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Research Article

Validity of Computed Tomography (CT) For the Assessment of Mandibular Bone Invasion by Squamous Cell Carcinoma in the Oral Cavity

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Abstract

The objective of this review is to evaluate the diagnostic accuracy of computed tomography (CT) for detection of mandibular bone invasion by squamous cell carcinoma (SCC). A systematic review was carried out with published journals between 1986 and 2010, in English, which compared detection of mandibular bone invasion using different imaging modalities with computed tomography (CT). The outcomes that were compared were sensitivity, specificity, and diagnostic accuracy values. We found 33 articles, including multi-sectional CT (MSCT) (twenty one articles), cone beam CT (CBCT) (one article) and Magnetic Resonance Imaging (MRI) (eleven articles). These articles showed that all tests have a high diagnostic accuracy for detection of mandibular bone invasion by SCC, with sensitivity values of 33%-100% (CT), and specificity values of 57.1%-100% (CT). However, it was also consistently shown that current imaging methods give a moderate to high diagnostic accuracy for the detection of mandibular bone invasion by SCC.

INTRODUCTION

The assessment of invasion of the maxillofacial bone is integral in patients with carcinomas of the oral cavity because the surgical procedure is influenced by the presence and extent of bone involvement. The incidence of oral cancer became less from 1975 up to the mid-1990s; this trend has now been reversed, particularly in young adults [1], although oral cancer represents 3% of all malignant tumors [2]. Oral cancer has a high fatality rate, with a 5-year survival rate of less than 60% [3]. The most common malignant tumor in the oral region is squamous cell carcinoma (SCC), which represents nearly 90 percent of malignant lesions in the oral cavity [4], particularly in the mandible, with more than 300,000 new cases diagnosed each year worldwide [5]. Computed tomography (CT) is a valuable examination for evaluating of mandibular bone invasion by SCC. It is the most economically advantageous technique in terms of the cost/benefit ratio.

An important role of imaging in evaluating patients with SCC of the oral cavity is to evaluate the presence and extent of mandibular bone invasion. The incidence of mandibular bone invasion stated in the reviewed papers range from 11% to 100% in relation to the different oral and oropharyngeal subsides involved [6-9]. A precise assessment of the extent of mandibular invasion is therefore important for treatment planning to obtain both tumor resection and good functional results of jaw. The accurate prediction of tumor invasion will also lead to more appropriate patient informed consent and preoperative planning for resection and construction. Different preoperative investigation may be applied alone or in combination to assess mandibular involvement. Panoramic radiography, bone scintigraphy, single photon emission computed tomography (SPECT) and magnetic resonance imaging (MRI) have all been used to predict mandibular invasion by SCC of the oral cavity. Mandibular bone invasion was not identified radiographically in 27% of patients with preoperative CT scans [10]. In this study we reviewed the different articles on mandibular bone invasion by SCC and evaluated the accuracy of imaging modality.

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MATERIALS AND METHODS

Protocol

To review the published articles on assessment of mandibular invasion by SCC using different imaging modalities.

Selection criteria

Eight criteria were used for this review (Table 1). Each paper was reviewed for these criteria in a sequential manner.

Study participants were patients of any age, with histopathological diagnosis of SCC. Index tests were panoramic radiography, CT, CBCT, PETCT, SPECT, and MRI. The condition to be detected was mandibular bone invasion, taking the histopathologically reference as the reference gold standard.

Article selection

One reviewer (MO) selected the published articles by reading their titles and summaries.

Data analysis

We calculated the average value for the sensitivity, specificity and diagnostic accuracy for each study.

RESULTS

Table 1 shows the criteria of review studies. Table 2 shows that the mean rate of mandibular bone invasion by carcinoma was 46.6%. Table 3 shows that after review the 22 articles on CT showed mean sensitivity of 72.9%, specificity of 88.7%, and accuracy of 82%. Table 4 shows that for MRI sensitivity was 86.3%, specificity was 80%, and accuracy was 83.4%.

Table 1: Criteria of review studies.

1. Compared imaging tests in single or muilliple form with histopathology examinations
2. Histopathology examination used as reference standard.
3. Imaging tests included: CT, cone beam CT, PETCT, SPECT, IVRI
4. Patients diagnosed with oral squamous carcinoma
5. Squamous carcinoma located only in the oral cavity.
6. Must be indicated the protocol for each applied imaging test (type of equipment, window and planes used, slice thickness in mil)
7. Diagnosis of bone tissue invasion by radiographically.
8. Sensitivity, specficity, and diagnostic accuracy of imaging modalities must be calculated.

Table 2: The rate of mandible invasion (histologically invaded) by squamous cell carcinoma.

Study	Year of publication	Site of tumors	No of patients	No. of Invaded Mandible	Invasion Rate (%)
Bergstedt et al. [11]	1981	Oral cavity	16	8	50
Baker et al. [12]	1982	Oral cavity	25	16	60
Weiseman et al.[8]	1982	Oral cavity	40	9	22
Wald et al. [13]	1983	Oral cavity	53	23	43
Gilbert et al. [7]	1985	Oral cavity	104	23	22
Leipzigh et al. [14]	1985	Oral cavity	31	17	55
Close et al. [15]	1986	Oral cavity	43	11	26
O'Brien et al. [16]	1986	Oral cavity	114	33	30
Ahuia et al. [17]	1989	Oral cavity	48	27	56
Pogrel et al. [18]	1989	Oral cavity	13	7	54
Bahadur [19]	1990	Oral cavity	44	11	25
Muller et al. [20]	1990	Oral cavity	52	29	56
Brown et al. [21]	1994	Oral cavity	35	21	60
Tsue et al. [22]	1994	Oral cavity	64	25	39
kalverzos et al. [23]	1996	Oral cavity	60	41	68
Curren et al. [24]	1996	Oral cavity	16	9	57
Ord et al. [25]	1997	Oral cavity	46	15	33
van den Brekelet et al. [26] [33]	1998	Oral cavity	29	12	42
Lane et al.[10]	2000	Oral cavity	26	14	54
Caroline et al. [27]	2000	Oral cavity	67	36	54
Mukerji et al. [28]	2000	Oral cavity	49	26	54
Zeiron et al. [29]	2001	Oral cavity	89	41	46
Yamamoto et al. [30]	2002	Oral cavity	39	13	33
lmaizumi et al. [31]	2005	Oral cavity	51	25	49
Goerres et al. [32]	2005	Oral cavity	34	22	35
Brokenbrough et al. [33]	2008	Oral cavity	36	22	61
Momin et al. [34]	2008	Oral cavity	55	43	86
Donq et al. [35]	2010	Oral cavity	46	12	26
Averages (%)			46.1	20.1	46.6

Table 3: Review of studies examines the accuracy of CT, CBCT, PET/CT and SPECT in the assessment of mandibular invasion in patients with SCC of the oral cavity.

Study	Year of publication	Site of tumors	No. of patients	Slice thickness	Imaging modality	Sensitivity (%)	Specificity (%)	Accuracy (%)
Close et al.[15]	1986	Oral Cavity	43	5	CT	100.0	96.9	97.7
Bahadur [19]	1990	Oral Cavity	22	n.i	CT	80.0	94.1	90.9
Brown et al.[21]	1994	Oral Cavity	35	4-5	CT	53.3	100.0	72.0
Tsue et al.[22]	1994	Oral Cavity Oropharynx	50	n.i	CT	50.0	85.7	70.0
kalverzos et al.[23]	1996	Oral Cavity	47	5	CT	78.1	80.0	78.7
Zupi et al.[36]	1996	Oral Cavity	50	2	CT	91.3	96.3	94.0
Curran et al.[24]	1996	Oral Cavity Oropharynx	16	5	CT	88.9	57.1	75.0
Ord et al. [25]	1997	Oral Cavity	41	n.i	CT	53	92.5	78.5
van Brekel et al.[26]	1998	Floor of Mouth Retromolar Trigone	23	5-6	CT	64.3	88.9	73.9
Lane et al[10]	2000	Retromolar Trigone	26	5	CT	50.0	91.7	69.2
Mukerji et al.[28]	2000	Oral Cavity	49	3	CT	96.2	87.0	91.8
Zeiron et al.[29]	2001	Oral Cavity	48	4 2-4	CT SPECT	75.0 95.0	78.0 48.0	43.0 67.0
Imola et al.[37]	2001	Oral Cavity	38	3 n.i	CT SPECT	55.0 95.0	88.9 72.2	71.0 86.8
Yamamoto et al.[30]	2002	Oral Cavity	39	5	SPECT	45.5	94.7	76.7
Brokenbrough et al.[38]	2003	Oral Cavity	36	1	DENTA SCAN	95.0	79.0	89.0
Imaizumi et al. [31]	2006	Oral Cavity	51	1	CT	100.0	88.0	94.0
Goerres et al.[32]	2005	Oral Cavity	34 34	1.25 4.25 4.42	CT PET/CT SPECT	92.0 100.0 92.0	100.0 91.0 86.0	97.0 94.0 88.0
Wiener et al. [39]	2006	Oral Cavity	52	1	CT	71.4	95.5	92.3
Babin E et al.[40]	2007	Oral Cavity	17	3	CT PET/CT	33.0 73.0	100.0 85.0	88.0 88.0
Momin et al. [34]	2008	Oral Cavity	50	1	CBCT OPG	89.0 73.0	60.0 80.0	91.0 79.0
Gu DH et al. [35]	2010	Oral Cavity	46	3 3.75	CT PET/CT	41.7 58.3	100.0 97.1	84.8 87.0

Table 4: Review of studies examines the accuracy of MRI in the assessment of mandibular invasion in patients with squamous cell carcinoma of the oral cavity.

Study	Year of publication	Site of tumors	No. of patients	Slice thickness	Imaging modality	Sensitivity (%)	Specificity (%)	Accuracy (%)
Brown et al. [21]	1994	Oral cavity	35	5	MRI	91.7	100.0	93.8
Tsue et al. [47]	1994	Oral cavity Oropharynx	11	n.i	MRI	100.0	50.0	63.6
Chung et al. [18]	1994	Oral cavity Oropharynx	22	5	MRI	100.0	40.0	72.7
Campbell et al. [19]	1995	Oral cavity	50	5-7	MRI	85.7	93.0	92.0
Zupi et al. [54]	1996	Oral cavity	50	n.i	MRI	39.1	96.3	70.0
van Brekel et al. [33]	1998	Floor of mouth Retromolar trigone	29	5	MRI	94.4	72.7	86.2
Crecco et al. [62]	1999	Retromolar trigone	22	5-7	MRI	91.0	91.0	91.0
Bolzoni et al. [6]	2004	Oral cavity Oropharynx	43	3-3.5	MRI	93.3	92.9	93.0
Imaizumi et al. [31]	2005	Oral cavity	51	3-4	MRI	96.0	54.0	74.0
Wiener et al. [34]	2006	Oral cavity	52	5	MRI	100.0	93.3	94.2
Dong et al. [53]	2010	Oral cavity	46	6	MRI	58.3	97.1	87.0
Averages (%)			37.4	(3-6)mm		86.3	80.0	83.4

DISCUSSION

CT is the imaging modality which is most commonly used to assessment the tumor invasion in the mandible. The diagnostic accuracy of preoperative CT to detect mandibular bone invasion has been evaluated with varies results as follow: Lane et al. [10] (sensitivity=50% and negative predictive value (NPV) =61%) determined the bone invasion was not identified radiographically in 27% of patients with preoperative CT scans and thus concluded that CT was a useful but potentially inaccurate predictor of bone invasion in tumors of the retromolar trigone. Yamamoto et al. [30] found a sensitivity of 45.5%, specificity of 94.7%, positive predictive value of 75%, and accuracy of 76.7%. Both authors (Lane [10] and Yamamoto [30]) found low sensitivity of (50%), (45.5%), and high negative predictive value (PPV) of (61.1%), (76.7%), respectively, because of limitations of the techniques that were used in their those retrospective research, such as that they studied the thick sections (5mm) of the axial plane image, which might only depict minimal erosion. Also, they did not reconstructed the studied in bone algorithm when evaluating for bone invasion.

Curran et al. reported in a previous paper [24] (specificity = 57%; PPV=73%) that they acquired their images using 5mm slices thick sections and did not routinely evaluate that CT was an inaccurate technique for preoperative evaluation of bone invasion by tumors. They found the low specificity (57%) of CT might be due to interference with the infiltrative pattern of bone invasion and so may lead to over-diagnosis of mandibular invasion [45].

Acton CH et al. [27] (sensitivity of 78% and specificity of 83%), Shaha et al. [15] (adiagnostic accuracy of 68%) and Bahadur et al. [19] (false negative rate of 28%) did not describe their CT techniques and concluded the clinical examination was superior to CT for assessing invasion of mandible. However, the accuracy of clinical assessment was controversial as was over-diagnosis of bone invasion leading to a high sensitivity and low specificity [27,41,46]. Furthermore, clinical examination is critical in assessing the depth of tumor invasion around the mandible and the height of the mandible [42,47]. Other authors (Close et al.[15], Bahadur et al. [19], Brown et al. [21], and Shaha et al. [48]) reported that average a false negative rate was 12.5% of CT for detecting mandibular invasion and argued the predictability and reliability of CT were disappointing. Brown et al. [21] reported that it is very difficult to distinguish between an irregular ridge and early tumor erosion of the bone in the axial image. On the other hand, Brown et al. [21] and Kalavrezos et al. [23] reported a higher incidence of 28% and 22% in false negative results in CT scans, respectively. Because of artifacts, especially in the coronal planes due to dental restorations, it is difficult to accurately assess the area of the inner cortex of the mandible due to its irregular shape. Furthermore, the use of a high radiation dose and the expensive nature of CT are disadvantageous. On the other hand, CBCT is a new diagnostic modality, which has been used for the examination of maxillofacial region such as in endodontic [49], minor oral surgery [38], and TMJ disorders [50], because of its limited exposure field, less intensive X-ray dose, lower cost, and reduced space requirements compared to conventional CT.

In our recent study in which CBCT was first applied for SCC in the oral cavity [34], we reported on the use of CBCT to investigate mandibular invasion of lower gingival carcinoma on 50 patients. We understood that CBCT image quality was hampered by severe dental artifacts and image noise resulting in difficulties in detecting subtle alveolar invasion. A paper by Close et al. [15] determined that the sensitivity, specificity, PPV and accuracy of CT scans were 100%, 97%, 100%, and 97%, respectively. However, these impressive results have not been reported in recent studies. They found high sensitivity (100%) in their research, due to fine evaluations of the details of bone destruction by repeated scans with overlapping cuts of 5 mm thick sections obtained every 3 mm of tissue, or 1.5 mm contiguous sections. All studies were evaluated in bone and soft tissue algorithm, which helped detect the cortex and the cancellous bone invasion. Mukherji et al. [28], in a series of 49 patients, used 3 mm thick bone algorithm CT images and reported a sensitivity of 96% and a specificity of 87%. The authors obtained the data at 3 mm thick slices reconstructed at 1- to 2- mm interval and noted that thinner slices may improve the ability of CT to detect mandibular bone invasion. They concluded that CT was a reliable imaging modality for evaluating mandibular bone invasion when appropriate CT techniques were used [10,28,30]. Some authors reported that early erosion is difficult to distinguish with an irregular ridge in the axial image by CT. Previous studies (McGregor et al. [51] and Abrahams et al. [52]) suggested that the intraoral occlusal views and post processing Dental CT software with algorithm may be used for detecting early cortical erosion along the occlusal surface of the alveolar ridge. However, previous authors have reported high false positive rates attributed for periodontal disease and false negative rates may be related to 50%-75% of bone thickness missing for a cancellous bone defect by intraoral occlusal views [18]. Therefore, this technique has not been widely used. Mukherji advised that a direct comparison of CT with MR imaging would be necessary to determine which study is better at detecting mandibular invasion [28].

MRI has the advantage of better demonstration of soft tissue and tumor interfaces. The images are not as degraded by dental amalgam or by the density of the mandible. A few of the studies focusing on MR imaging are relatively limited. Among them, some researchers have reported a high rate of false positive studies with MR imaging [26,28,31,53]. Campbell et al. [42] stated that a positive PPV of MR imaging was 67% for evaluating mandibular bone invasion. Similarly, Chung et al. [41] reported that a PPV of MR imaging was <70% for evaluating of cortical bone evaluation and <50% for medullary bone evaluation. Bolzoni et al. [6] reported a high diagnostic accuracy of MR imaging for detecting mandibular bone invasion, a sensitivity of 93% and specificity of 93%. However, to the best of our knowledge, two studies to have performed a direct comparison of CT and MR imaging are that of van den Brekel et al. [26] and Imaizumi et al. [31]. van den Brekel et al. [26] studied 5-6 mm bone algorithm CT axial images and reported that the retrospective sensitivity and specificity were 94% and 73% for MRI and 64% and 89% for CT, and stated that neither of these to two imaging modalities was accurate enough, though it seems that CT images used in the study were not optimal for the evaluation. Wiener et al. [44] compared the diagnostic accuracy of 16-multidtector CT with MRI and reported that MRI was superior to CT in evaluating bone invasion. However, Imaizumi et al. [31] studied a series of 60 patients with oral SCC that were revealed by clinically examination to have mandibular bone invasion. They reported that the presence or extent of bone invasion was difficult to evaluate with the 5-mm thick axial images alone. They also stated that the respective sensitivity and specificity were 100% and 96% for CT scan and 96% and 54% for MR imaging, and concluded that thin slice bone algorithm images are most suitable for evaluating tumor invasion into the mandible by CT. Furthermore, van den Brekel et al. [26] and Imaizumi A. et al. [31] reported that MRI often overestimates the extent of tumor invasion, because the tumor and the surrounding inflammation in the bone marrow show similar signal intensity, and also motion artifacts from tongue movement and swallowing. The false positive cases of MRI in the evaluation of mandibular cortical bone invasion were due mostly to chemical shift artifact by bone marrow fat [31]. On the other hand, Signal et al. [33] stated that CT depicts cortical-invaded bone better and the extent of medullary bone invasion is more precisely defined with MR imaging although no evidence was provided to support their views. Conventional radiographs including orthopantomographs (OPG) provide an excellent general survey of the entire mandible. However, superimposition of the cervical spine anteriorly is a disadvantage. Accurate assessment of bone invasion is difficult by conventional radiography since at least 30% to 75% of cancellous bone must be replaced by tumor to be detected on pantomography [17,46].

Detection of bone invasion can be improved by reconstructing the image with a high-resolution bone algorithm in addition to a soft tissue algorithm. The bone algorithm improves the ability of the surgeon to visualize the mandibular cortex and increase the likelihood of detecting early cortical erosion (the type that often occurs in retromolar trigone) carcinomas. Furthermore, axial and coronal imaging reconstructed with high-resolution bone algorithms may also serve to improve the ability to detect cortical bone invasion in lesions that extend to the lingual cortex of the mandible.

CONCLUSION

It is controversial as to which modality has more advantages for evaluating mandibular invasion. According to these findings we suggest that CT is useful in the assessment of mandibular bone invasion by SCC. Furthermore, Nakayama et al., reported that CT clearly represents changes in bone tissue due to carcinoma if the following conditions are fulfilled:

1. Use of thin sections; 2. Keeping the scanning plane parallel to the mandibular plane in order to eliminate any artifacts caused by metallic dental restorations; 3. Obtaining super high resolution CT images in the optimal bone window. [53].

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