



Comparison of CECT and CT perfusion in differentiating benign from malignant neck nodes in oral cavity cancers

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ABSTRACT

Aim: The objective of the study was to assess the performance of CT Perfusion in comparison to CECT for pre-operative detection of metastases to lymph nodes in squamous cell cancers of oral cavity.

Methods: Twenty-five patients with squamous cell cancers of oral cavity underwent CECT and CTP. Two radiologists evaluated CECT and CTP parameters independently. Surgery and post-operative histopathology was performed in all patients.

Results: Level wise analysis of the largest node was done. 102 lymph nodes on CECT and 82 lymph nodes on CTP were correlated with post-operative histopathological findings. CECT had a sensitivity, specificity and accuracy of 75 %, 98.6 % and 91.2 % (p-value <0.001) respectively in differentiating benign from metastatic nodes. Mean transit time [MTT] was significantly the most accurate CTP parameter and carried a sensitivity, specificity, accuracy and AUC of 90.5 %, 93.4 %, 92.7 % and 0.96 (p < 0.001). The sensitivity of MTT was higher than the sensitivity of overall CECT.

Conclusions: CTP is a promising tool for detection of metastatic cervical nodes in squamous cell cancers of the oral cavity.

1. Introduction

Squamous cell cancers of the oral cavity are very common and can arise in various subsites with a high incidence of cervical lymph nodal metastases.

Metastases to cervical lymph nodes are the single most important negative prognostic factor [1]. Contralateral nodal metastases can occur because of the intercommunicating submucosal network of lymphatics in oral cavity that freely communicates across the midline [2]. The 5-year survival rate is reduced by 50 % if metastatic nodes are present on one side of the neck and by an additional 25 % if they are present on both sides of the neck [3].

Current management challenge in oral cavity carcinoma is clinically negative neck with some centers performing neck dissection and others choosing to perform a sentinel lymph node biopsy. This is performed due to the relatively high likelihood of nodal metastasis even in a clinically negative neck. When lymph nodes are positive on

histopathology, it also adds the need for post-operative radiotherapy [4].

The diagnostic usefulness of any imaging modality in oral cavity cancers can be assessed by its ability to detect the presence of metastatic neck nodes [5]. Standard contrast-enhanced computed tomography (CECT) and magnetic resonance imaging (MRI) allow detection of enlarged, necrotic nodes, often with extracapsular spread [6], however, these methods cannot accurately differentiate benign from malignant small, non-enlarged lymph nodes [7].

CTP [CT Perfusion] is a rapid and non-invasive technique. Due to wider availability and faster scanning times, CTP is potentially well suited to study neck lymph nodes and can be readily incorporated into the patient's routine conventional CT examination. CTP yields useful information about the vascular physiologic and hemodynamic characteristics of a tumor by generating maps of blood flow (BF), blood volume (BV), mean transit time (MTT) and permeability (PMB) [8]. This quantitative information is based on time changes in x-ray attenuation over a

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fixed area of interest during the first pass of iodinated contrast medium [9]. This information can assist with diagnosis, staging, risk stratification and therapy monitoring for patients with cancer [10].

The purpose of this study was to assess the performance of CT Perfusion in comparison to CECT in characterisation of cervical lymph nodes in squamous cell cancers of oral cavity.

2. Materials and methods

This was a prospective single center study conducted over a period from September 2018 to March 2020. The study group included 25 consecutive patients of either sex and more than 18 years of age, presenting with FNAC/Biopsy proven oral cavity cancers who were scheduled to undergo radical or selective neck dissection. Patients with a prior history of head and neck malignancy, irradiation or chemotherapy in the head and neck region, nephropathy, hypersensitivity to iodine containing contrast media, and untreated hyperthyroidism were excluded from the study. Approval of the institutional ethics committee (F.No.17/IEC/MAMC/2018/19) was taken for the study and written informed consent was obtained from all patients.

All patients underwent CT perfusion study followed by CECT imaging of the neck before surgery. The examination was performed using 128 slice MDCT scanner (Somatom Definition AS+, Siemens Healthcare, Erlangen, Germany). After imaging, 17/25 patients underwent ipsilateral modified radical neck dissection [MRND], 6/25 patients underwent supraomohyoid neck dissection [SOHND] and 2/25 patients underwent bilateral neck dissection (MRND on left side and SOHND on right side in both the patients) depending on clinical TNM staging and decision made by an experienced head and neck surgeon. The dissected lymph nodes were then sent level-wise for histopathology in labelled containers. Histopathological results were then correlated with CECT and CTP in a level by level manner. Largest node at each level both on imaging and in the histopathological specimen were evaluated.

2.1. CT perfusion protocol

For CT perfusion, 40 mL of low osmolar nonionic contrast (Iohexol 350 mg/mL; Omnipaque, GE Healthcare) was injected into the antecubital vein at a rate of 5 mL/sec followed by 30 mL of saline chase, also at 5 mL/sec rate using a dual head pressure injector. Multiphase dynamic CT acquisition of the selected neck volume was done starting 4 s after the injection of contrast. The scanning parameters were as follows: 80 kVp, 170 mAs, 32×1.2 mm collimation, 0.30 s rotation time, 3 mm slice thickness, 96 mm scan range, 1.5 s scan time and 96 mm/1.5 s table movement speed, total scanning time approximately 60 s.

2.2. CECT examination protocol

After perfusion CT, routine whole neck CECT was performed from base of skull to thoracic inlet after giving additional 20 mL of low osmolar nonionic contrast (Iohexol 350 mg/mL; Omnipaque, GE Healthcare) at a rate of 5 mL/sec. The scanning parameters were as follows: 120 kVp, quality reference mAs of 165, 128×0.6 mm collimation, 0.8 pitch 1.0 s rotation time, 5 mm slice thickness, lasting for approximately 10 s.

2.3. Postprocessing of 4D CT perfusion

CT perfusion images were post processed on a separate workstation using vendor provided CT perfusion software (Neck module of Syngo Volume Perfusion CT Body). Time enhancement curve was obtained by placing a region of interest (ROI) in the common/internal carotid artery.

Adequate sized circular or oval shaped ROIs (region of interest) according to the size of the lymph nodes were manually drawn. In case of lymph nodes showing areas of necrosis, ROIs were drawn in the solid enhancing area excluding the necrotic area, surrounding blood vessels

and soft tissue. Deconvolution method was used to generate perfusion maps, because it includes complete time series of images for calculation which leads to a greater reduction in image noise and improves diagnostic confidence [11]. ROIs placed on the MIPs were automatically applied to parametric perfusion maps. Perfusion parameters obtained were- BF in ml/100 mL/min, BV in ml/100 mL, MTT in seconds, PMB in ml/100 mL/min.

2.4. Image analysis

Images were evaluated by two radiologists with 8 years and 12 years of experience in head and neck radiology. Any differences in the opinion were resolved by consensus.

2.4.1. CECT analysis

On CECT images, levels of nodes was evaluated as per the image based classification by Peter M. Som [Level I-VII] [12].

During the study, 324 cervical lymph nodes of variable size were identified at different levels bilaterally on contrast enhanced CT examination (CECT) of neck in 25 patients and only the largest lymph node at each level was included in the study, taking the total number of lymph nodes on CECT to 128.

Out of 128 lymph nodes identified on CECT, only 102 were correlated with their postoperative histopathology. 26/128 lymph node were excluded from the study because they were located on contralateral side in patients undergoing ipsilateral neck dissection. 102 lymph node were assessed for different CECT characteristics.

Features of lymph nodes assessed on CECT were size (short axis diameter ≥ 11 mm and long axis diameter ≥ 15 mm), shape (oval, round or irregular), margin (smooth well marginated or ill-defined), enhancement (homogeneous, heterogeneous with foci of necrosis or peripheral rim enhancement with central necrosis) and extra-nodal extension (present or absent).

The nodes were categorized into benign and malignant on CECT based on major and minor criteria. We formulated 2 major criteria and 4 minor criteria. The 2 major criteria includes- peripheral rim enhancement with central necrosis and extra-nodal extension and 4 minor criteria includes- enlarged short or long axis dimension, round or irregular in shape, ill-defined margins and heterogeneous enhancement with foci of necrosis. Malignant lymph nodes were identified on CECT when at least one major or more than two minor criteria were fulfilled.

Features on CECT were then correlated with histopathological results in a level by level manner.

2.4.2. CTP analysis

Out of 128 nodes identified on CECT, perfusion parameters were calculated in 110 lymph nodes. Perfusion parameters could not be obtained in 8/128 nodes due to their small size causing partial volume effect artifacts. Nodes with central necrosis (10/128) on CT examination were directly diagnosed as harboring metastases and were excluded from the perfusion study since necrosis has almost no vascularity and hence very low perfusion.

Out of 110 lymph nodes with perfusion parameters, only 82 were correlated with the postoperative histopathology. 28/110 were located on the contralateral side in patients undergoing ipsilateral neck dissection.

2.5. Statistical analysis

The collected data was transformed into variables, coded and entered in Microsoft Excel. Data was analyzed and statistically evaluated using SPSS-PC-25 version.

Quantitative data was expressed in mean \pm standard deviation or median with inter-quartile range and difference between two comparable groups were tested by student's *t*-test (unpaired) or Mann Whitney 'U' test. Qualitative data was expressed in percentages. Statistical

difference between the proportions was tested by chi square test or Fisher's exact test. Differences at $p < 0.05$ were considered significant. ROC curve was drawn to know the cutoff value of CT perfusion parameters to differentiate between benign and malignant lymph nodes. Sensitivity, specificity, PPV, NPV and accuracy of various parameters to differentiate malignant from benign was calculated.

3. Results

3.1. Subsites and levels of lymph nodes

Among all the patients with oral cavity cancer, carcinoma of oral tongue (11/25) accounted for majority of the lesions followed by carcinoma of buccal mucosa(5/25), buccal mucosa and gingiva(5/25), gingiva(3/25) and lower lip(1/25). Various sites of primary tumor with number of lymph nodes evaluated on CECT and pathological TNM staging is tabulated in Table 1.

Out of 102 lymph nodes evaluated on CECT, 70 lymph nodes were benign and 32 lymph nodes were malignant on postoperative histopathology. Maximum number of lymph nodes were found at level II constituting 26.7 % of lymph nodes (17 benign and 10 malignant). Level wise distribution of lymph nodes is presented in Table 2.

3.2. CECT analysis of cervical lymph nodes

CECT characteristics of benign and malignant lymph nodes is described in Table 3a and 3b.

Diagnostic performance of CECT to differentiate malignant from benign nodes is presented in Table 4. Specificity(94.3 %) and accuracy (83.3 %) were more when SAD was used as the size criterion where as sensitivity(71.9 %) was more when LAD was used to differentiate benign and malignant lymph nodes. Extra-nodal extension(ENE) and peripheral rim enhancement with central necrosis had the highest specificity (100 %) and positive predictive value (100 %) in identification of malignant lymph nodes. Using criteria described above, overall CECT had a sensitivity, positive predictive value and accuracy of 75 %, 96 % and 91.2 % for malignant lymph nodes. However, when we excluded the lymph nodes with central necrosis, sensitivity was significantly reduced

Table 1

Distribution of patients based on the location of primary tumor, pathological TNM staging and number of lymph nodes evaluated on CECT in each patient.

Primary site of tumor	pTNM Staging	Number of lymph nodes on CECT
Oral tongue	T3N1M0	5
Oral tongue	T2N2bM0	3
Oral tongue	T3N2bM0	5
Oral tongue	T2N0M0	4
Oral tongue	T3N2bM0	5
Oral tongue	T2N0M0	4
Oral tongue	T2N3bM0	7
Oral tongue	T1N0M0	4
Oral tongue	T2N1M0	4
Oral tongue	T3N2aM0	4
Oral tongue	T3N3bM0	4
Buccal mucosa	T2N0M0	3
Buccal mucosa	T2N2aM0	3
Buccal mucosa	T4aN0M0	3
Buccal mucosa	T2N3bM0	4
Buccal Mucosa	T2N0M0	3
Gingiva	T1N0M0	3
Gingiva	T4aN1M0	5
Gingiva	T4aN0M0	4
Buccal mucosa and gingiva	T1N0M0	3
Buccal mucosa and gingiva	T4aN0M0	5
Buccal mucosa and gingiva	T4aN3bM0	7
Buccal mucosa and gingiva	T4N1M0	3
Buccal mucosa and gingiva	T4aN2cM0	4
Lower lip	T4aN0M0	3
Total		102

from 75 % to 66.7 %. These centrally necrotic nodes were excluded to facilitate comparison with CTP parameters which is not a reliable technique to evaluate necrotic nodes. Moreover, central necrosis is a highly specific criterion to predict malignancy and these nodes do not need further investigational tools.

3.3. CT perfusion analysis of cervical lymph nodes

CT perfusion parameters of benign and malignant lymph nodes is presented in Table 5 with graphical representation in the form of box and whisker plot in Fig. 1. Blood flow(BF) and permeability(PMB) were significantly higher and mean transit time(MTT) was significantly reduced in malignant lymph nodes compared to benign lymph nodes (Fig. 2A-C).

ROC curve analysis was performed to determine the cutoff value for differentiating metastatic from benign lymph nodes (Fig. 3A-D). The sensitivity, specificity, accuracy, positive predictive value, and negative predictive value for the detection of metastatic nodes is presented in Table 6. MTT had the highest accuracy(92.7 %) and AUC(0.96)(Fig. 3A) suggesting that it was the most reliable parameter to differentiate malignant from benign lymph nodes.

3.4. Comparison of CT perfusion and CECT

Since MTT was the most reliable parameter to differentiate malignant from benign lymph nodes, the performance of MTT was compared with that of overall CECT.

MTT(90.5 %) had higher sensitivity than overall CECT(75 %) where as the specificity of MTT(93.4 %) was slightly lower compared to overall CECT(98.6 %). There was no significant difference seen in the accuracy of MTT and overall CECT. After excluding the nodes with central necrosis/peripheral rim enhancement the difference in sensitivity of MTT (90.5 %) and overall CECT(66.7 %) was further accentuated.

Comparison of diagnostic performance of MTT of CTP and overall CECT to differentiate between benign and malignant lymph nodes is presented in Table 7.

4. Discussion

Among various prognostic factors in oral cavity cancers, nodal metastases is associated with a significant risk of recurrence and death despite multimodal treatment [13].

In meta-analysis by Dunne et al. [14], they reported that the 5-year survival rates were 17–55.8% among patients with head and neck squamous cell cancers[HNSCC] with metastatic nodes and 44.6–76 % among patients without metastatic nodes.

CECT is the first line imaging modality for most of the patients with oral cavity cancers and with advent of CT perfusion, it can better differentiate metastatic nodes from benign which will further aid in planning management strategy.

4.1. CECT

In our study, SAD was more accurate(83.3 %) and specific(94.3 %) compared to LAD whereas, LAD was more sensitive(71.9 %) among the size criteria. Similar results were also obtained by Van den Brekel et al. [15] in their study where they reported that minimal axial diameter with cutoff ranging from 10 mm to 12 mm was the most accurate criteria in identifying metastatic lymph nodes.

ENE(90.2 %) was the most accurate feature to differentiate malignant lymph nodes from benign among the individual CECT features in our study. ENE and peripheral rim enhancement with central necrosis had the highest specificity(100 %) to differentiate malignant lymph nodes from benign. Comparable results were obtained in various previous studies by K Sarvanan et al. [16], Geetha NT et al. [17] and M E Saafan et al. [18] where they could obtain 100 % specificity for central

Table 2
Distribution of benign and malignant cervical lymph node based on levels (n = 102).

Level of Lymph nodes	Histopathological Diagnosis				Total Number	Percentage
	Benign(n = 70)		Malignant(n = 32)			
	Number	Percentage	Number	Percentage		
Ia	16	15.7	3	2.9	19	18.6
Ib	17	16.8	8	7.9	25	24.7
II	17	16.8	10	9.9	27	26.7
III	14	13.7	5	4.9	19	18.6
IV	2	1.9	2	1.9	4	3.8
Va	4	3.8	3	2.9	7	6.7
Vb	0	0	1	0.9	1	0.9
VI	0	0	0	0	0	0
Total	70	68.7	32	31.3	102	100

Table 3a
Comparison of size of lymph nodes with the postoperative histopathology using 11 mm cutoff for short axis dimension and 15 mm cutoff for long axis dimension.

Size criteria	Benign(n = 70)		Malignant(n = 32)		Total Number	
	Number	Percentage	Number	Percentage		
SAD	<11 mm	66	94.3 %	13	40.6%	79
	≥11 mm	4	5.7%	19	59.4%	23
Total		70	100 %	32	100 %	102
LAD	<15 mm	55	78.6%	9	28.1%	64
	≥15 mm	15	21.4%	23	71.9 %	38
Total		70	100 %	32	100 %	102

(SAD- short axis dimension, LAD- long axis dimension).

necrosis with peripheral enhancement in differentiating malignant from benign lymph nodes.

In our study, overall sensitivity, specificity and accuracy of CECT

features using major and minor criteria was 75 %, 98.6 % and 91.2 % respectively.

In a study by M Sumi et al. [19], they reported lower sensitivity, specificity and accuracy for CECT(68 %, 82 % and 80 %) compared to that in our study(75 %, 98.6 % and 91.2 %). This might be due to the fact that they considered only two criteria to identify metastatic lymph nodes where as we used 2 major and 4 minor criteria as mentioned above to identify metastatic lymph nodes.

Similarly, lower specificity(89.66 %) and accuracy(84.85 %) for CECT were reported in a study by M E Saafan et al. [18]. They also considered only 3 criteria to identify nodal metastases which included a size criteria of ≥11 mm in SAD, central necrosis with peripheral enhancement and conglomeration of 3 or more lymph nodes. However, the sensitivity(82.9 %) was slightly higher compared to that in our study.

Table 3b
Comparison of different CECT Features and histopathology results of cervical lymph nodes (n = 102).

CECT Features		Histopathology				P value
		Benign (n = 70)		Malignant (n = 32)		
		Number	Percentage	Number	Percentage	
Shape	Oval	68	97.2%	11	34.4%	<0.001
	Irregular	1	1.4%	11	34.4%	
	Round	1	1.4%	10	31.2%	
Total		70	100 %	32	100 %	
Margin	Well-defined	69	98.6 %	11	34.4%	<0.001
	Ill-defined	1	1.4%	21	65.6%	
	Total	70	100 %	32	100 %	
Enhancement/Necrosis	Homogenous	69	98.6 %	5	15.6%	<0.001
	Heterogeneous enhancement with foci of necrosis	1	1.4%	19	59.4%	
	Peripheral rim enhancement with central necrosis	0	0%	8	25 %	
Total		70	100 %	32	100 %	
Extra-nodal extension (ENE)	Absent	70	100 %	10	31.2%	<0.001
	Present	0	0%	22	68.8%	
	Total	70	100 %	32	100 %	

Table 4
Diagnostic performance of individual characteristics of CECT features to diagnose malignancy in lymph nodes.

CECT features	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	LR + ve	Accuracy (%)
SAD(≥11 mm cutoff)	59.4	94.3	82.6	83.5	11	83.3
LAD(≥15 mm cutoff)	71.9	78.6	60.5	85.9	3.36	76.5
Irregular/Round shape	65.6	97.1	91.3	86.1	22.62	87.2
Ill-defined margin	65.6	98.6	95.4	86.3	46.85	88.2
Heterogeneous enhancement with foci of necrosis	59.4	98.6	95.0	84.2	42.35	86.3
Peripheral rim enhancement with central necrosis(CN)	25	100	100	74.5	–	76.5
Extra-nodal extension	68.7	100.0	100.0	87.5	–	90.2
Overall CECT	75	98.6	96	89.6	52.5	91.2
Overall CECT (excluding the nodes with central necrosis)	66.7	98.6	94.1	89.6	46.7	90.4

(PPV- positive predictive value, NPV- negative predictive value, LR- likelihood ratio, SAD- short axis dimension, LAD- long axis dimension).

Table 5

Comparison of individual CT perfusion characteristics between benign and malignant lymph nodes (n = 82).

Perfusion Parameters	Histopathology finding		P value
	Benign (n = 61)	Malignant (n = 21)	
BV			
Mean ± SD	14.79 ± 9.12	16.13 ± 11.65	0.89
Median (IQR)	13 (8–20)	13 (8.4–17)	
BF			
Mean ± SD	38.79 ± 21.11	56.38 ± 16.18	<0.001
Median (IQR)	34 (23.1–47.7)	52.3 (46–64)	
MTT			
Mean ± SD	16.09 ± 6.26	5.4 ± 2.48	<0.001
Median (IQR)	15.2 (11.6–19.7)	4.8(3.2–7)	
PMB			
Mean ± SD	14.47 ± 6.71	24.93 ± 4.15	<0.001
Median (IQR)	15.1(9.4–19)	25.3 (22.1–27.6)	

(BV-blood volume, BF- blood flow, MTT-mean transit time, PMB-permeability, SD-standard deviation, IQR-inter-quartile range).

4.2. CT perfusion

In many CT perfusion studies performed earlier to evaluate the perfusion of HNSCC and cervical lymph nodes, perfusion images were acquired with coverage of 20–80 mm of the neck because of the limitation of z-axis coverage in conventional CTP [3,20,21]. However, in our study the coverage of neck for CTP study was 9.6 cm.

Among the perfusion parameters, MTT had the highest accuracy (92.7 %) and AUC(0.96) in our study followed by BF and PMB. No significant difference was seen in the values of BV between the malignant and benign nodes of any size.

Similar results were obtained by Trojanowska et al. [3] in their study where they reported significantly higher BF and PS values for malignant lymph nodes. However, they reported no significant difference in the MTT values of benign and malignant lymph nodes which was not in concordance with our study. Also they reported significantly higher BV values for malignant lymph nodes which again contradicts the finding of insignificant BV values in our study. The alteration in the perfusion parameters in malignancy reflects mean vessel density, short tumor vessels with lack of smooth muscles, leaky vascular endothelium and AV shunting [22]. This discrepancy between our study and Trojanowska et al. may result from relative reduction in mean vessel density in nodes as their size increases [10], which may result in reduced BV. The average size of lymph nodes in our study were 8.5 mm in SAD and 14.1 mm in LAD. The average size of lymph nodes evaluated in the study by Trojanowska et al. has not been mentioned.

Significant differences in BF and MTT values between metastatic and benign LNs (p < 0.05) were also reported by the Zhong et al [23] in their study.

In the study conducted by Bisdas et al. [21], they reported no significant difference in the perfusion parameters between malignant and benign nodes. In their study, large malignant nodes with signs of central necrosis were also included where as, these nodes were excluded from evaluation in our study and care was taken to assess perfusion parameters from the homogeneous part of the node in case of heterogeneity.

4.3. Comparison of CT perfusion and CECT

To our knowledge, this is the first study which compares CECT and CT perfusion to differentiate malignant from benign lymph nodes.

Among the perfusion parameters, MTT was most reliable parameter to differentiate malignant from benign lymph nodes. We excluded the nodes with central necrosis in perfusion study. Therefore, we compared performance of MTT with overall CECT excluding nodes with central necrosis. MTT depicted a higher sensitivity than overall CECT to differentiate malignant from benign lymph nodes (90.5 % and 66.7 %).

There was no significant difference between the accuracy of overall CECT including centrally necrotic nodes or excluding centrally necrotic nodes. This might be due to the fact that, the number of lymph nodes with central necrosis was less in our study (n = 8).

Higher sensitivity of a test has a higher negative prognostic value. Thus, higher sensitivity of MTT reduces the chances of missing a patient with positive nodes which helps in planning surgery to remove all involved nodes and reduces the need for revision surgery (neck dissection).

4.4. Radiation dose

The radiation dose for the combined PCT and routine whole-neck CT ranged from 116.5 to 118.17 mGy (mean, 117.3 mGy) as volume CT dose index (CTDI) and from 1455.4 to 1468.9 mGy · cm (mean, 1462.1 mGy · cm) as dose-length product (DLP). This was lower than the mean radiation dose mentioned in a previous study of CTP for HNSCC performed with 64-MDCT at 120 kV and 60 mA was 476.2 mGy as CTDI and 1904.8 mGy · cm as DLP [20].

The additional radiation burden of CT perfusion is offset by the limited scan area and the fact that majority of these patients usually undergo radiotherapy as a part of their management protocol.

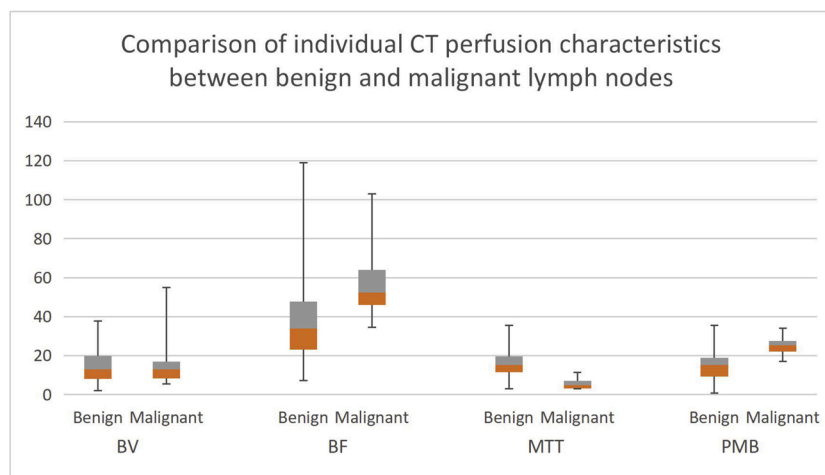


Fig. 1. Box and whisker plot comparing perfusion parameters of benign and malignant nodes.

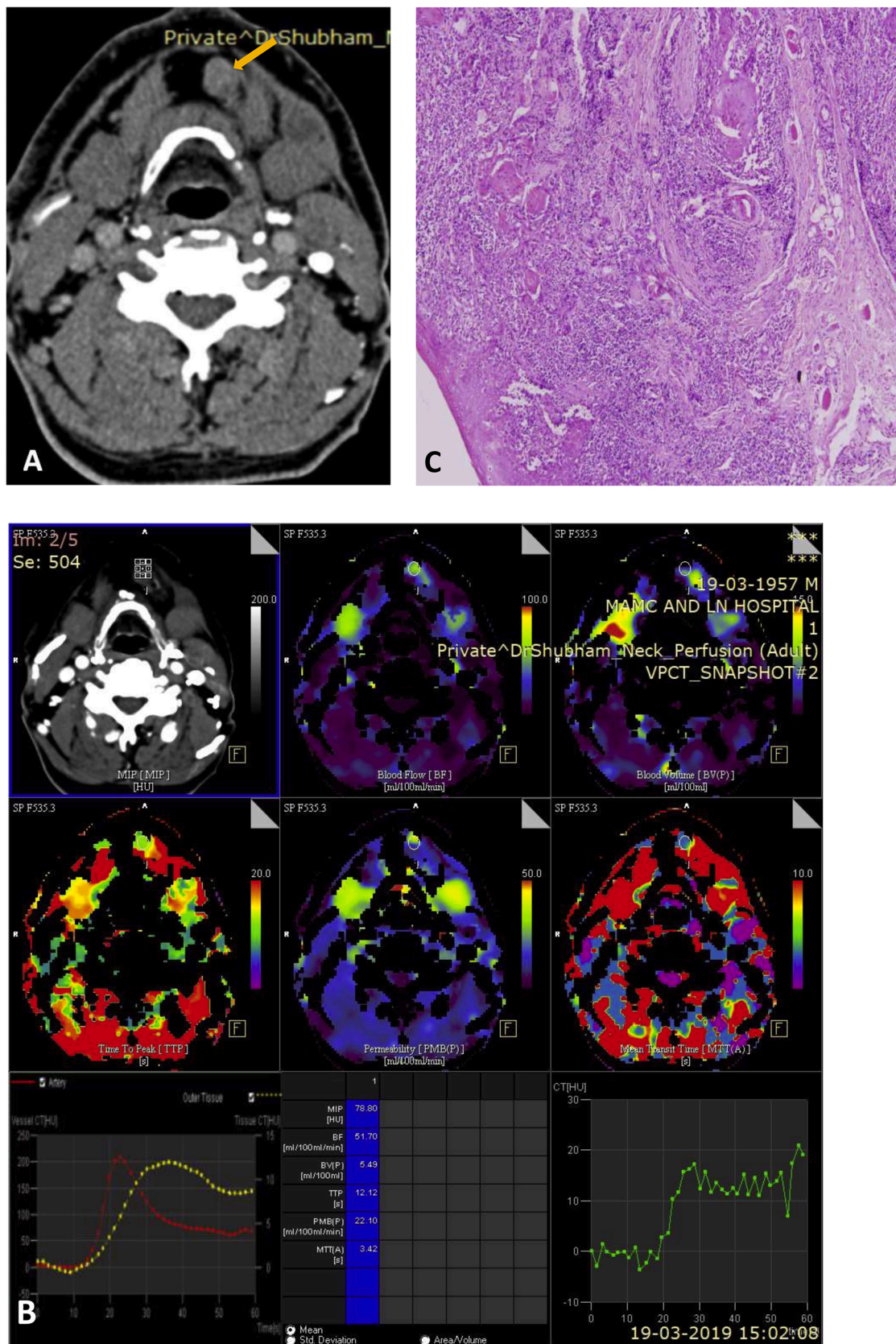


Fig. 2. A: Post contrast axial CT image showing enlarged cervical lymph node at level Ia appearing oval in shape with well defined margins and maintained fat planes (arrow in A). B: Perfusion color maps with placement of ROI over the lymph node at level Ia in the MIP images show reduced MTT(3.4 s) and slightly increased PMB (22.1 mL/100 mL/min) and BF(51.7 mL/100 mL/min). However BV(5.5 mL/100 mL) appears reduced.(Post-operative histopathology showed malignant lymph node.). C: HPE microphotograph reveals Hematoxylin and eosin stain section of a lymph node with tumour deposit from moderately differentiated squamous cell carcinoma infiltrating into underlying tissue with dense peritumoural lymphocytic infiltrate.

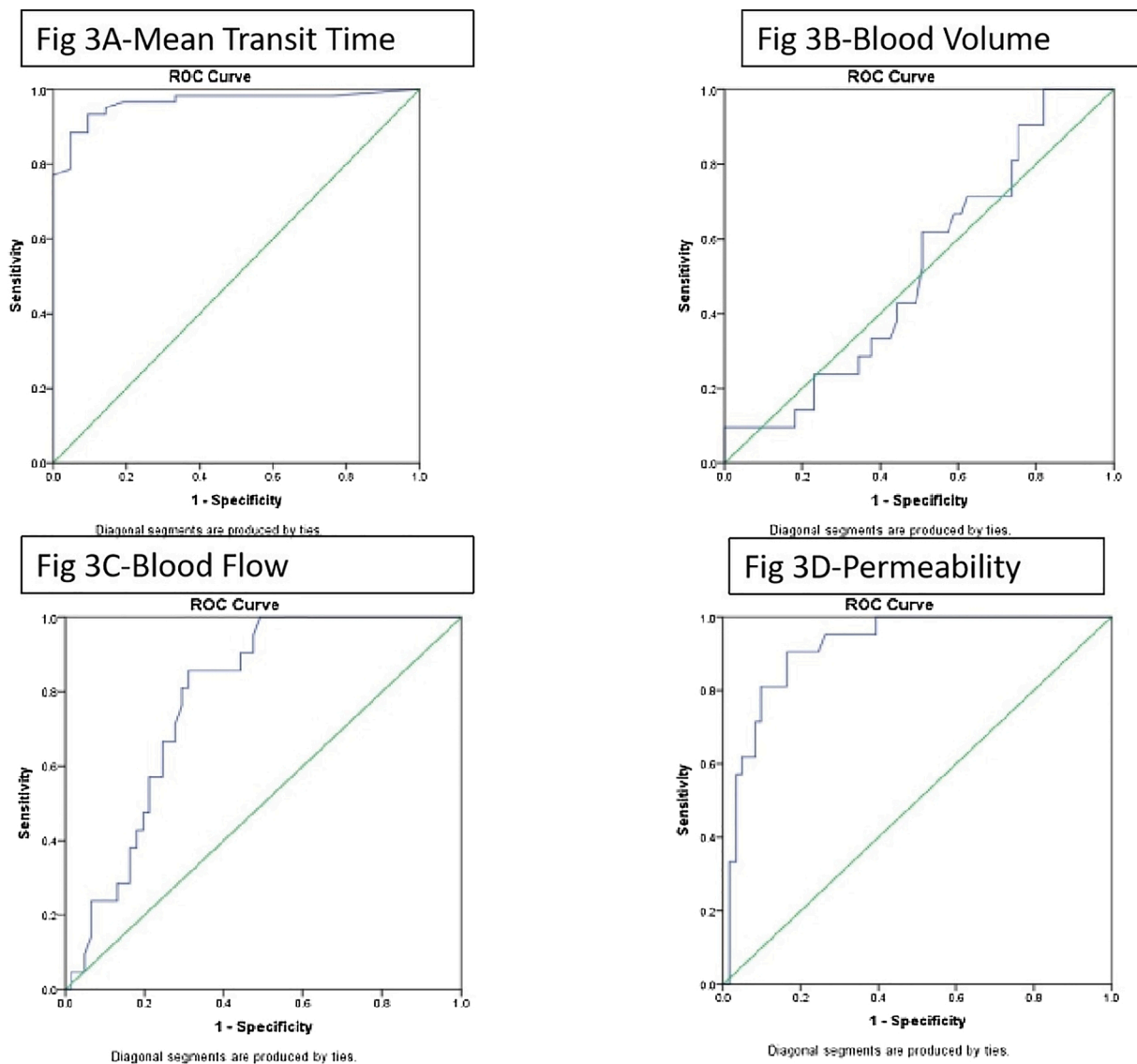


Fig. 3. A: Results of ROC analysis of mean transit time with AUC of 0.96. B: Results of ROC analysis of blood volume with AUC of 0.52. C: Results of ROC analysis of blood flow with AUC of 0.78. D: Results of ROC analysis of permeability with AUC of 0.92.

Table 6

Diagnostic performance of individual characteristics of CT perfusion to differentiate between benign and malignant lymph nodes.

	BV	BF	MTT	PMB
Cut off	7.55	43.35	8.65	19.95
AUC	0.52	0.78	0.96	0.92
Sensitivity (%)	90.5	85.7	90.5	90.5
Specificity (%)	24.6	68.9	93.4	83.6
PPV (%)	29.2	48.6	82.6	65.5
NPV (%)	88.2	93.3	96.6	96.2
Accuracy (%)	41.5	73.2	92.7	85.4

(AUC- area under curve, PPV- positive predictive value, NPV- negative predictive value).

4.5. Limitations

The main limitation was the small sample size of our study. The distribution of benign(70/102) and malignant(32/102) lymph nodes in our study was unequal. Majority of the patients underwent ipsilateral neck dissection and therefore the assessment of contralateral neck nodes could not be made.

Table 7

Comparison of diagnostic performance of MTT of CTP and overall CECT to differentiate between benign and malignant lymph nodes.

Characteristics	Sensitivity (%)	Specificity (%)	Accuracy (%)
MTT	90.5	93.4	92.7
Overall CECT	75	98.6	91.2
Overall CECT (excluding nodes with Central necrosis)	66.7	98.6	90.4

5. Conclusion

CTP is a promising imaging tool in the detection or exclusion of metastatic cervical nodes, even subcentimeter nodal metastases in which it is difficult to differentiate metastatic from benign nodes at morphologic imaging and has the potential for not only determining the extent of neck dissection but also planning radiation therapy.

The combined use of CECT and CTP might improve the staging of head and neck tumors however, this requires further validation.

Ethical statement

Approval of the institutional ethics committee (F.No.17/IEC/MAMC/2018/19) was taken for the study and written informed consent was obtained from all patients.

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CRedit authorship contribution statement

Shubham Suryavanshi: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing - original draft. **Jyoti Kumar:** Conceptualization, Methodology, Software, Investigation, Data curation, Writing - review & editing, Supervision, Project administration. **Alpana Manchanda:** Investigation, Data curation, Writing - review & editing, Supervision. **Ishwar Singh:** Investigation, Resources, Data curation, Writing - review & editing. **Nita Khurana:** Validation, Data curation, Writing - review & editing.

Declaration of Competing Interest

The authors report no declarations of interest

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