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REVIEW

Computed tomography versus magnetic resonance imaging for diagnosing cervical lymph node metastasis of head and neck cancer: a systematic review and meta-analysis

J Sun[1]
B Li[2]
CJ Li[1]
Y Li[1]
F Su[3]
QH Gao[4]
FL Wu[4]
T Yu[5]
L Wu[6]
LJ Li[1]

[1]Department of Head and Neck Oncology, West China Hospital of Stomatology, State Key Laboratory of Oral Diseases, Sichuan University, Chengdu, People's Republic of China; [2]West China School of Stomatology, State Key Laboratory of Oral Diseases, Sichuan University, Chengdu, People's Republic of China; [3]Department of stomatology, Tianjin University of Traditional Chinese Medicine, Tianjin, People's Republic of China; [4]Department of Oral and Maxillofacial Surgery, State Key Laboratory of Oral Diseases, West China Hospital of Stomatology, Sichuan University, Chengdu, People's Republic of China; [5]Department of Head and Neck Oncology Surgery, Sichuan Cancer Hospital, Chengdu, People's Republic of China; [6]Center for Clinical and Translational Science, Mayo Clinic, Rochester, MN, USA

Correspondence: CJ Li; LJ Li
Department of Head and Neck Oncology, West China Hospital of Stomatology, State Key Laboratory of Oral Diseases, Sichuan University, 14# sec 3, South Renmin Road, Chengdu, 610041, People's Republic of China
Tel +86 28 8550 1428
Email lichunjie07@qq.com; muzili63@163.com

Abstract: Computed tomography (CT) and magnetic resonance imaging (MRI) are common imaging methods to detect cervical lymph node metastasis of head and neck cancer. We aimed to assess the diagnostic efficacy of CT and MRI in detecting cervical lymph node metastasis, and to establish unified diagnostic criteria via systematic review and meta-analysis. A systematic literature search in five databases until January 2014 was carried out. All retrieved studies were reviewed and eligible studies were qualitatively summarized. Besides pooling the sensitivity (SEN) and specificity (SPE) data of CT and MRI, summary receiver operating characteristic curves were generated. A total of 63 studies including 3,029 participants were involved. The pooled results of meta-analysis showed that CT had a higher SEN (0.77 [95% confidence interval {CI} 0.73–0.87]) than MRI (0.72 [95% CI 0.70–0.74]) when node was considered as unit of analysis ($P<0.05$); MRI had a higher SPE (0.81 [95% CI 0.80–0.82]) than CT (0.72 [95% CI 0.69–0.74]) when neck level was considered as unit of analysis ($P<0.05$) and MRI had a higher area under concentration-time curve than CT when the patient was considered as unit of analysis ($P<0.05$). With regards to diagnostic criteria, for MRI, the results showed that the minimal axial diameter of 10 mm could be considered as the best size criterion, compared to 12 mm for CT. Overall, MRI conferred significantly higher SPE while CT demonstrated higher SEN. The diagnostic criteria for MRI and CT on size of metastatic lymph nodes were suggested as 10 and 12 mm, respectively.

Keywords: computed tomography, magnetic resonance imaging, metastasis, head and neck cancer, meta-analysis

Introduction

The occurrence of cervical lymph node metastasis in patients with head and neck cancers are very common.[1] The presence of cervical lymph node metastasis may affect the optimal treatment choice as well as prognosis in patients.[2] Management of patients presenting with cervical lymph node metastasis includes selective or radical neck dissection, followed by radiotherapy and/or chemotherapy depending on the pathological findings of the nodes.[3–5] Besides, the detection of cervical lymph node metastasis is very important for predicting prognosis in patients with head and neck cancers.[6–8]

Many imaging techniques exist for identifying cervical lymph node metastasis in patients with head and neck cancers.[9–12] Among them, computed tomography (CT) and magnetic resonance imaging (MRI) are the most widely used tools.[13] Both of them have improved accuracy of nodal staging over clinical palpation and the nodes which are clinically occulted can be visualized through these techniques.[14] Usually the cervical lymph nodes demonstrate similar density as muscle on pre-contrast images of CT examination, and they can be separated from adjacent vessels by their differential enhancement after contrast administration.[15] On the other hand, MRI is considered to have similar accuracy for identifying the cervical lymph node metastasis of head and neck cancer.[16,17] Because of the intrinsic high soft-tissue discrimination, MRI has become the preferred method for evaluating the soft tissues of the head and neck recently.[18] Under current health care settings, the routine practice for evaluating patients with head and neck cancer is to perform either CT or MRI, but not both.[19] Thus, to determine whether one of the two techniques is superior to the other is critical for providing guidance for clinical practice. Besides, since relevant studies utilized very different diagnostic criteria, it is warranted to determine the unified criteria that are most appropriate. A systematic review to assess all available evidence is thus needed for providing a comprehensive evaluation for these aims.

The aim of this study was thus to compare CT and MRI for detecting cervical lymph node metastasis in patients with head and neck cancer and to establish the unified diagnostic criteria by performing a systematic review and meta-analysis.

Methods

Inclusion criteria

The inclusion criteria were as follows: a) types of study: diagnostic accuracy test studies designed as cohort studies; b) participants: patients with biopsy proven head and neck cancers who would undergo neck dissection; c) index tests: CT and/or MRI; d) target condition: cervical lymph node metastasis; e) reference standard: histopathology examination; f) outcome: rates of true positive, false positive, false negative, and true negative or related data that could be used to calculate them.

Literature search

With no language restriction, the following databases were searched for retrieving studies: MEDLINE (1948 to 25 January 2014), EMBASE (1980 to 25 January 2014), China National Knowledge Infrastructure (1994 to 25 January 2014), VIP Chinese Journal Database (1989 to 25 January 2014), and Chinainfo (1998 to 25 January 2014).

The search strategy was optimized for all consulted databases, taking into account the differences in the various controlled vocabularies as well as the differences of database-specific technical variations.[20] Once relevant articles were identified, their reference lists were searched for additional articles. Both Medical Subject Headings (MeSH) and free text words were used in the search strategy with the following MeSH terms: "head and neck neoplasm", "neoplasm metastases", "SEN and SPE", "Tomography, Spiral Computed" and "Magnetic Resonance Imaging".

Study selection

Two reviewers independently examined the titles and abstracts of each search record to remove obviously irrelevant ones, and then retrieved the full text articles for potentially eligible articles. The full-texts were further examined according to the inclusion criteria. Discrepancies were resolved by consensus.

Data extraction

A standardized data extraction form was used by two authors independently for data extraction from included studies. Discrepancies were resolved by discussion, with input from a third author. The contents of the form included: name of first author, publication year, country, participants' age, sex, number of included patients, tumor location, unit, details of CT and/or MRI, study design (prospective or retrospective).

Quality assessment

The methodological quality of included studies was assessed by The Quality Assessment Diagnostic Accuracy Studies statement-2 (QUADAS-2),[21] which included four domains: patient selection, index test, reference standard, and flow and timing. Each domain was assessed in terms of risk of bias and the first three were assessed in terms of concerns regarding applicability. Signaling questions were included to assist judgments on risk of bias. The signaling questions in the QUADAS-2 were presented as shown in Table 1. The result for each item was categorized as yes (Y), unclear (U), or no (N). The summary risk of bias for each study was categorized as low (A), unclear (B), or high (C).

Meta-analysis

Measures of diagnostic efficacy of CT and/or MRI included sensitivity (SEN), specificity (SPE), positive likelihood ratio (+LR), negative likelihood ratio (–LR), accuracy (ACC), and diagnostic odds ratios (DOR) with 95% confidence intervals (CIs). Summary receiver operating characteristic (SROC) curves were then drawn. The area under the curve (AUC) and Q* (the point where SEN is equal to SPE on the SROC curve) were calculated.

To detect any differences for SEN, SPE, AUC, and Q* between CT and MRI, a Z-test was conducted

Table 1 Signaling questions in the QUADAS-2

Domain	Patient selection	Index test	Reference standard	Flow and timing
Signaling questions (yes/no/unclear)	1 Was a consecutive or random sample of patients enrolled?	4 Were the index test results interpreted without knowledge of the results of the reference standard?	5 Is the reference standard likely to correctly classify the target condition?	7 Was there an appropriate interval between index test(s) and reference standard?
	2 Was a case-control design avoided?		6 Were the reference standard results interpreted without knowledge of the results of the index test?	8 Did all patients receive a reference standard?
	3 Did the study avoid inappropriate exclusions?			9 Were all patients included in the analysis?

Abbreviation: QUADAS-2, The Quality Assessment Diagnostic Accuracy Studies statement-2.

($Z= (VAL1-VAL2)/SQRT(SE1^2+SE2^2)$). The test standard was set at $\alpha=0.05$. VAL indicates the mean of SEN, SPE, AUC or Q* of the CT or MRI and SE indicates the standard error of the corresponding variable.

Heterogeneity analysis

Heterogeneity between studies was evaluated by I^2 statistic.[22,23] If $I^2\leq50\%$ and $P\geq0.10$, the heterogeneity was considered not significant and in such case the fixed-effects model would be used in meta-analysis. Otherwise, the random-effects model would be used.[24,25]

Meta-regression

Meta-regression was used to determine any potential source of heterogeneity that might influence the overall assessment. The test standard for meta-regression was set at $\alpha=0.10$. Relevant variables which might cause heterogeneities were tested, and any suggested sources of heterogeneity were considered as proof for a subgroup analysis. Variables detected by meta-regression included publication year (0= published before 2000; 1= published in or after 2000), race (0= Mongolia; 1= Caucasian), study type (0= retrospective; 1= prospective), risk of bias (0= high; 1= unclear; 2= low), blinding of the radiologists (0= no or unclear; 1= yes) and blinding of the pathologists (0= no or unclear; 1= yes). Meta-disc 1.4 and STATA 11.0 (StataCorp LP, College Station, TX, USA) were used to perform the statistical analyses.[26,27]

Results

Selection of literature

The computerized and manual search retrieved a total of 306 articles. After assessing the titles and abstracts, 144 articles were found to be potentially relevant. After the full text assessment, 63 studies met the inclusion criteria and were included in this meta-analysis (Figure 1).[28–90]

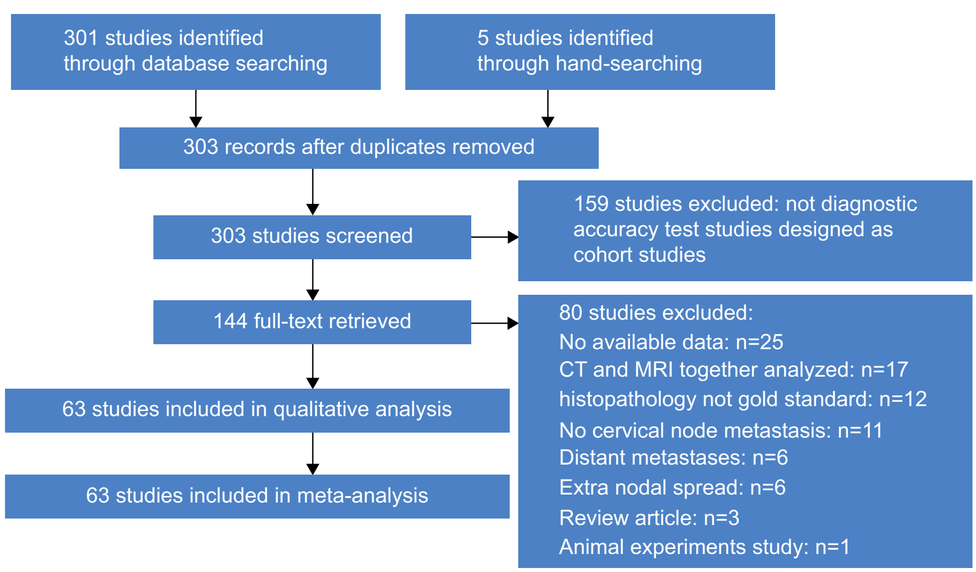

Figure 1 Flow chart of the literature search and selection.
Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging.

Study characteristics

Of the 63 included studies, 24 were retrospective and 39 were prospective. A total of 3,029 participants were involved in these studies. Among those patients, 1,044 underwent both CT and MRI examination, 2,395 underwent MRI examination, and 1,678 underwent CT examination. Three kinds of unit of analysis were used, including node, neck level (the neck was classified as five levels according to anatomical landmarks), and patients. When node was considered as the unit of analysis, available studies involved 22 with CT and 30 with MRI. When neck level was considered as the unit of analysis, eight studies with CT and 16 with MRI were available. When patient was considered as the unit of analysis, available studies included eight with CT and eleven with MRI. The tumor locations included floor of mouth, nasopharynx, retro-molar trigonum, mandibule, maxilla, supra-glottic larynx, oropharynx, laryngopharynx, hypopharynx, parotid gland, submandibular gland, tonsil, thyroid gland, cervical esophageal, paranasal sinuses et al. The characteristics of included studies are listed in Table 2.

Quality of included studies

All included studies had fairly good applicability. For the risk of bias assessment, only two studies had a low risk of bias, five had a high risk, and 56 had an unclear risk (Table 3).

Comparison of CT and MRI in detecting cervical lymph node metastasis with node as unit of analysis

For CT, meta-regression analysis showed that the diagnostic efficacy was not affected by any of the tested variables. These variables thus did not account for heterogeneity between studies. After pooling 22 studies, we detected that CT had a mean (CI) SEN of 0.77 (95% CI 0.73–0.80), SPE of 0.85 (0.84–0.87), +LR of 3.84 (2.51–5.87), –LR of 0.34 (0.24–0.27), ACC of 0.8357, and DOR of 13.57 (6.99–26.33). The SROC was demonstrated in Figure 2 and the AUC was 0.8429 and Q* was 0.7745. For MRI, meta-regression analysis also showed that the diagnostic efficacy was not affected by any of the tested variables. After pooling 30 studies, we identified that MRI had a mean (CI) SEN of 0.72 (0.70–0.74), SPE of 0.84 (0.83–0.85), +LR of 5.06 (3.72–6.88), –LR of 0.27 (0.21–0.34), ACC of 0.8126, and DOR of 25.21 (15.97–39.80). The SROC is shown in Figure 2 and the AUC was 0.9054 and Q* was 0.8371.

By comparing the diagnostic efficacy between CT and MRI when node was treated as the unit of analysis, the results indicated that CT had a higher SEN, although the SPE and summarized diagnostic efficacy were comparable. The details are listed in Table 4.

Comparison of CT and MRI in detecting cervical lymph node metastasis with neck level as unit of analysis

For MRI, meta-regression analysis detected that none of the tested variables accounted for heterogeneity between studies. After pooling 16 studies, it was detected that MRI had a mean (CI) SEN of 0.80 (0.77–0.82), SPE of 0.81 (0.80–0.82), +LR of 5.34 (3.24–8.82), –LR of 0.27 (0.20–0.37), ACC of 0.5257, DOR of 24.61 (12.21–49.61) and the AUC was 0.8860 and Q* was 0.8165 (Figure 3). For CT, similarly none of the tested variables accounted for heterogeneity. The pooling of available studies identified that CT had a mean (CI) SEN of 0.80 (0.75–0.84), SPE of 0.72 (0.69–0.74), +LR of 5.60 (2.13–14.73), –LR of 0.26 (0.19–0.36), ACC of 0.6888, DOR of 23.76 (7.87–71.79) and the AUC was 0.8787 and Q* was 0.8091 (Figure 3).

The comparison between CT and MRI showed that MRI had significantly higher SPE than CT while the other variables were comparable between these two techniques (Table 4).

Comparison of CT and MRI in detecting cervical lymph node metastasis with patient as unit of analysis

For the two studies, the pooled results showed that CT had a mean (CI): SEN, 0.81 (0.65–0.92); SPE, 0.35 (0.24–0.42); +LR, 1.14 (0.87–1.50); –LR, 0.70 (0.32–1.52); DOR, 1.66 (0.57–4.82) (Figure S1). For MRI, which included ten studies, meta-regression analysis showed that study type significantly affected the assessment of diagnostic efficacy (P=0.04) (Table 5). Based on the subgroup analysis according to study types, for the four retrospective studies, the pooled results indicated that MRI had a mean (CI) SEN, 0.77 (0.69–0.85); SPE, 0.48 (0.42–0.55); +CR, 2.42 (0.99–5.91); –CR, 0.54 (0.27–1.06); DOR, 5.24 (0.96–28.55) (Figure S2). For the five prospective studies, the pooled results showed that MRI had a mean (CI) SEN, 0.80 (0.72–0.86); SPE, 0.35 (0.67–0.86); +LR, 2.79 (1.44–5.40); –LR, 0.25 (0.08–0.76); DOR, 14.63 (3.64–58.70) (Figure S3). Pooling of the overall nine studies indicated the mean (CI) values for the following parameters to be: SEN, 0.79 (0.73–0.84); SPE, 0.56 (0.51–0.62); +LR, 2.64 (1.30–5.34); –LR, 0.37(0.20–0.71); DOR, 8.87 (2.42–32.55); AUC (0.8158); Q* (0.7498) (Figure S4).

Table 2 Study characteristics and included data sets for CT and MRI of the included articles

Study ID	Country	Study type	Patients (M/F)	Age (yr), mean (range)	Tumor location	Imaging modality	Unit
Adams et al[28] 1998	Germany	P	60 (16/44)	58.3 (38–76)	Tongue, FOM, Palate, MAN, MAX	MRI, CT	node
Akoglu et al[29] 2005	Turkey	P	23 (19/4)	58.3 (40–78)	Head and neck	MRI, CT	node
Anzai et al[30] 1994	USA	P	12 (7/5)	39–78	EAC, MAN, BCC, RMT, Lip, Oral cavity, Larynx	MRI	node
Ao et al[31] 1998	Japan	R	42 (9/33)	60 (39–78)	Larynx	MRI, CT	node
Bondt et al[32] 2009	The Netherlands	P	16 (9/7)	40–77	Tongue, NP, RMT, SMG, Cheek, RMT, SP, Nose	MRI, CT	neck level
Braams et al[33] 1996	The Netherlands	P	11 (7/4)	62.3 (46–73)	FOM, RMT, Cheek, Gingiva	MRI, CT	node
Braams et al[34] 1995	The Netherlands	P	12 (8/4)	65.3 (48–85)	Tongue, Lip, Gingiva, RMT, FOM	MRI	node
Bruschini et al[35] 2003	Italy	P	22 (19/3)	62.3 (46–79)	Larynx, OP, Oral cavity, Skin	CT	node
Curtin et al[36] 1997	Canada	R	213 (150/63)	59.6 (18–84)	Oral cavity, OP, HP, Larynx	MRI, CT	neck level
Dammann et al[37] 2005	Germany	P	64 (43/21)	56 (26–83)	Oral cavity, OP	MRI, CT	neck level
Ding et al[38] 2005	People's Republic of China	P	92 (58/34)	53 (24–81)	Tongue	MRI	neck level
Dirix et al[39] 2010	Sweden	P	22 (13/9)	60 (41–83)	Oral cavity, Larynx, HP	MRI	node
Eida et al[40] 2003	Japan	P	111 (74/37)		FOM, Tongue, Palate, Gingiva, Cheek	CT	node
Fan et al[41] 2006	People's Republic of China	R	42 (37/5)	53.6 (45–70)	OP, HP, Cervical esophageal	CT	patient
Fukunari et al[42] 2010	Japan	R	20	58 (23–81)	Tongue, Gingiva, Buccal, MAN, FOM	MRI	node
Gross et al[43] 2001	USA	R	26 (8/18)	40 (10–80)	Thyroid	MRI	node
Gu et al[44] 2000	People's Republic of China	P	62	58 (44–77)	Head and neck	MRI	node
Guenzel et al[45] 2013	Germany	P	120 (95/25)	41–85	OP, Larynx	MRI	node
Guo et al[46] 2006	People's Republic of China	R	48 (28/20)	56 (21–66)	Tongue, Buccal, Gingiva, FOM, Palate	MRI	node
Hannah et al[47] 2002	Australia	P	48 (34/14)	61 (26–92)	Oral cavity, OP, SGL, HP	CT	neck level
Hao et al[48] 2000	People's Republic of China	P	60		Tongue, Gingiva, FOM, Palate, RMT, Buccal, Larynx, HP	MRI	node
Hafidh et al[49] 2006	Ireland	R	48 (42/6)	56 (32–80)	Oral cavity, OP, HP, Paranasal sinuses, Ear(skin)	MRI, CT	node
Hlawitschka et al[50] 2002	Germany	P	38 (28/10)	59 (41–89)	Tongue, Buccal, Palate, MAX	MRI, CT	node
Hoffman et al[51] 2000	USA	P	9 (6/3)	43–76	Oral cavity, OP, Lip	MRI	node, neck level
Jeong et al[52] 2007	Greece	R	47 (41/6)	56.3	Oral cavity, Larynx, OP, HP, PG	CT	neck level
Kau et al[53] 1999	Germany	P	111 (95/16)	29–78	Larynx, OP, LP, Lip, Ear	MRI, CT	node, neck level
Kawai et al[54] 2005	Japan	P	29 (23/6)	60 (28–81)	Tongue, OP, NP, Larynx, Buccal, Palate, PG, Gingiva	MRI	neck level
Ke et al[55] 2006	People's Republic of China	R	20 (15/5)	54.5 (31–69)	Tongue, Larynx, Thyroid gland	CT	node
Krabbe et al[56] 2008	The Netherlands	P	38 (21/17)	59 (53–680)	Tongue, Gingiva, FOM, Tonsillar fossa	MRI, CT	node
Laubenbacher et al[57] 1994	Germany	P	22 (20/2)	54.4 (38–70)	OP, HP	MRI	node, neck level
Lee et al[58] 2013	People's Republic of China	P	22 (21/1)	49.8 (26–66)	Tongue, Buccal, OP, FOM, HP, Palate, RMT, epiglottis, Pyriform sinus	MRI	patient
Lu et al[59] 2007	People's Republic of China	P	13 (11/2)	58 (47–71)	Oral cavity, HP, OP, Larynx	CT	node
Lwin et al[60] 2012	UK	R	102 (68/34)	59 (23–89)	Tongue, FOM, Palate, Buccal, RMT, Tonsil, Gingiva	MRI	patient
Mcguirt et al[61] 1995	UK	P	49		Oral cavity, OP, HP	CT	node
Nakamoto et al[62] 2009	Japan	R	65 (50/15)	62 (27–81)	Larynx, HP, MAX, Tongue, OP, PG, Gingiva, FOM, NP, Ethmoid, EAM, Thyoid	MRI	patient
Nishimura et al[63] 2006	Japan	P	16 (13/3)	65.8 (37–76)	Cervical Esophageal	MRI	node
Olmos et al[64] 1999	The Netherlands	P	12 (6/6)	61.8 (44–73)	OP, Larynx, HP, Tongue, MAX	MRI	neck level

(*Continued*)

Table 2 (*Continued*)

Study ID	Country	Study type	Patients (M/F)	Age (yr)	Tumor location	Imaging modality	Unit
Ou et al[65] 2007	People's Republic of China	R	24 (19/5)	50 (23–80)	Tongue, OP, Palate, Cheek, Maxillary sinus, Branchial cleft	MRI	node
Paulus et al[66] 1998	Belgium	R	25 (21/4)	48–74	SGL, Tongue, Glottis, Palate, RMT, FOM, HP, Vocal cord, Vestibule, Pyriform sinus	CT	node
Perrone et al[67] 2011	Italy	R	17 (10/7)	63 (15–85)	Head and neck	MRI	patient
Peters et al[68] 2013	The Netherlands	R	149 (120/29)	62 (40–78)	SGL, Glottis, NP, Cervical Esophageal	MRI, CT	patient
Pohar et al[69] 2006	USA	R	25 (17/8)	63.4	Oral cavity, OP, HP, Larynx, Nasal cavity	CT	node, neck level
Ren et al[70] 2000	People's Republic of China	P	20 (18/2)	45–68	SGL	CT	node
Schwartz et al[71] 2004	USA	P	20 (20/0)	61 (42–78)	Oral cavity, OP	CT	node
Semedo et al[72] 2006	Portugal	P	20 (20/0)	57.3 (36–78)	HP, Larynx, OP	MRI	node
Seitz et al[73] 2009	Germany	R	66 (39/27)	63 (25–89)	Oral cavity, OP	MRI	node, patient
Stokkel et al[74] 2000	The Netherlands	P	54 (31/23)	60 (34–81)	Tongue, FOM, Gingiva, RMT, OP	CT	node
Stuckensen et al[75] 2000	Germany	P	106 (89/17)	59.6 (33–87)	FOM, Tongue, RMT, MAN, MAX, Buccal	MRI, CT	neck level
Sumi et al[76] 2007	Japan	R	38 (32/6)	65	HP, Gingiva, OP, Tongue, Larynx, FOM	MRI, CT	node
Sumi et al[77] 2006	Japan	P	26		OP, Gingiva, Larynx, Tongue	MRI	node
Sumi et al[78] 2003	Japan	P	32	24–80	OP, Gingiva, FOM, Tongue, Buccal, EAC	MRI	node
Sun et al[79] 2013	People's Republic of China	R	114 (60/54)	51.2 (34–70)	Thyroid gland, Larynx, NP, HP, Tongue, PG, Cervical Esophageal, Maxillary sinus, Ear	CT	node
Sun et al[79] 2013	People's Republic of China	R	86 (45/41)	52.7 (35–75)	Thyroid gland, Larynx, NP, HP, Tongue, PG, Cervical Esophageal, Maxillary sinus, Ear	MRI	node
Tai et al[80] 2002	People's Republic of China	P	40 (24/16)	25–65	NP	MRI	patient
Takashima et al[81] 1997	Japan	R	50 (13/37)	57 (24–81)	Thyroid	MRI	node
Tuli et al[82] 2008	India	P	20 (12/8)	54.75 (30–85)	Tongue	MRI, CT	patient
Van den Brekel et al[83] 1991	The Netherlands	P	100	63±12.8	Tongue, FOM, SP, Lip, Tonsil, Pharyngeal wall, Ear, Tonsil, PS, SGL, Gingiva	MRI	patient
Vandecaveye et al[84] 2008	Belgium	P	36	41–81	Nasal cavity, SGL, FOM, OP, Glottis, Tongue, HP	MRI	node, neck level, patient
Wang et al[85] 1999	Japan	P	14 (10/4)	46 (26–71)	Thyroid	MRI	node
WIDE et al[86] 1999	UK	R	58	58.1 (32–82)	Tongue, FOM, Buccal, RMT, OP, Gingiva	MRI	neck level
Wilson et al[87] 1994	UK	P	12		FOM, Tongue, Tonsillar, Skin, Pinna, PG, Thyroid	MRI	neck level
Wu et al[88] 2010	People's Republic of China	R	24 (23/1)	53.6 (45–85)	Larynx, HP	CT	node
Yoon et al[89] 2008	Korea	R	67 (58/9)	60 (24–85)	Larynx, Pharynx, Tonsil, Tongue, Oral cavity, Skin, MAX	MRI, CT	neck level
Yuan et al[90] 2000	People's Republic of China	R	19 (12/7)	42–66	Larynx	MRI	neck level

Abbreviations: M, male; F, female; R, Retrospective; P, Prospective; EAC, external auditory canal; BCC, branchial cleft cyst; PS, piriform sinus; SGL, supra-glottic larynx; TGL, trans-glottic larynx; CT, computed tomography; MRI, magnetic resonance imaging; FOM, floor of mouth; MAN, mandibule; MAX, maxilla; RMT, retro-molar trigonum; NP, nasopharynx; SMG, submandibular gland; OP, oropharynx; HP, hypopharynx; LP, laryngopharynx; PG, parotid gland; SP, supropharynx; yr, years.

Table 3 Risk of bias of included studies

Study ID	Patient selection			Index test	Reference standard			Flow and timing		Summary risk of bias	Applicability
	1	2	3	4	5	6	7	8	9		
Adams et al[28] 1998	U	Y	Y	Y	Y	U	Y	Y	Y	B	H
Akoglu et al[29] 2005	Y	Y	Y	U	Y	U	U	Y	Y	B	H
Anzai et al[30] 1994	U	Y	Y	U	Y	U	Y	Y	Y	B	H
Ao et al[31] 1998	U	Y	Y	U	Y	U	U	Y	Y	B	H
Bondt et al[32] 2009	Y	Y	Y	Y	Y	U	U	Y	Y	B	H
Braams et al[33] 1996	U	Y	Y	Y	Y	U	Y	Y	Y	B	H
Braams et al[34] 1995	U	Y	Y	Y	Y	U	U	Y	Y	B	H
Bruschini et al[35] 2003	U	Y	Y	Y	Y	Y	U	Y	Y	B	H
Curtin et al[36] 1997	Y	Y	Y	U	Y	U	U	Y	Y	B	H
Dammann et al[37] 2005	U	Y	Y	Y	Y	U	Y	Y	Y	B	H
Ding et al[38] 2005	U	Y	Y	Y	Y	U	Y	Y	Y	B	H
Dirix et al[39] 2010	U	Y	Y	U	Y	U	Y	Y	Y	B	H
Eida et al[40] 2003	U	Y	Y	Y	Y	U	U	Y	Y	B	H
Fan et al[41] 2006	U	Y	Y	Y	Y	U	U	Y	N	A	H
Fukunari et al[42] 2010	U	Y	Y	U	Y	U	U	Y	Y	B	H
Gross et al[43] 2001	U	Y	Y	Y	Y	U	Y	Y	Y	B	H
Gu et al[44] 2000	U	Y	Y	Y	Y	U	U	Y	Y	B	H
Guenzel et al[45] 2013	U	Y	Y	U	Y	U	U	Y	Y	B	H
Guo et al[46] 2006	U	Y	Y	U	Y	U	U	Y	N	A	H
Hannah et al[47] 2002	U	Y	Y	U	Y	U	U	Y	Y	B	H
Hao et al[48] 2000	U	Y	Y	Y	Y	Y	U	Y	Y	B	H
Hafidh et al[49] 2006	U	Y	Y	Y	Y	U	U	Y	Y	B	H
Hlawitschka et al[50] 2002	Y	Y	Y	U	Y	U	U	Y	N	A	H
Hoffman et al[51] 2000	U	Y	Y	U	Y	U	U	Y	Y	B	H
Jeong et al[52] 2007	U	Y	Y	Y	Y	U	U	Y	Y	B	H
Kau et al[53] 1999	Y	Y	Y	Y	Y	U	Y	Y	Y	B	H
Kawai et al[54] 2005	Y	Y	Y	Y	Y	U	Y	Y	Y	B	H
Ke et al[55] 2006	Y	Y	Y	Y	Y	U	Y	Y	Y	B	H
Krabbe et al[56] 2008	U	Y	Y	U	Y	U	U	Y	Y	B	H
Laubenbacher et al[57] 1994	U	Y	Y	U	Y	U	U	Y	Y	B	H
Lee et al[58] 2013	Y	Y	Y	U	Y	U	Y	Y	Y	B	H
Lu et al[59] 2007	Y	Y	Y	Y	Y	U	U	Y	Y	B	H
Lwin et al[60] 2012	U	Y	Y	Y	Y	U	U	Y	Y	B	H
Mcguirt et al[61] 1995	Y	Y	Y	U	Y	Y	U	Y	Y	B	H
Nakamoto et al[62] 2009	U	Y	Y	U	Y	U	U	Y	Y	B	H
Nishimura et al[63] 2006	Y	Y	Y	U	Y	U	Y	Y	Y	B	H
Olmos et al[64] 1999	U	Y	Y	U	Y	U	Y	Y	N	A	H
Ou et al[65] 2007	U	Y	Y	U	Y	U	U	Y	Y	B	H
Paulus et al[66] 1998	U	Y	Y	U	Y	U	U	Y	Y	B	H
Perrone et al[67] 2011	U	Y	Y	U	Y	U	U	Y	Y	B	H
Peters et al[68] 2013	U	Y	Y	Y	Y	U	U	Y	Y	B	H
Pohar et al[69] 2006	Y	Y	Y	Y	Y	U	U	Y	Y	B	H
Ren et al[70] 2000	U	Y	Y	Y	Y	U	U	Y	Y	B	H
Schwartz et al[71] 2004	U	Y	Y	Y	Y	U	U	Y	Y	B	H
Semedo et al[72] 2006	Y	Y	Y	Y	Y	U	U	Y	Y	B	H
Seitz et al[73] 2009	Y	Y	Y	Y	Y	Y	Y	Y	Y	C	H
Stokkel et al[74] 2000	U	Y	Y	U	Y	U	Y	Y	Y	B	H
Stuckensen et al[75] 2000	Y	Y	Y	U	Y	U	Y	Y	Y	B	H
Sumi et al[76] 2007	U	Y	Y	U	Y	U	Y	Y	Y	B	H
Sumi et al[77] 2006	Y	Y	Y	Y	Y	U	Y	Y	Y	B	H
Sumi et al[78] 2003	Y	Y	Y	U	Y	U	U	Y	Y	B	H
Sun et al[79] 2013	Y	Y	Y	Y	Y	U	U	Y	Y	B	H
Tai et al[80] 2002	U	Y	Y	Y	Y	U	U	Y	N	A	H
Takashima et al[81] 1997	U	Y	Y	Y	Y	U	Y	Y	Y	B	H

(*Continued*)

Table 3 (*Continued*)

Study ID	Patient selection			Index test	Reference standard			Flow and timing		Summary risk of bias	Applicability
	1	2	3	4	5	6	7	8	9		
Tuli et al[82] 2008	Y	Y	Y	Y	Y	U	Y	Y	Y	B	H
Van den Brekel et al[83] 1991	U	Y	Y	Y	Y	U	Y	Y	Y	B	H
Vandecaveye et al[84] 2008	Y	Y	Y	Y	Y	Y	U	Y	Y	B	H
Wang et al[85] 1999	U	Y	Y	Y	Y	Y	Y	Y	Y	C	H
WIDE et al[86] 1999	U	Y	Y	Y	Y	U	U	Y	Y	B	H
Wilson et al[87] 1994	Y	Y	Y	Y	Y	U	U	Y	Y	B	H
Wu et al[88] 2010	U	Y	Y	U	Y	U	U	Y	Y	B	H
Yoon et al[89] 2008	U	Y	Y	U	Y	U	Y	Y	Y	B	H
Yuan et al[90] 2000	U	Y	Y	U	Y	U	Y	Y	Y	B	H

Abbreviations: Y, yes; U, unclear; N, no; A, high risk of bias; B, unclear risk of bias; C, low risk of bias; H, high applicability.

The comparison between CT and MRI showed that MRI had significantly higher AUC than CT while the other variables demonstrated no statistical significance between them. The details are listed in Table 4.

Lymph node size criteria

The size of metastatic lymph nodes used as diagnostic criteria of MRI and CT varied considerably among studies and among different neck levels (Table S1). To determine the best diagnostic criteria, a meta-analysis was conducted for different neck levels with lymph node unit data. For each neck level, the SROC curve was drawn to show the diagnostic efficacy of MRI for different node sizes (Figure 4). The results revealed that the minimal axial diameter of 10 mm in lymph node-bearing regions could be considered as the best size criterion for assessing cervical lymph node metastasis in patients with head and neck cancer (Table S2). For CT, the suggested criterion was 12 mm (Table S3). Considering the limited number of studies for CT, SROC curves were not drawn.

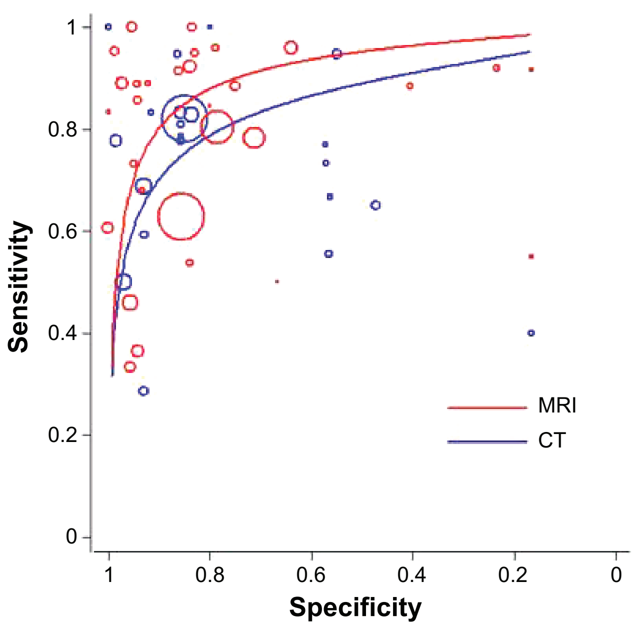

Figure 2 Summary receiver operator characteristic curves of CT and MRI (node as unit of analysis).
Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging.

Discussion

Head and neck cancer is a common malignant neoplasm worldwide.[1] One of the most important factors that influences treatment approaches and therapeutic outcomes for patients with head and neck cancer is the presence of metastatic cervical lymph node. The accurate detection of the cervical lymph node metastasis is thus very important.[91,92] Clinical palpation used to be the method to detect cervical nodal metastasis before the development of imaging technologies. However, studies have shown that both the SEN and the SPE of this technique were unsatisfactory, with a high false positive rate of 25%–51%. The improvements in imaging technologies may make it possible for cervical lymph nodes metastasis in head and neck cancer patients can be effectively diagnosed, especially with CT and MRI.[11,12,93–96] However, under current health care settings usually only one imaging technique will be performed. Thus a systematic evaluation regarding whether one of the two imaging techniques (CT and MRI) can have a better efficacy than the other will be critical to better guide the clinical practice.

In our systematic review and meta-analysis, we comprehensively evaluated all available evidence from 63 studies for evaluating this question whether one of the two imaging techniques (CT and MRI) can have a better efficacy.

Table 4 Comparison of meta-analysis results on diagnostic efficacy between CT and MRI

Unit	Variable	Number detected	SEN (95% CI)	SPE (95% CI)	AUC (SE)	Q* (SE)
Node	CT	2,483	0.77 (0.73–0.87)	0.85 (0.84–0.87)	0.8429 (0.0341)	0.7745 (0.0318)
	MRI	7,100	0.72 (0.70–0.74)	0.84 (0.83–0.85)	0.9054 (0.0198)	0.8371 (0.0215)
	P		0.0176	0.2739	0.1098	0.1262
Neck level	CT	1,665	0.84 (0.75–0.84)	0.72 (0.69–0.74)	0.8787 (0.0268)	0.8091 (0.0270)
	MRI	4,022	0.80 (0.77–0.82)	0.81 (0.80–0.82)	0.8860 (0.0262)	0.8165 (0.0269)
	P		1.0000	0.0000	0.8689	0.8702
Patient	CT	230	0.67 (0.52–0.80)	0.74 (0.68–0.81)	0.6860 (0.0815)	0.6418 (0.0643)
	MRI	716	0.78 (0.70–0.81)	0.76 (0.72–0.80)	0.8631 (0.0437)	0.7937 (0.0424)
	P		0.1992	0.6161	0.0491	0.0683

Abbreviations: AUC, area under the curve; CI, confidence interval; SE, standard error; CT, computed tomography; MRI, magnetic resonance imaging; SEN, sensitivity; SPE, specificity.

Besides pooling results from available studies, we assessed potential sources of heterogeneities via meta-regression and conducted sub-group analyses for significant heterogeneity sources detected. Our meta-analyses suggested that CT had a higher SEN than MRI when node was used as unit of analysis; MRI had a higher SPE when neck level was used as unit of analysis; and MRI had a higher AUC when patient was used as unit of analysis. Our findings showed that CT and MRI are effective tools for detecting the cervical lymph node metastasis in patients with head and neck cancer. Since the diagnostic criteria presented in relevant studies varied significantly, we also summarized available evidence to reveal the most appropriate ones for these two techniques, respectively. Usually, the diagnosis of metastatic cervical lymph nodes consisted of two parts, namely, structural and size changes. The structural changes included central necrosis or cystic degeneration, spherical (rather than flat or bean) shape, or abnormal grouping of nodes (a cluster of three or more lymph nodes of borderline size). In different studies, the description of the structural changes differed only mildly. However, the criteria for sizes differed considerably. Most authors recommended using the minimal axial diameter to assess metastasis. The criterion for minimal axial diameter varied between 5 to 15 mm. Our meta-analysis showed that the minimal axial diameter of 10 mm in lymph node-bearing regions could be considered as the best criterion for assessing cervical lymph node metastasis in patients with head and neck cancer for MRI, compared to 12 mm for CT. Several limitations should be acknowledged for the interpretation of our findings. Firstly, although we conducted meta-regression analyses and showed that the assessed variables largely did not account for heterogeneities between studies, additional undetected variables may account for heterogeneities which warrants further research. Secondly, in some of our analyses, only a very limited number of studies were available. For example, when focusing on the 12 mm size criterion, there was only one study available for evaluating CT with node unit, and future studies for evaluating relevant topics are warranted. In conclusion, through this comprehensive systematic review and meta-analysis, we identified that CT and MRI had acceptable diagnostic efficacy in detecting cervical lymph node metastasis in patients with head and neck cancer. When node was used as unit of analysis, CT had a higher SEN. When neck level was used as unit of analysis, MRI had a higher SPE. Out findings suggest that MRI is superior to CT in the diagnosis of cervical lymph node metastasis, especially in diagnosis confirmation. While CT had a better efficacy in diagnosis exclusion. The diagnostic criteria for MRI and CT for size of metastatic lymph nodes were established. Further high-quality studies are warranted to confirm our findings.

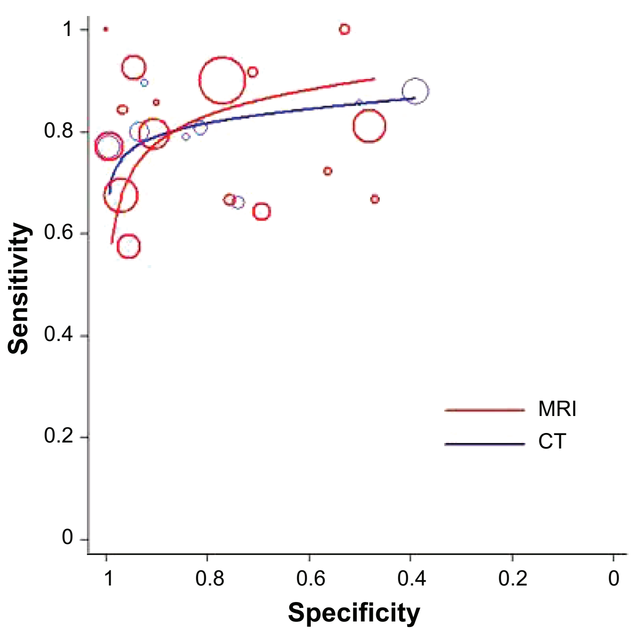

Figure 3 Summary receiver operator characteristic curves of CT and MRI (neck level as unit of analysis).
Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging.

Table 5 Results of meta-regression (MRI patient)

Variable	Coefficient	SE	*P*-value	RDOR	95% CI
Cte	–0.511	2.5493	0.8539	–	–
S	–0.330	0.1896	0.1798	–	–
Publication year	0.881	1.5156	0.6020	2.41	(0.02–300.01)
Race	1.786	1.1884	0.2298	5.97	(0.14–262.04)
Study type	3.288	0.9742	0.0432	26.80	(1.21–595.04)
Blinding of radiologists	–0.774	1.1952	0.5636	0.46	(0.01–20.70)
Blinding of pathologists	–0.290	1.5278	0.8615	0.75	(0.01–96.74)
Risk of bias	–0.227	0.9225	0.8217	0.80	(0.04–15.02)

Abbreviations: MRI, magnetic resonance imaging; CI, confidence interval; SE, standard error; RDOR, relative diagnostic odds ratio.

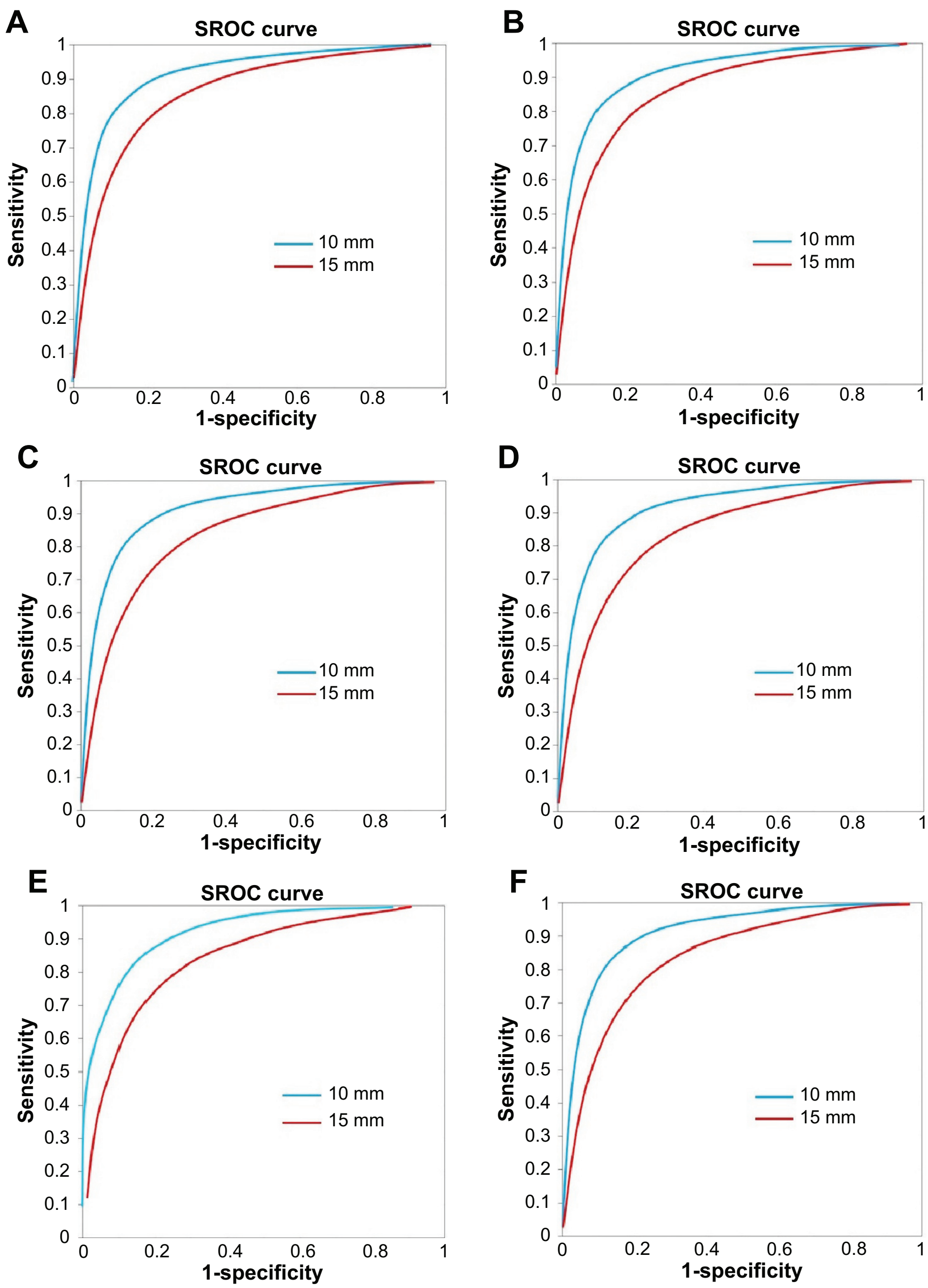

Figure 4 Summary receiver operator characteristic curves of CT and MRI (lymph node size criteria).
Abbreviations: CT, computed tomography; MRI, magnetic resonance imaging; SROC, summary receiver operating characteristic.

Disclosure

The first and corresponding authors had full access to all of the data in the study and had final responsibility for the decision to submit for publication. The authors have no conflicts of interest in this work.

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Supplementary materials

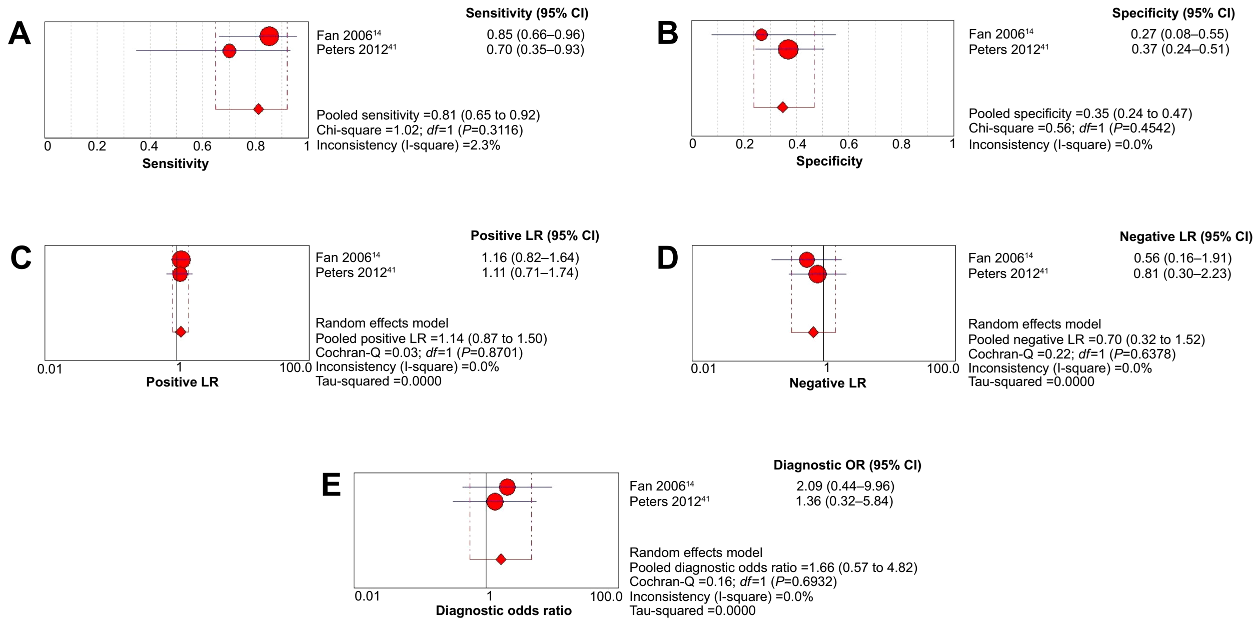

Figure S1 Meta-analysis of CT for detecting cervical lymph node metastasis in head and neck cancer patients (patient as unit of analysis).
Abbreviations: CT, computed tomography; CI, confidence interval; LR, likelihood ratio; *df*, degrees of freedom; SROC, summary receiver operating characteristic; AUC, area under the curve; SE, standard error.

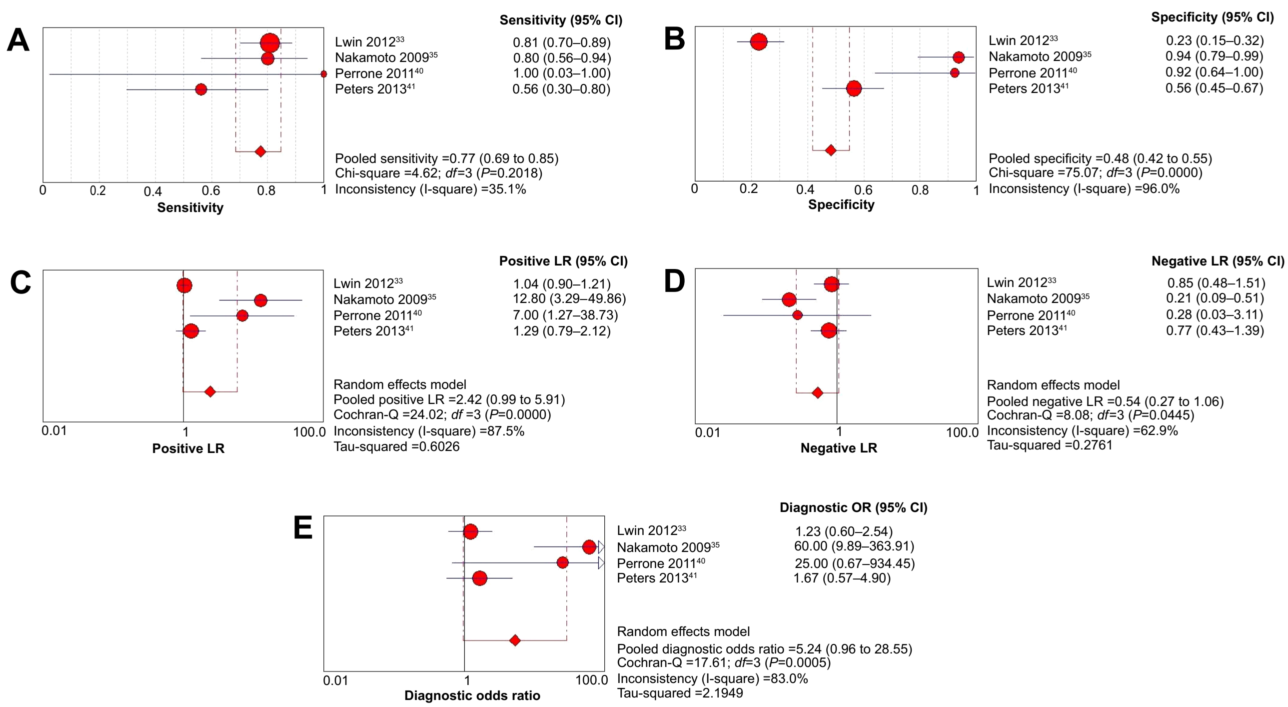

Figure S2 Meta-analysis of MRI for detecting cervical lymph node metastasis in head and neck cancer patients (patient as unit of analysis) (retrospective studies).
Abbreviations: MRI, magnetic resonance imaging; CI, confidence interval; *df*, degrees of freedom; LR, likelihood ratio; OR, odds ratio.

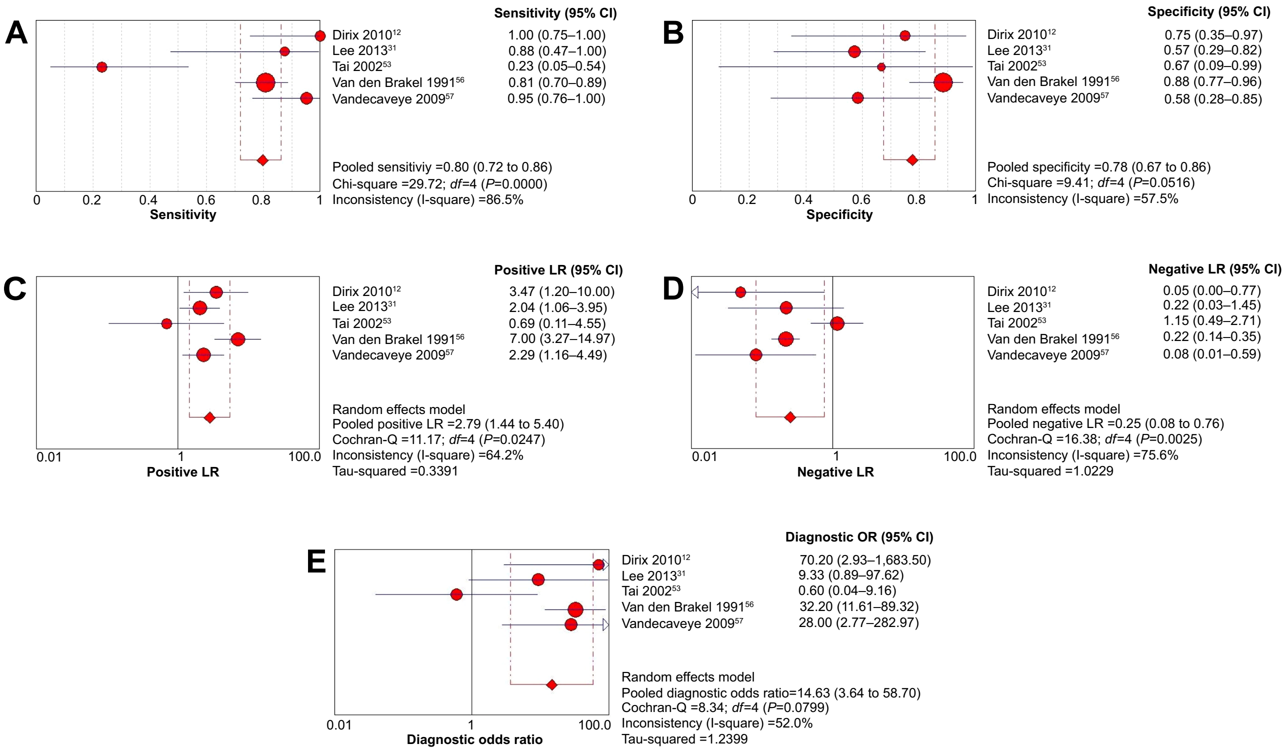

Figure S3 Meta-analysis of MRI for detecting cervical lymph node metastasis in head and neck cancer patients (patient as unit of analysis) (prospective studies).
Abbreviations: MRI, magnetic resonance imaging; CI, confidence interval; *df*, degrees of freedom; LR, likelihood ratio; OR, odds ratio.

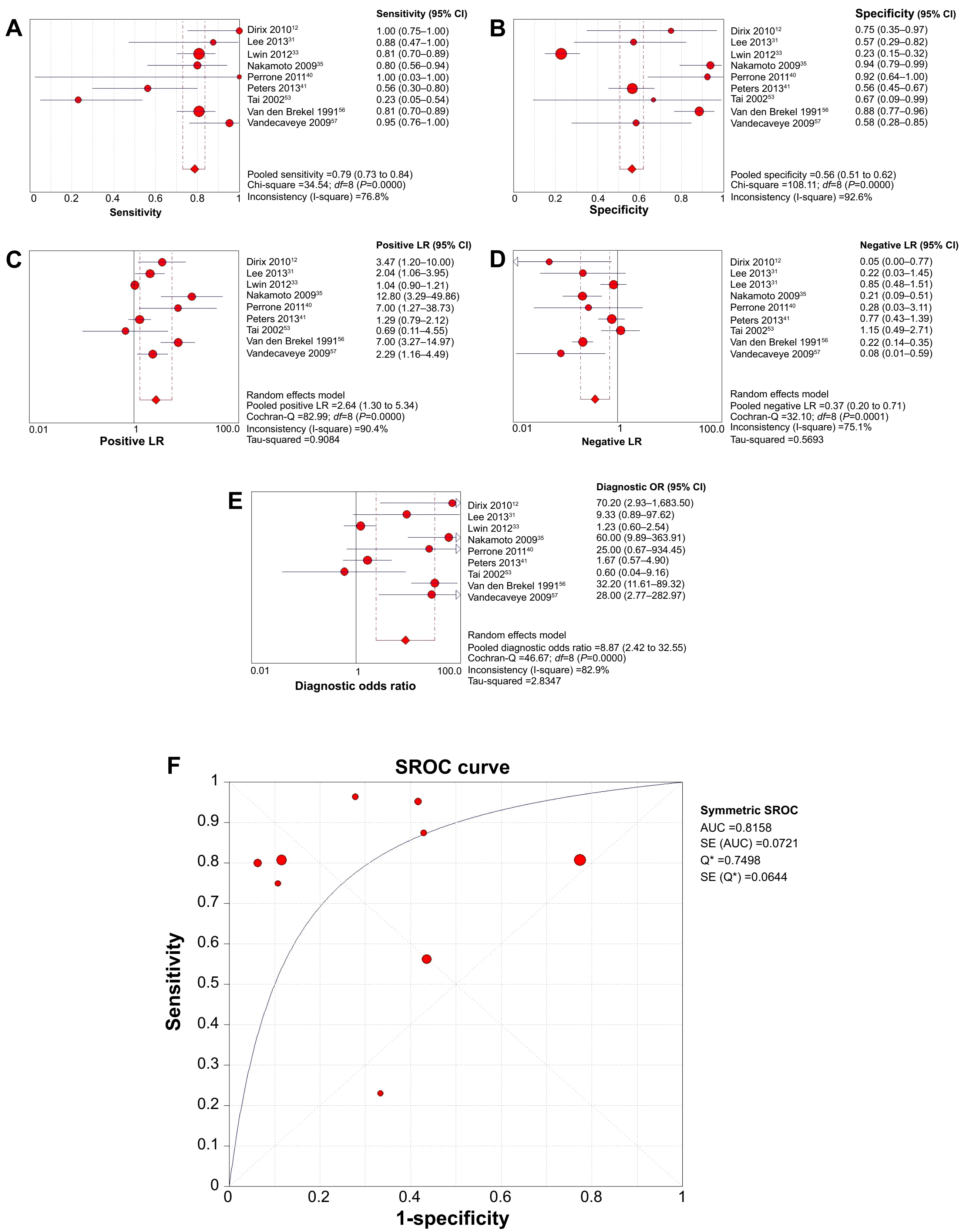

Figure S4 Meta-analysis of MRI for detecting cervical lymph node metastasis in head and neck cancer patients (patient as unit of analysis).

Abbreviations: MRI, magnetic resonance imaging; CI, confidence interval; *df*, degrees of freedom; LR, likelihood ratio; OR, odds ratio; SROC, summary receiver operating characteristic; AUC, area under the curve; SE, standard error.

Table S1 Study characteristics of lymph node size per neck level

Study ID	Method	Unit	I	II	III	IV	Retro	Others	TP	FP	FN	TN
Adams et al[1] 1998	CT	node	12	12	12	12	12	12	96	175	21	992
Adams et al[1] 1998	MRI	node	12	12	12	12	12	12	94	250	23	917
Akoglu et al[2] 2005	CT	node	15	15	15	15	15	15	21	2	6	12
Akoglu et al[2] 2005	MRI	node	15	15	15	15	15	15	16	1	11	13
Anzai et al[4] 1994	MRI	node	10	10	10	10	10	10	38	7	2	34
Braams et al[7] 1995	CT	node	11	10	10	10	10	10	5	10	4	13
Braams et al[7] 1995	MRI	node	10	11	10	10	10	10	5	6	10	134
Braams et al[7] 1995	MRI	node	11	10	10	10	10	10	8	10	14	167
Curtin et al[9] 1997	CT	neck level	5	5	5	5	5	5	57	415	1	62
Curtin et al[9] 1997	CT	neck level	7	7	7	7	7	7	56	396	2	81
Curtin et al[9] 1997	CT	neck level	8	8	8	8	8	8	55	372	3	105
Curtin et al[9] 1997	CT	neck level	9	9	9	9	9	9	53	329	5	148
Curtin et al[9] 1997	CT	neck level	10	10	10	10	10	10	51	291	7	186
Curtin et al[9] 1997	CT	neck level	11	11	11	11	11	11	46	210	12	267
Curtin et al[9] 1997	CT	neck level	12	12	12	12	12	12	43	157	15	320
Curtin et al[9] 1997	CT	neck level	15	15	15	15	15	15	32	76	26	401
Curtin et al[9] 1997	MRI	neck level	5	5	5	5	5	5	53	382	5	95
Curtin et al[9] 1997	MRI	neck level	7	7	7	7	7	7	52	367	6	110
Curtin et al[9] 1997	MRI	neck level	8	8	8	8	8	8	50	329	8	148
Curtin et al[9] 1997	MRI	neck level	9	9	9	9	9	9	48	281	10	196
Curtin et al[9] 1997	MRI	neck level	10	10	10	10	10	10	47	248	11	229
Curtin et al[9] 1997	MRI	neck level	11	11	11	11	11	11	41	167	17	310
Curtin et al[9] 1997	MRI	neck level	12	12	12	12	12	12	38	134	20	343
Curtin et al[9] 1997	MRI	neck level	15	15	15	15	15	15	30	67	28	410
Dammann et al[10] 2005	CT	neck level	10	10	10	10	10	10	32	17	8	236
Dammann et al[10] 2005	MRI	neck level	10	10	10	10	10	10	37	14	3	239
Ding et al[12] 2005	MRI	neck level	8	8	8	8	8	8	132	27	34	255
Dirix et al[12] 2010	MR-DW	neck level	10	10	10	10	10	10	30	3	2	93
Dirix et al[12] 2010	MR-DW	node	10	10	10	10	10	10	40	4	5	149
Dirix et al[12] 2010	MR-DW	patient	10	10	10	10	10	10	13	2	0	6
Eida et al[13] 2003	CT	node	8	9	6	7			3	5	3	162
Fan et al[14] 2006	CT	patient	10	11	10	10	10	10	23	11	4	4
Fukunari et al[15] 2010	MR	node	10	10	10	10	10	10	19	13	0	66
Gross et al[16] 2001	MR	node	11	10	10	10	10	10	143	22	6	39
Gu et al[17] 2000	MRI	node	10	11	10	10	10	10	8	3	1	50
Guenzel et al[18] 2013	MR	node	10	10	10	10	10	10	23	26	2	8
Guenzel et al[18] 2013	MR	node	15	15	15	15	15	15	20	6	2	28
Guo et al[19] 2006	MRI	node	10	10	10	10	10	10	8	3	1	36
Hafidh et al[22] 2006	CT	node	10	10	10	10	10	10	8	10	12	2
Hafidh et al[22] 2006	MRI	node	10	10	10	10	10	10	11	10	9	2
Hao et al[21] 2000	MRI	node	15	15	10	10	10	10	30	2	11	38

(Continued)

Table S1 (*Continued*)

Study ID	Method	Unit	I	II	III	IV	Retro	Others	TP	FP	FN	TN
Kau et al[26] 1999	CT	neck level	15	15	15	15	15	15	6	17	1	17
Kau et al[26] 1999	MRI	neck level	15	15	15	15	15	15	2	17	1	15
Kau et al[26] 1999	CT	node	15	15	15	15	15	15	13	20	7	18
Kau et al[26] 1999	MRI	node	15	15	15	15	15	15	23	22	3	15
Kawai et al[27] 2005	MRSPIR	neck level I	5						8	28	0	22
Kawai et al[27] 2005	MRSPIR	neck level I	6						8	18	0	32
Kawai et al[27] 2005	MRSPIR	neck level I	7						8	10	1	39
Kawai et al[27] 2005	MRSPIR	neck level I	8						8	5	1	44
Kawai et al[27] 2005	MRSPIR	neck level I	9						8	1	1	48
Kawai et al[27] 2005	MRSPIR	neck level I	10						5	0	2	51
Kawai et al[27] 2005	MRSTIR	neck level I	5						8	24	0	26
Kawai et al[27] 2005	MRSTIR	neck level I	6						8	16	0	34
Kawai et al[27] 2005	MRSTIR	neck level I	7						8	7	0	43
Kawai et al[27] 2005	MRSTIR	neck level I	8						8	6	0	44
Kawai et al[27] 2005	MRSTIR	neck level I	9						8	1	1	48
Kawai et al[27] 2005	MRSTIR	neck level I	10						6	0	4	48
Kawai et al[27] 2005	MRSPIR	neck level II		5					25	21	0	12
Kawai et al[27] 2005	MRSPIR	neck level II		6					25	19	0	14
Kawai et al[27] 2005	MRSPIR	neck level II		7					25	16	1	16
Kawai et al[27] 2005	MRSPIR	neck level II		8					25	10	2	21
Kawai et al[27] 2005	MRSPIR	neck level II		9					25	1	6	26
Kawai et al[27] 2005	MRSPIR	neck level II		10					24	0	6	28
Kawai et al[27] 2005	MRSTIR	neck level II		5					25	22	0	11
Kawai et al[27] 2005	MRSTIR	neck level II		6					25	19	1	13
Kawai et al[27] 2005	MRSTIR	neck level II		7					25	19	1	13
Kawai et al[27] 2005	MRSTIR	neck level II		8					25	11	1	21
Kawai et al[27] 2005	MRSTIR	neck level II		9					25	6	2	25
Kawai et al[27] 2005	MRSTIR	neck level II		10					25	4	2	27
Kawai et al[27] 2005	MRSPIR	neck level III			5			5	15	7	0	36
Kawai et al[27] 2005	MRSPIR	neck level III			6			6	15	4	2	37
Kawai et al[27] 2005	MRSPIR	neck level III			7			7	15	2	2	39
Kawai et al[27] 2005	MRSPIR	neck level III			8			8	15	2	2	39
Kawai et al[27] 2005	MRSPIR	neck level III			9			9	13	0	3	42
Kawai et al[27] 2005	MRSPIR	neck level III			10			10	12	0	3	43
Kawai et al[27] 2005	MRSTIR	neck level III			5			5	15	10	0	33
Kawai et al[27] 2005	MRSTIR	neck level III			6			6	15	8	1	34
Kawai et al[27] 2005	MRSTIR	neck level III			7			7	15	3	4	36
Kawai et al[27] 2005	MRSTIR	neck level III			8			8	15	2	4	37
Kawai et al[27] 2005	MRSTIR	neck level III			9			9	11	0	4	43
Kawai et al[27] 2005	MRSTIR	neck level III			10			10	8	0	7	43
Ke et al[28] 2006	CT	node	15	10	10	10	10	10	10	3	3	4

Laubenbacher et al[30] 1994	MRI	neck level	15	15	15	15	15	15	13	7	5	9
Laubenbacher et al[30] 1994	MRI	node	15	15	15	15	15	15	65	126	18	312
Lee et al[31] 2013	MR-DW	patient	2	2	2	2	2	2	7	3	1	11
Lee et al[31] 2013	MR-TSE	patient	2	2	2	2	2	2	7	6	1	8
Lu et al[32] 2007	CT	node	15	10	10	19	10	10	11	1	3	6
Lwin et al[33] 2012	MR	patient	10	15	10	10	5	10	63	82	15	24
Mcguirt et al[34] 1995	CT	node	15	15	10	10	10	10	18	3	1	19
Nakamoto et al[35] 2009	MRI	patient	10	10	10	10	10	10	16	2	4	30
Olmos et al[37] 1999	MRI	neck level	10	10	10	10	10	10	22	11	2	27
Paulus et al[39] 1998	CT	node	15	15	10	10	10	10	8	1	0	4
Peters et al[41] 2013	CT	patient	3	3	3	3	3	3	10	56	0	1
Peters et al[41] 2013	CT	patient	4	4	4	4	4	4	8	48	2	9
Peters et al[41] 2013	CT	patient	5	5	5	5	5	5	6	29	4	28
Peters et al[41] 2013	CT	patient	6	6	6	6	6	6	5	18	5	39
Peters et al[41] 2013	CT	patient	7	7	7	7	7	7	5	6	5	51
Peters et al[41] 2013	CT	patient	8	8	8	8	8	8	4	5	6	52
Peters et al[41] 2013	CT	patient	9	9	9	9	9	9	3	1	7	56
Peters et al[41] 2013	CT	patient	10	10	10	10	10	10	3	1	7	56
Ren et al[43] 2000	CT	node	5	5	5	5	5	5	36	9	2	11
Schwartz et al[44] 2004	CT	node	10	15	10	10	10	10	21	1	6	68
Semedo et al[45] 2006	MR	node	10	10	10	10	10	10	24	8	1	30
Seitz et al[46] 2009	MR	node	10	10	10	10	5	10	92	6	12	18
Tai et al[53] 2002	MRI	patient	11	10	10	10	10	10	3	1	10	2
Van den Brekel et al[56] 1991	MRI	neck level	10	10	10	10	10	10	87	13	42	415
Van den Brekel et al[56] 1991	MRI	patient	10	10	10	10	10	10	63	6	15	46
Vandecaveye et al[57] 2008	MR-TSE	neck level	10	10	10	10	10	10	27	10	20	208
Vandecaveye et al[57] 2008	MR-TSE	node	10	10	10	10	10	10	34	10	40	217
Vandecaveye et al[57] 2008	MR-TSE	patient	10	10	10	10	10	10	20	5	1	7
Wang et al[58] 1999	MRI	node	10	10	10	10	10	10	23	0	15	130
WIDE et al[59] 1999	MRI	neck level	10	15	10	10	10	10	18	11	9	34
Wilson et al[60] 1994	MRI	neck level	5	5	5	5	5	5	17	16	0	18
Wu et al[61] 2010	CT	node	8	8	8	8	8	8	10	1	2	11
Yoon et al[62] 2008	CT	neck level	15	15	10	10	10	10	57	2	17	326
Yoon et al[62] 2008	MRI	neck level	15	15	10	10		10	57	2	17	326
Yuan et al[63] 2000	MRI	neck level	12	12	10	10	10	10	12	1	2	9

Abbreviations: MRI, magnetic resonance imaging; CT, computed tomography; MR-TSE, ; MR-DW, ; MRSTIR, ; MRSPIR, ; TP, true positive; FP, false positive; TN, true negative.

Table S2 Meta-analysis results on diagnostic efficacy of MRI on size of metastatic lymph nodes

Unit	Node size (mm)	SEN (95% CI)	SPE (95% CI)	AUC (SE)	Q* (SE)
Level I	10	0.768 (0.725–0.808)	0.901 (0.880–0.919)	0.9159 (0.0348)	0.8487 (0.0394)
	11	0.883	0.866		
	12	0.803	0.786		
	15	0.774 (0.709–0.830)	0.721 (0.682–0.758)	0.8653 (0.0295)	0.7959 (0.0287)
Level II	10	0.812 (0.778–0.844)	0.883 (0.861–0.902)	0.9151 (0.0341)	0.8477 (0.0385)
	11	0.542	0.953		
	12	0.803	0.786		
	15	0.774 (0.709–0.830)	0.721 (0.682–0.758)	0.8653 (0.0295)	0.7959 (0.0287)
Level III	10	0.801 (0.767–0.833)	0.894 (0.875–0.911)	0.9121 (0.0314)	0.8444 (0.0350)
	12	0.803	0.786		
	15	0.785 (0.712–0.846)	0.704 (0.662–0.742)	0.8385 (0.0274)	0.7705 (0.0253)
Level IV	10	0.801 (0.767–0.833)	0.894 (0.875–0.911)	0.9121 (0.0314)	0.8444 (0.0350)
	12	0.803	0.786		
	15	0.785 (0.712–0.846)	0.704 (0.662–0.742)	0.8385 (0.0274)	0.7705 (0.0253)
Retro	5	0.885	0.750		
	10	0.780 (0.742–0.814)	0.899 (0.880–0.915)	0.9138 (0.0315)	0.8464 (0.0354)
	12	0.803	0.786		
	15	0.785 (0.712–0.846)	0.704 (0.662–0.742)	0.8385 (0.0274)	0.7705 (0.0253)
Others	10	0.801 (0.767–0.833)	0.894 (0.875–0.911)	0.9121 (0.0314)	0.8444 (0.0350)
	12	0.803	0.786		
	15	0.785 (0.712–0.846)	0.704 (0.662–0.742)	0.8385 (0.0274)	0.7705 (0.0253)

Abbreviations: MRI, magnetic resonance imaging; SEN, sensitivity; CI, confidence interval; SPE, specificity; AUC, area under the curve; SE, standard error.

Table S3 Meta-analysis results on diagnostic efficacy of CT on size of metastatic lymph nodes

Unit	Node size (mm)	SEN (95% CI)	SPE (95% CI)	AUC (SE)	Q* (SE)
Level I	5	0.947	0.550		
	8	0.722 (0.465–0.903)	0.966 (0.928–0.988)		
	10	0.617 (0.464–0.755)	0.864 (0.770–0.930)		
	11	0.556	0.565		
	12	0.821	0.850		
	15	0.802 (0.711–0.875)	0.677 (0.573–0.771)	0.8519 (0.0818)	0.7830 (0.0776)
Level II	5	0.947	0.550		
	8	0.769	0.917		
	9	0.500	0.970		
	10	0.607 (0.468–0.735)	0.510 (0.363–0.656)	0.7272 (0.1426)	0.6747 (0.1157)
	11	0.556	0.565		
	12	0.821	0.850		
	15	0.802 (0.711–0.875)	0.818 (0.746–0.876)	0.9083 (0.0599)	0.8402 (0.0658)
Level III	5	0.947	0.550		
	6	0.500	0.970		
	8	0.500	0.970		
	10	0.746 (0.659–0.820)	0.809 (0.739–0.867)	0.8499 (0.0783)	0.7811 (0.0740)
	12	0.821	0.850		
	15	0.723 (0.574–0.844)	0.577 (0.432–0.713)		
Level IV	5	0.947	0.550		
	7	0.500	0.970		
	8	0.500	0.970		
	10	0.746 (0.659–0.820)	0.809 (0.739–0.867)	0.8499 (0.0783)	0.7811 (0.0740)
	12	0.821	0.850		
	15	0.723 (0.574–0.844)	0.577 (0.432–0.713)		
Retro	5	0.947	0.550		
	8	0.500	0.970		
	10	0.746 (0.659–0.820)	0.809 (0.739–0.867)	0.8499 (0.0783)	0.7811 (0.0740)
	12	0.821	0.850		
	15	0.723 (0.574–0.844)	0.577 (0.432–0.713)		
Others	5	0.947	0.550		
	8	0.500	0.970		
	10	0.746 (0.659–0.820)	0.809 (0.739–0.867)	0.8499 (0.0783)	0.7811 (0.0740)
	12	0.821	0.850		
	15	0.723 (0.574–0.844)	0.577 (0.432–0.713)		

Abbreviations: CT, computed tomography; SEN, sensitivity; CI, confidence interval; SPE, specificity; AUC, area under the curve; SE, standard error.

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