (23)	Resection histopathology; consensus lesion masks by junior and expert annotators	Consensus lesion masks involving junior and expert annotators.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image/lesion/ patient	Patient-disjoint partition was reported, but performance remained image/pixel-level and repeated observations within patients may still be correlated.
Huang, C.-T., 2026 (24)	Expert manual pixel masks	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	No direct histopathologic linkage to the spatial reference was established in the locked extraction.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Menaga, K., 2026 (25)	Expert manual segmentation masks	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	No direct histopathologic linkage to the spatial reference was established in the locked extraction.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Wang, 2019 (26)	Histopathology/expert annotation	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Siripoppohn, 2021 (27)	Expert annotation	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	No direct histopathologic linkage to the spatial reference was established in the locked extraction.	Pixel/image	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Siripoppohn V 2022 (28)	Histopathology	Spatial annotator procedure not separately specified in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.

Supplementary Table 1. Methodological assessment of study families included in the spatial AI review (**Part B.** Spatial reference annotation and unit-level considerations)

Study	Reference annotation	Annotator process	Pathology–spatial linkage	Primary unit	Unit / clustering considerations
Tiankanon 2022 (29)	Histopathology plus two-expert segmentation annotation	Two-expert segmentation annotation.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Pornvoraphat P 2023 (30)	Histopathology	Spatial annotator procedure not separately specified in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Chen, Y.-T., 2024 (31)	Expert pixel masks from source study	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	No direct histopathologic linkage to the spatial reference was established in the locked extraction.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Pornvoraphat, P. 2024 (32)	Histopathology for GIM and two-expert masks/labels	Two-expert masks/labels.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Tiankanon 2024 (33)	Targeted/random biopsy with unanimous review by two pathologists	Biopsy diagnosis reviewed unanimously by two pathologists; spatial assessment was site-based rather than a pixel mask.	Site-level histopathology from protocolized targeted/random biopsies.	Biopsy site/area	Multiple biopsy-site/area observations were obtained per patient; within-patient clustering is relevant.
Obukhova 2025 (34)	Three to five ROI masks per image annotated by an experienced endoscopist; histology not reported	Three to five ROI masks per image annotated by an experienced endoscopist.	No direct histopathologic linkage to the spatial reference was established in the locked extraction.	Image/pixel/ROI	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Yu 2026 (35)	Consensus annotation by five experienced endoscopists	Consensus annotation by five experienced endoscopists.	No direct histopathologic linkage to the spatial reference was established in the locked extraction.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.

Supplementary Table 1. Methodological assessment of study families included in the spatial AI review (**Part B.** Spatial reference annotation and unit-level considerations)

Study	Reference annotation	Annotator process	Pathology–spatial linkage	Primary unit	Unit / clustering considerations
Zhang, M., 2026 (36)	Expert endoscopic consensus/pixel masks; histology not reported	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	No direct histopathologic linkage to the spatial reference was established in the locked extraction.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Zhao Q 2023 (37)	Histopathology	Spatial annotator procedure not separately specified in the locked extraction.	Site-level histopathology from routine and AI-prompted biopsies; reference sampling was index-test informed.	Patient/video and image/pixel	Patient/video evaluation included multiple biopsy sites; site-level observations are clustered within patients.
Chen H 2025 (38)	Histopathology and senior-endoscopist reviewed masks	Masks reviewed by senior endoscopists.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image/pixel	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.
Gong EJ 2023 (39)	Histopathology/expert diagnosis	Expert spatial annotation reported; annotator number/consensus was not fully captured in the locked extraction.	Histopathology established/confirmed lesion diagnosis; the spatial mask/region was primarily endoscopic or expert-defined rather than directly pathology-registered.	Image and patient/procedure	Image/pixel/lesion-level evaluation with possible repeated observations per patient; patient-level independence and clustering were not fully established.

Supplementary Table 1. Methodological assessment of study families included in the spatial AI review (**Part C.** QUADAS-2 judgments for study families with a conventional diagnostic-accuracy component**)**

Study	D1: patient selection	D2: index test	D3: reference standard	D4: flow and timing	Overall RoB
Kanesaka, 2018 (2)	High	High	Low	High	High
Takemoto, S., 2019 (3)	High	High	Unclear	High	High
Yoon HJ 2019 (4)	High	Unclear	Unclear	High	High
Teramoto/Fujita 2021 (8)	High	High	Low	High	High
Zhang L 2021 (9)	High	High	Low	High	High
Cui, 2022 (10)	High	High	Unclear	High	High
Jin J 2022 (11)	High	High	Unclear	High	High
Liu 2023 (12)	High	High	Unclear	Unclear	High
Ma, L., 2023 (18)	High	High	Unclear	High	High
Takemoto S 2023 (20)	Unclear	High	Low	High	High
Pornvoraphat P 2023 (30)	High	High	Low	High	High
Tiankanon 2024 (33)	Unclear	Unclear	Low	High	High
Zhao Q 2023 (37)	High	Low	High	Low	High

Supplementary Table 2. Study-level spatial evaluation characteristics and reported performance

Study	Target / modality	Spatial task	Reference annotation	Evaluation format / unit	Representative spatial performance as reported	Validation context
Ishida 2017 (1)	Early gastric cancer / early gastric neoplasia; Magnifying NBI	Segmentation/demarcation detection	Expert-drawn lesion/demarcation regions	Predominantly offline/stored endoscopic image evaluation. Unit: Image/superpixel/lesion area.	Correct lesion-area/demarcation detection rate 63% in the proof-of-concept evaluation.	internal/ technical
Kanesaka, 2018 (2)	Early gastric cancer / early gastric neoplasia; M-NBI	CADx and delineation	Histopathology; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Image.	Computer-aided identification/delineation was evaluated on selected ME-NBI images; no standardized overlap metric was retained in the locked extraction.	internal/ technical
Takemoto, S., 2019 (3)	Early gastric cancer / early gastric neoplasia; WLI	Patch classification and lesion localization	ESD histopathology and expert annotation; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Offline block/patch validation plus independent image-level localization evaluation. Unit: Image block/patch.	Unseen-image localization: 73.3% of cancer blocks and 98.8% of normal blocks correctly identified.	internal/ technical
Yoon HJ 2019 (4)	Early gastric cancer / early gastric neoplasia; White-light endoscopy	Early gastric cancer detection	Histopathology of resection specimens; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Image.	Lesion localization formed part of the lesion-based CNN, but no standardized spatial overlap metric was retained in the locked extraction.	patient-disjoint internal split
An P 2020 (5)	Early gastric cancer / early gastric neoplasia; White-light and indigo-carmine chromoendoscopy	Early gastric cancer resection-margin delineation	Expert masks and post-ESD histopathology; Direct/strong endoscopy–pathology mapping for the resection margin.	Stored-image segmentation plus ESD-video and pathology-mapping validation. Unit: Patient/image/video/pixel.	Margin-delineation accuracy 85.7% with chromoendoscopy and 88.9% with WLI at overlap ≥0.60; pathology-mapped minimum margin distance mean 3.44 mm.	internal/ technical
Du, W., 2021 (6)	Early gastric cancer / early gastric neoplasia; WLI	Segmentation	Expert pixel masks; pathology confirmation not clearly described	Predominantly offline/stored endoscopic image evaluation. Unit: Image/pixel.	Patient-disjoint internal test: DSC/F1 0.923 and precision 0.922.	patient-disjoint internal split
Ling T 2021 (7)	Early gastric cancer / early gastric neoplasia; Magnifying narrow-band imaging	Early gastric cancer differentiation and margin delineation	Postresection histopathology and expert masks	Independent image validation plus technical real-time margin delineation on unprocessed videos; not a live patient procedure. Unit: Patient/image/pixel-reader.	Margin-delineation accuracy 82.7% for differentiated and 88.1% for undifferentiated EGC at overlap ≥0.80.	external validation; multicenter
Teramoto/ Fujita 2021 (8)	Early gastric cancer / early gastric neoplasia; WLI	CADe detection/false-positive	Histopathology; pathology confirmed diagnosis, but spatial	Predominantly offline/stored endoscopic image evaluation. Unit: Image.	Segmentation/classification was evaluated on stored images; no single standardized overlap metric	internal/ technical

Supplementary Table 2. Study-level spatial evaluation characteristics and reported performance

Study	Target / modality	Spatial task	Reference annotation	Evaluation format / unit	Representative spatial performance as reported	Validation context
		reduction; Segmentation/classification	mask was not directly pathology-registered		was retained in the locked extraction.	
Zhang L 2021 (9)	Early gastric cancer / early gastric neoplasia; White-light endoscopy	Multiclass gastric lesions; eligible EGC and HGIN class	Histopathology; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Image.	mean IoU 0.698 for DeepLabv3 segmentation on the 1,091-image test set.	internal/ technical
Cui, 2022 (10)	Early gastric cancer / early gastric neoplasia; Gastroscopy	CADe/segmentation	Pathology/expert labels; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Image.	Mask R-CNN segmentation/detection was evaluated internally; no single standardized overlap metric was retained in the locked extraction.	internal/ technical
Jin J 2022 (11)	Early gastric cancer / early gastric neoplasia; White-light and narrow-band imaging	Early gastric cancer detection and segmentation	Histopathology/expert lesion masks; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Primary spatial metrics from stored still images; prospective positive-video feasibility component, not live spatial deployment. Unit: Image, frame, and video.	Mask R-CNN system was evaluated on images and video; no single standardized overlap metric was retained in the locked spatial extraction.	prospective component
Liu 2023 (12)	Early gastric cancer / early gastric neoplasia; Magnifying narrow-band imaging	Gastric low-grade intraepithelial neoplasia and early gastric cancer	Histopathology and expert lesion masks; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Patient/image/pixel.	Dice 0.867; mean IoU 0.584; precision 0.776 for ME-NBI neoplastic-lesion segmentation.	external validation; multicenter
Okumura S 2022 (13)	Early gastric cancer / early gastric neoplasia; Magnifying narrow-band imaging	Early gastric cancer demarcation line	Expert demarcation and histopathology in one case; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Case/image boundary.	Demarcation-line similarity was assessed by case-level Euclidean distance; reported distances ranged from 7.82 to 25.36 in the study-specific scale.	internal/ technical
Qiu, 2022 (14)	Early gastric cancer / early gastric neoplasia; ME-NBI	Recognition/segmentation	Expert/pathology labels as reported; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Image.	Improved U-Net recognition/segmentation was evaluated internally; no single standardized overlap metric was retained in the locked extraction.	internal/ technical
Teramoto A 2022 (15)	Early gastric cancer / early gastric neoplasia; Endoscopic images	Early versus advanced gastric cancer detection	Clinical/pathologic diagnosis and expert invasion masks; pathology confirmed diagnosis, but spatial	Predominantly offline/stored endoscopic image evaluation. Unit: Image and case.	Detection plus region-segmentation system; no single standardized spatial overlap	internal/ technical

Supplementary Table 2. Study-level spatial evaluation characteristics and reported performance

Study	Target / modality	Spatial task	Reference annotation	Evaluation format / unit	Representative spatial performance as reported	Validation context
		and invasion-region segmentation	mask was not directly pathology-registered		metric was retained in the locked extraction.	
Yamashita T 2022 (16)	Early gastric cancer / early gastric neoplasia; 5-aminolevulinic-acid photodynamic endoscopy	Early gastric neoplasia/adenoma detection and lesion-area segmentation	Histopathology/endoscopic resection findings; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Mixed prospective/retrospective feasibility evaluation; lesion/image spatial assessment. Unit: Lesion/image.	Lesion-area efficiency 0.485 with false-positive area 0.038 in the higher-performing photodynamic analysis.	prospective component
Du W 2023 (17)	Early gastric cancer / early gastric neoplasia; White-light endoscopy	Early gastric cancer segmentation	Expert lesion masks with histopathologic diagnosis; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Image/pixel.	DSC 0.911; JSI 0.845; TJI 0.817 on the unseen/external test set.	external validation; multicenter
Ma, L., 2023 (18)	Early gastric cancer / early gastric neoplasia; C-WLI, NBI, ME-NBI and chromoendoscopy	Classification and localization/segmentation	Histopathology for EGC and expert review; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Stored-image localization/segmentation; pilot/video demonstration not treated as formal live evaluation. Unit: Image.	Localization/segmentation was evaluated on a random held-out image test; no standardized overlap metric was retained in the locked extraction.	internal/ technical
Shibata 2023 (19)	Early gastric cancer / early gastric neoplasia; Conventional endoscopy; modality details limited	Multiclass classification and lesion segmentation	Clinical/pathologic diagnosis; details limited in abstract	Predominantly offline/stored endoscopic image evaluation. Unit: Image and case.	Dice index 0.56 for EGC segmentation.	internal/ technical
Takemoto S 2023 (20)	Early gastric cancer / early gastric neoplasia; White-light endoscopy	Early gastric cancer detection and demarcation	ESD histopathology-defined lesion extent; Direct lesion-extent linkage to ESD histopathology.	Predominantly offline/stored endoscopic image evaluation. Unit: Image and lesion/case.	Mean IoU 0.665 for case-level demarcation; case-level EGC detection sensitivity 0.949.	internal/ technical
Zhang K 2024 (21)	Early gastric cancer / early gastric neoplasia; Gastroscopic images	Early gastric cancer detection and lesion segmentation	Expert lesion masks/clinical diagnosis	Predominantly offline/stored endoscopic image evaluation. Unit: Image/lesion mask.	Detection/segmentation report: precision 0.929, recall 0.953, F1 0.941; the published count structure was not a standard independent spatial 2×2.	internal/ technical
Hong K 2025 (22)	Early gastric cancer / early gastric neoplasia; NBI and near-focus NBI	Early gastric cancer boundary segmentation	Expert endoscopic/pathologic lesion masks; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Image/pixel.	Dice 0.831 with NBI and 0.853 with nF-NBI for boundary segmentation.	internal/ technical

Supplementary Table 2. Study-level spatial evaluation characteristics and reported performance

Study	Target / modality	Spatial task	Reference annotation	Evaluation format / unit	Representative spatial performance as reported	Validation context
Wang, B., 2025 (23)	Early gastric cancer / early gastric neoplasia; WLI	Multi-task classification and segmentation	Resection histopathology; consensus lesion masks by junior and expert annotators; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Image/lesion/patient.	Segmentation Dice/IoU 0.905/0.832 internally; external Dice 0.898–0.907 and IoU 0.818–0.834.	patient-disjoint internal split; external validation; multicenter
Huang, C.-T., 2026 (24)	Early gastric cancer / early gastric neoplasia; NBI	Segmentation	Expert manual pixel masks	Predominantly offline/stored endoscopic image evaluation. Unit: Image/pixel.	Positive-only NBI tests reported IoU 0.40–0.59 with precision 0.77–0.90.	internal/ technical
Menaga, K., 2026 (25)	Early gastric cancer / early gastric neoplasia; WLI not otherwise specified	Segmentation	Expert manual segmentation masks	Predominantly offline/stored endoscopic image evaluation. Unit: Image/pixel.	Dice 0.89; IoU 0.83; precision 0.90; F1 0.88.	internal/ technical
Wang, 2019 (26)	Gastric intestinal metaplasia; Endoscopy	Localization/segmentation	Histopathology/expert annotation; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Image/pixel.	GIM localization/segmentation report; no standardized overlap metric was retained in the locked extraction.	internal/ technical
Siripoppohn, 2021 (27)	Gastric intestinal metaplasia; Endoscopic images	Segmentation	Expert annotation	Predominantly offline/stored endoscopic image evaluation. Unit: Pixel/image.	Technical GIM segmentation report; no standardized overlap metric was retained in the locked extraction.	internal/ technical
Siripoppohn V 2022 (28)	Gastric intestinal metaplasia; White-light and narrow-band imaging	Gastric intestinal metaplasia detection and segmentation	Histopathology; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Offline still-image segmentation with reported real-time-capable inference; no live clinical spatial evaluation. Unit: Image/pixel.	mean IoU 0.570; image-level sensitivity 0.93, specificity 0.80; 31.53 frames/s.	internal/ technical
Tiankanon 2022 (29)	Gastric intestinal metaplasia; WLI and NBI	GIM detection and semantic segmentation	Histopathology plus two-expert segmentation annotation; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Image/pixel.	Image-level sensitivity 0.93, specificity 0.80; 31.53 frames/s; semantic segmentation was part of the system evaluation.	internal/ technical
Pornvoraphat P 2023 (30)	Gastric intestinal metaplasia; White-light and narrow-band imaging	Gastric intestinal metaplasia detection and segmentation	Histopathology; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Offline still-image segmentation with reported real-time-capable inference; no live clinical spatial evaluation. Unit: Image/pixel.	mean IoU 0.55; image-level sensitivity 0.91, specificity 0.96; reported speed 173 frames/s.	internal/ technical

Supplementary Table 2. Study-level spatial evaluation characteristics and reported performance

Study	Target / modality	Spatial task	Reference annotation	Evaluation format / unit	Representative spatial performance as reported	Validation context
Chen, Y.-T., 2024 (31)	Gastric intestinal metaplasia; NBI	Segmentation	Expert pixel masks from source study	Predominantly offline/stored endoscopic image evaluation. Unit: Image/pixel.	mIoU 0.733; F1 0.825; mean precision 0.866 in the secondary-dataset test.	internal/ technical
Pornvoraphat, P. 2024 (32)	Gastric intestinal metaplasia; White-light and narrow-band imaging	Gastric intestinal metaplasia segmentation	Histopathology for GIM and two-expert masks/labels; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Held-out offline spatial evaluation with real-time technical capability; no live patient deployment. Unit: Image/pixel.	mean IoU 0.55; image-level sensitivity 0.94 and specificity 0.97.	internal/ technical
Tiankanon 2024 (33)	Gastric intestinal metaplasia; WLI and NBI	GIM detection/segmentation assistance	Targeted/random biopsy with unanimous review by two pathologists	Prospective live real-time diagnostic/segmentation assistance with site-level biopsy reference. Unit: Biopsy site/area.	Prospective live biopsy-site evaluation; AI diagnostic accuracy 0.885 with NBI and 0.893 with WLI. A standardized segmentation-overlap metric was not reported.	prospective component; live spatial evaluation
Obukhova 2025 (34)	Gastric intestinal metaplasia; Endoscopic still images, modality NR	GIM segmentation	Three to five ROI masks per image annotated by an experienced endoscopist; histology not reported	Predominantly offline/stored endoscopic image evaluation. Unit: Image/pixel/ROI.	IoU 0.88 for GIM segmentation.	internal/ technical
Yu 2026 (35)	Gastric intestinal metaplasia; NBI/LBI/LCI	Few-shot segmentation	Consensus annotation by five experienced endoscopists	Predominantly offline/stored endoscopic image evaluation. Unit: Image/pixel.	Few-shot GIM segmentation was evaluated internally; the locked extraction did not retain a single standardized performance value for manuscript reporting.	internal/ technical
Zhang, M., 2026 (36)	Gastric intestinal metaplasia; Linked color imaging	Segmentation	Expert endoscopic consensus/pixel masks; histology not reported	Prospectively acquired patient-sourced image dataset; spatial evaluation remained internal/offline. Unit: Image/pixel.	mIoU 0.641; F1 0.781; sensitivity 0.821; specificity 0.910 in five-fold internal evaluation.	prospective component
Zhao Q 2023 (37)	Gastric atrophy / chronic atrophic gastritis; Conventional gastroscopy video	Chronic atrophic gastritis and high-risk OLGA stage	Histopathology	Prospective live real-time video evaluation; AI-marked atrophy sites directly informed additional biopsy. Unit: Patient/video and image/pixel.	Real-time spatial marking was evaluated clinically; primary reported patient-level CAG performance was sensitivity 0.893 and specificity 0.905 rather than a mask-overlap metric.	external validation; multicenter; prospective component; live spatial evaluation

Supplementary Table 2. Study-level spatial evaluation characteristics and reported performance

Study	Target / modality	Spatial task	Reference annotation	Evaluation format / unit	Representative spatial performance as reported	Validation context
Chen H 2025 (38)	Gastric atrophy / chronic atrophic gastritis; Conventional gastroscopy images	Chronic atrophic gastritis	Histopathology and senior-endoscopist reviewed masks; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Predominantly offline/stored endoscopic image evaluation. Unit: Image/pixel.	Atrophic-region segmentation: mean Dice 0.94, mean IoU 0.90, MAE 0.05.	internal/ technical
Gong EJ 2023 (39)	Multiple stages of gastric carcinogenesis; White-light gastroscopy	Gastric atrophy, intestinal metaplasia, dysplasia, and early gastric cancer	Histopathology/expert diagnosis; pathology confirmed diagnosis, but spatial mask was not directly pathology-registered	Spatial segmentation evaluated internally; separate external and prospective screening-endoscopy components assessed broader clinical classification. Unit: Image and patient/procedure.	Internal lesion-segmentation rate 93.4%; system later evaluated prospectively in screening endoscopy.	external validation; multicenter; prospective component

Reported spatial measures were retained in the form used by the original studies and were not converted to a common scale. Values shown are representative spatial results selected from the locked extraction; diagnostic classification metrics are included only when the study did not report a separate standardized spatial-overlap metric and the metric helps characterize the evaluated spatial workflow. Study families could contribute to more than one spatial task. **Abbreviations:** CAG, chronic atrophic gastritis; DSC, Dice similarity coefficient; EGC, early gastric cancer; ESD, endoscopic submucosal dissection; GIM, gastric intestinal metaplasia; IoU, intersection over union; JSI, Jaccard similarity index; LCI, linked-color imaging; MAE, mean absolute error; ME-NBI, magnifying endoscopy with narrow-band imaging; NBI, narrow-band imaging; nF-NBI, near-focus narrow-band imaging; NR, not reported; ROI, region of interest; WLI, white-light imaging.

Supplementary Table 3. Study-level validation, implementation, and reproducibility characteristics

Study	Model / system and architecture	Validation / clinical stage	Reader comparison	Workflow / intended spatial use	Hardware / inference information	Code / trained-model availability	Failure analysis
Ishida 2017 (1)	Machine-learning demarcation-line detector — Superpixel features plus supervised SVM	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	Offline superpixel/SVM method	No open code/model identified	No formal failure-case analysis identified
Kanesaka, 2018 (2)	SVM using variation vectors — SVM using variation vectors	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR; Limited/NR	No open code/model identified	No formal failure-case analysis identified
Takemoto, S., 2019 (3)	GoogLeNet block classifier — ImageNet-pretrained GoogLeNet	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	Research workstation	No open code/model identified	No formal failure-case analysis identified
Yoon HJ 2019 (4)	Lesion-based EGC CNN — VGG-16 with joint classification-localization loss	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR	No open code/model identified	No formal failure-case analysis identified
An P 2020 (5)	ENDOANGEL margin delineation — Real-time fully convolutional segmentation networks	internal/offline	No formal reader comparison identified	Margin delineation evaluated for ESD/resection planning, including endoscopy–pathology correspondence.	NR	No open code/model identified	No formal failure-case analysis identified
Du, W., 2021 (6)	ResUNet — U-Net with pretrained ResNet34 encoder	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	Research workstation	No open code/model identified	No formal failure-case analysis identified
Ling T 2021 (7)	EGC differentiation/margin system — Two convolutional neural networks (CNN1 classification; CNN2 segmentation)	external, multicenter	Yes; reader n=5; cases=58; Expert endoscopists	Real-time-capable margin delineation tested on unprocessed EGC videos; intended for resection-margin assessment.	NR	No open code/model identified	No formal failure-case analysis identified
Teramoto/Fujita 2021 (8)	SSD plus CNN; Hybrid segmentation-classification network — SSD plus CNN; Hybrid segmentation-classification network	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR; Limited/NR	No open code/model identified	No formal failure-case analysis identified

Supplementary Table 3. Study-level validation, implementation, and reproducibility characteristics

Study	Model / system and architecture	Validation / clinical stage	Reader comparison	Workflow / intended spatial use	Hardware / inference information	Code / trained-model availability	Failure analysis
Zhang L 2021 (9)	Five-class gastric-lesion CNN — ResNet34 classifier with DeepLabv3 localization	internal/offline	Yes; reader n=10; cases=1091; Experienced endoscopists	No procedure-integrated spatial use demonstrated	NR	No open code/model identified	No formal failure-case analysis identified
Cui, 2022 (10)	Improved Mask R-CNN — Improved Mask R-CNN	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR; Limited/NR	No open code/model identified	No formal failure-case analysis identified
Jin J 2022 (11)	EGC Mask R-CNN — Mask region-based convolutional neural network	prospective	Yes; cases=400; Experts; Senior endoscopists; …	Prospective/video capability evaluated, but no direct spatial procedure-modification outcome.	speed fps 35	No open code/model identified	No formal failure-case analysis identified
Liu 2023 (12)	CNN1/CNN2 gastric neoplasia CAD — YOLOv3/EfficientNet-B2 classification plus VGG16-UNet segmentation	external, multicenter	Yes; reader n=3; cases=100; Senior endoscopists; Junior endoscopists	No procedure-integrated spatial use demonstrated	NR	No open code/model identified	No formal failure-case analysis identified
Okumura S 2022 (13)	Unsupervised DL-candidate boundary system — SLIC superpixels, handcrafted features, and k-means clustering	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR	No open code/model identified	No formal failure-case analysis identified
Qiu, 2022 (14)	Improved U-Net/recognition model — Improved U-Net/recognition model	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR; Limited/NR	No open code/model identified	No formal failure-case analysis identified
Teramoto A 2022 (15)	Cascade gastric-cancer model — DenseNet-121 three-class classifier followed by separate U-Net segmentation models	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR	No open code/model identified	No formal failure-case analysis identified
Yamashita T 2022 (16)	PDD gastric lesion AI — Deep-learning lesion detection/segmentation model	prospective	No formal reader comparison identified	Prospective component for photodynamic lesion-area detection; no routine workflow deployment established.	NR	No open code/model identified	No formal failure-case analysis identified

Supplementary Table 3. Study-level validation, implementation, and reproducibility characteristics

Study	Model / system and architecture	Validation / clinical stage	Reader comparison	Workflow / intended spatial use	Hardware / inference information	Code / trained-model availability	Failure analysis
Du W 2023 (17)	EGC segmentation network — Deep semantic segmentation network	external, multicenter	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR	No open code/model identified	No formal failure-case analysis identified
Ma, L., 2023 (18)	GAIN-ResNet50 / CA-U-Net — ResNet50 classifier with gastric area interaction network; CA-U-Net localization	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	Research workstation	No open code/model identified	Formal failure-case analysis
Shibata 2023 (19)	DenseNet121 classification plus U-Net segmentation — 13 pretrained CNNs compared; DenseNet121 best; U-Net segmentation	internal/offline	No formal reader comparison identified	Cloud-screening concept only	NR	No open code/model identified	Limited error analysis
Takemoto S 2023 (20)	EGC detection-demarcation CAD — Convolutional neural network segmentation/detection scheme	internal/offline	Yes; reader n=6; cases=38; Endoscopists	No procedure-integrated spatial use demonstrated	NR	No open code/model identified	No formal failure-case analysis identified
Zhang K 2024 (21)	IMR-CNN — Improved Mask R-CNN with bidirectional feature fusion and channel/spatial purification	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR	No open code/model identified	No formal failure-case analysis identified
Hong K 2025 (22)	EGC boundary models — Deep convolutional segmentation models	internal/offline	Yes; Junior/intermediate/senior endoscopists	No procedure-integrated spatial use demonstrated	NR	No open code/model identified	No formal failure-case analysis identified
Wang, B., 2025 (23)	TSP-SAM — Task-specific prompting Segment Anything Model with multi-task classifiers	external, multicenter	No formal reader comparison identified	External technical validation; partial workflow description, no procedure-modification endpoint.	Research workstation	No open code/model identified	Formal failure-case analysis
Huang, C.-T., 2026 (24)	Pyramid Spatial Pooling U-Net — PSP U-Net	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	Research workstation	No open code/model identified	No formal failure-case analysis identified

Supplementary Table 3. Study-level validation, implementation, and reproducibility characteristics

Study	Model / system and architecture	Validation / clinical stage	Reader comparison	Workflow / intended spatial use	Hardware / inference information	Code / trained-model availability	Failure analysis
Menaga, K., 2026 (25)	GLIU-Net — Graph learning-enhanced U-Net	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	PyTorch research workstation	No open code/model identified	No formal failure-case analysis identified
Wang, 2019 (26)	Localization network — Localization network	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR; Limited/NR	No open code/model identified	No formal failure-case analysis identified
Siripoppohn, 2021 (27)	Fast segmentation CNN with edge-guided path — Fast segmentation CNN with edge-guided path	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR; Limited/NR	No open code/model identified	No formal failure-case analysis identified
Siripoppohn V 2022 (28)	BiSeNet GIM segmentation — Bilateral segmentation network with transfer learning, CLAHE, and augmentation	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	frames per second 31.53	No open code/model identified	No formal failure-case analysis identified
Tiankanon 2022 (29)	BiSeNet GIM segmentation model — BiSeNet with transfer learning	internal/offline	No formal reader comparison identified	Potential real-time use only	NR; PPV 0.82; NPV 0.92; 31.53 FPS	No open code/model identified	No formal failure-case analysis identified
Pornvoraphat P 2023 (30)	Real-time GIM BiSeNet — Bilateral segmentation network with auxiliary head, tailored preprocessing, and modality-specific thresholds	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	frames per second 173	No open code/model identified	No formal failure-case analysis identified
Chen, Y.-T., 2024 (31)	Mask Focal Modulation Network — FocalNet-Tiny backbone with segmentation decoder	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	Research workstation	Open code; no open trained model identified	No formal failure-case analysis identified
Pornvoraphat, P. 2024 (32)	Real-time multi-mode GIM segmentation — BiSeNet with switch adapter, color selector, and high-resolution half-precision inference	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	NR	No open code/model identified	No formal failure-case analysis identified

Supplementary Table 3. Study-level validation, implementation, and reproducibility characteristics

Study	Model / system and architecture	Validation / clinical stage	Reader comparison	Workflow / intended spatial use	Hardware / inference information	Code / trained-model availability	Failure analysis
Tiankanon 2024 (33)	Deep-GI — NR in abstract	prospective, live spatial	Yes; cases=375; Trainee endoscopists versus separately recorded AI output	Prospective live biopsy-site/area evaluation; AI output recorded during endoscopy, with trainee comparison.	Limited	No open code/model identified	No formal failure-case analysis identified
Obukhova 2025 (34)	ADSAR U-Net with consistency loss — U-Net with adaptive domain-specific augmentation/regularization and consistency loss	internal/offline	No formal reader comparison identified	Decision-support concept only	Segmentation software; details limited	No open code/model identified	No formal failure-case analysis identified
Yu 2026 (35)	Attention-based progressive prototype alignment network (APANet) — Attention-based progressive prototype alignment	internal/offline	No formal reader comparison identified	No procedure-integrated spatial use demonstrated	Limited	No open code/model identified	No formal failure-case analysis identified
Zhang, M., 2026 (36)	VM-UNetV2 — VM-UNetV2	prospective	No formal reader comparison identified	Prospectively sourced LCI dataset with internal five-fold segmentation evaluation; no live deployment.	NVIDIA RTX 4090 research workstation	Open code; no open trained model identified	No formal failure-case analysis identified
Zhao Q 2023 (37)	CAG U-Net/OLGA model — U-Net lesion segmentation and severity assessment	external, multicenter, prospective, live spatial	Yes; Endoscopists	Live AI marking of suspected atrophic areas could prompt additional targeted biopsy; direct procedure-integrated spatial use.	NR	No open code/model identified	No formal failure-case analysis identified
Chen H 2025 (38)	Swin/SSFormer CAG system — Swin Transformer classification plus SSFormer segmentation	internal/offline	Yes; reader n=6; cases=130; Six endoscopists	No procedure-integrated spatial use demonstrated	NR	No open code/model identified	No formal failure-case analysis identified
Gong EJ 2023 (39)	Gastric carcinogenesis CDSS — Multitask classification and segmentation deep-learning system	external, multicenter, prospective	No formal reader comparison identified	CDSS applied prospectively during screening endoscopy; segmentation result itself	NR	No open code/model identified	No formal failure-case analysis identified

Supplementary Table 3. Study-level validation, implementation, and reproducibility characteristics

Study	Model / system and architecture	Validation / clinical stage	Reader comparison	Workflow / intended spatial use	Hardware / inference information	Code / trained-model availability	Failure analysis
				derived from internal testing.			

Validation and implementation domains are reported individually rather than combined into a readiness score. “Live spatial evaluation” requires evaluation of the spatial AI output during an actual endoscopic procedure; rapid inference on stored images or prerecorded video alone was not considered live clinical use. Open-code status refers to a publicly accessible source-code repository identified in the locked extraction; no included study family had an openly available trained model. **Abbreviations:** AI, artificial intelligence; CAG, chronic atrophic gastritis; CDSS, clinical decision support system; EGC, early gastric cancer; GIM, gastric intestinal metaplasia; LCI, linked-color imaging; NBI, narrow-band imaging; NR, not reported; SVM, support vector machine; WLI, white-light imaging.

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Supplementary Fig. 1: Validation and clinical-translation profile of spatial AI studies. Each row represents one included study family and each column a prespecified validation, implementation, or reproducibility domain. Domains were assessed individually and were not combined into a composite readiness score. Cells indicate Yes, No, Unclear, Limited, or not applicable (N/A). Limited denotes a partial or demonstration-only evaluation; N/A indicates that patient-disjoint internal testing was not applicable to a prospective clinical cohort. Video evaluation required assessment of spatial output on video; rapid inference on stored images alone was not sufficient. Procedure-altering use required documented modification of biopsy or treatment planning. EGC, early gastric cancer; GIM, gastric intestinal metaplasia; CAG, chronic atrophic gastritis.

STUDY FAMILY	VALIDATION DESIGN & EVALUATION						CLINICAL TRANSLATION			REPRODUCIBILITY & ERROR ANALYSIS		
Grouped by gastric target chronological within each group	Patient-disjoint internal testing	External validation	Multicenter validation	Prospective component	Video evaluation	Live spatial evaluation	Reader comparison	Procedure-altering spatial use	Margin / resection-planning evaluation	Open code	Trained model available	Failure analysis
EGC / EARLY GASTRIC NEOPLASIA · n = 25												
Ishida (2017)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Kanesaka (2018)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Takemoto (2019)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Yoon (2019)	Yes	No	No	No	No	No	No	No	No	No	No	No
An (2020)	Unclear	No	No	No	Yes	No	No	No	Yes	No	No	No
Du (2021)	Yes	No	No	No	No	No	No	No	No	No	No	No
Ling (2021)	Unclear	Yes	Yes	No	Yes	No	Yes	No	Yes	No	No	No
Teramoto / Fujita (2021)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Zhang L (2021)	Unclear	No	No	No	No	No	Yes	No	No	No	No	No
Cui (2022)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Jin (2022)	Unclear	No	No	Yes	Yes	No	Yes	No	No	No	No	No
Liu (2022)	Unclear	Yes	Yes	No	No	No	Yes	No	No	No	No	No
Okumura (2022)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Qiu (2022)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Teramoto (2022)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Yamashita (2022)	Unclear	No	No	Yes	No	No	No	No	No	No	No	No
Du (2023)	Unclear	Yes	Yes	No	No	No	No	No	No	No	No	No
Ma (2023)	No	No	No	No	Limited	No	No	No	No	No	No	Yes
Shibata (2023)	Unclear	No	No	No	No	No	No	No	No	No	No	Limited
Takemoto (2023)	Unclear	No	No	No	No	No	Yes	No	No	No	No	No
Zhang K (2024)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Hong (2025)	Unclear	No	No	No	No	No	Yes	No	No	No	No	No
Wang B (2025)	Yes	Yes	Yes	No	No	No	No	No	No	No	No	Yes
Huang (2026)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Menaga (2026)	Unclear	No	No	No	No	No	No	No	No	No	No	No
GASTRIC INTESTINAL METAPLASIA (GIM) · n = 11												
Wang (2019)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Siripoppohn (2021)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Siripoppohn (2022)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Tiankanon (2022)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Pornvoraphat (2023)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Chen Y-T (2024)	Unclear	No	No	No	No	No	No	No	No	Yes	No	No
Pornvoraphat (2024)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Tiankanon (2024)	N/A	No	No	Yes	Yes	Yes	Yes	No	No	No	No	No
Obukhova (2025)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Yu (2026)	Unclear	No	No	No	No	No	No	No	No	No	No	No
Zhang M (2026)	Unclear	No	No	Yes	No	No	No	No	No	Yes	No	No
GASTRIC ATROPHY / CAG · n = 2												
Zhao (2023)	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No	No
Chen H (2025)	Unclear	No	No	No	No	No	Yes	No	No	No	No	No
MULTIPLE-STAGE CARCINOGENESIS · n = 1												
Gong (2023)	Unclear	Yes	Yes	Yes	No	No	No	No	No	No	No	No

DOMAIN STATUS Yes · No · Unclear · Limited · N/A

Domains are reported separately; no composite readiness score was calculated.

Limited = partial or demonstration-only evaluation. N/A = patient-disjoint internal testing not applicable to a prospective clinical cohort.

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	Title
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	Abstract
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	Introduction
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	Introduction
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	Methods: Study design and study selection
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	Methods: Study design and study selection; Supplementary Information
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	Supplementary Information: search strategies
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	Methods: Study design and study selection
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	Methods: Study design and study selection; Data extraction and methodological assessment
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	Methods: Data extraction and methodological assessment
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	Methods: Data extraction and methodological assessment
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	Methods: Data extraction and methodological assessment; Supplementary Table 1
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Methods: Data extraction and methodological assessment; Evidence synthesis
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	Methods: Evidence synthesis
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	Methods: Data extraction and methodological assessment
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Methods: Evidence synthesis; Tables 1-3; Figs. 2-3
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	Methods: Evidence synthesis
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	Methods: Evidence synthesis

Section and Topic	Item #	Checklist item	Location where item is reported
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	Not applicable
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	Not applicable
Certainty assessment	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	Not applicable
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	Results: Study selection and study characteristics; Fig. 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	Not applicable
Study characteristics	17	Cite each included study and present its characteristics.	Results: Study selection and study characteristics; Table 1
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Results: Validation and clinical applicability; Supplementary Table 1
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Results: Spatial tasks and performance; Table 2; Supplementary Table 2
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	Results: Study characteristics and validation; Tables 1 and 3
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	Not applicable
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	Results: Spatial tasks and performance; Validation and clinical applicability
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	Not applicable
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	Not applicable
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	Not applicable
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	Discussion
	23b	Discuss any limitations of the evidence included in the review.	Discussion
	23c	Discuss any limitations of the review processes used.	Discussion
	23d	Discuss implications of the results for practice, policy, and future research.	Discussion
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	Methods: Study design and study selection
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Methods: Study design and study selection
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	Methods: Study design and study selection

PRISMA 2020 Checklist

Section and Topic	Item #	Checklist item	Location where item is reported
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	Not applicable
Competing interests	26	Declare any competing interests of review authors.	Competing interests
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Data availability