High expression of podoplanin in squamous cell carcinoma of the tongue occurs predominantly in patients \( \leq 40 \) years but does not correlate with tumour spread

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Abstract

More than 30% of patients with squamous cell carcinoma (SCC) of the mobile tongue have clinically undetectable lymph node metastasis. Tumour cells can spread as single cells or collectively. A protein known to play a role in both processes is podoplanin, which is expressed in endothelial cells not only in lymph vessels but also in some aggressive tumours with high invasive and metastastic potential. Here we studied samples from 129 patients with primary SCC of the tongue for expression of podoplanin using immunohistochemistry. mRNA levels were analysed in another 27 cases of tongue SCC with adjacent clinically tumour-free tongue tissue and 14 tongue samples from healthy donors. Higher levels of podoplanin were seen in tumours compared to both normal tongue and clinically normal tongue in the tumour vicinity. No association was found between levels of podoplanin, presence of lymph node metastases or other clinical factors. Patients aged 40 or less were more likely to express high levels of podoplanin protein compared to older patients (\( p = 0.027 \)). We conclude that levels of podoplanin in primary tongue SCCs are not associated with lymph node metastases. However, tongue SCCs arising in young patients (\( \leq 40 \) years of age) are more likely to express high levels of podoplanin than tongue SCCs that arise in the more elderly. The data suggest that podoplanin has a distinctive role in young patients, who are known to have a poor prognosis; these patients may, therefore, benefit from podoplanin inhibitory therapies.

Keywords: squamous cell carcinoma; tongue; podoplanin

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Introduction

The majority of intraoral squamous cell carcinomas (SCC) are located in the mobile tongue. Compared to tumours in other sites of the oral cavity, tongue SCCs more frequently metastasise to cervical lymph nodes and more than 30% of patients with tongue SCC have occult lymph node metastasis at the time
of diagnosis, as confirmed by histology even if clinically undetectable [1]. The high frequency of spread to lymph nodes is due to the dense lymphatic network present in the tongue, with most of the lymph fluid draining to lymph nodes in the submental and submandibular triangles (level I) and the upper jugular nodal group (level II). This rich lymphatic network also has connections across the midline, explaining why nodal metastasis can occur on both sides of the neck when the tumour is located in the midline of the tongue [1]. The frequent spread to lymph nodes from the tongue emphasises the importance of early detection for successful treatment of tongue SCC.

Tumour cells can invade either as single cells or collectively. Epithelial-to-mesenchymal transition (EMT) is important in single cell invasion. During EMT, epithelial cells lose epithelial markers such as E-cadherin and instead acquire mesenchymal characteristics including a migratory phenotype [2]. The EMT process is regulated at the transcriptional, translational and post-translational levels [3]. The molecular and pathophysiological aspects of collective invasion are less well understood. A protein known to play a role in both EMT and collective invasion is podoplanin [4].

Podoplanin is a transmembrane glycoprotein involved in formation of lymph vessels [5]. Apart from being expressed in endothelial cells in lymph vessels, podoplanin can be found in, for example, osteocytes and basal keratinocytes [5] and also in some tumours with high invasive and metastatic potential, including squamous cell carcinomas of the head and neck (SCCHNs) [5]. SCCHNs with high levels of podoplanin were reported to show significantly higher rates of lymph node metastasis, irrespective of the number of lymph vessels [6]. This finding is of clinical relevance, as diagnostic biopsies are often of limited size and accordingly the number of lymph vessels can be hard to estimate, whereas expression of podoplanin in tumour cells can be easily calculated. Restriction of podoplanin expression to the periphery of tumour nests in SCCHN has also been shown to be an indicator of good prognosis [7]. Specifically, looking at tongue SCC, the majority of tumours studied so far show high expression of podoplanin. High podoplanin expression has also been seen in the basal layer of hyperplastic and dysplastic lesions adjacent to SCCHN and interpreted as overexpression occurring early in head and neck tumorigenesis [6].

Here, we studied the prognostic impact of podoplanin in a large group of 129 tongue SCCs. We also measured the number of lymph vessels in the biopsies to clarify their impact on the clinical course of this disease.

Table 1. Results from scoring of podoplanin expression and number of lymph vessels in relation to age of the patient, N-status and status at the end of the study

| Podoplanin | Age group | N-status | Lymph vessels | Status |
|-----------|-----------|----------|---------------|--------|
| QS = 0    | <40       | NO       | 0 1–2         | ADF    |
|           |           |          |               | DDF    |
|           |           | N+       | 2 3           | AWD    |
|           |           |          |               | DOD    |
|           | 41–65     |          |               | DWD    |
|           | >65       |          |               |        |
| QS = 1–5  |           | 2 (11%)  | 2 (4%)        | 4 (6%) |
|           |           |          |               | 6 (6%) |
|           |           |          |               | 2 (6%) |
|           |           |          |               | 5      |
|           |           |          |               | 3      |
|           |           |          |               | 0      |
|           |           |          |               | 4      |
|           |           |          |               | 4      |
| QS = 6–18 | 14 (78%)  | 34 (53%) | 41 (43%)      | 17 (52%)|
|           | 26 (56%)  | 49 (51%) | 11 (42%)      | 6 (6%) |
|           | 26 (41%)  | 49 (51%) | 11 (42%)      | 6 (6%) |
| 129       | 64 (64%)  | 96 (96%) | 47 (47%)      | 47 (47%)|
|           | 64 (64%)  | 96 (96%) | 47 (47%)      | 47 (47%)|
|           | 96 (96%)  | 96 (96%) | 96 (96%)      | 96 (96%)|
|           | 96 (96%)  | 96 (96%) | 96 (96%)      | 96 (96%)|
|           | 96 (96%)  | 96 (96%) | 96 (96%)      | 96 (96%)|

QS = QuickScore (see text), ADF = alive disease free, DDF = dead disease free, AWD = alive with disease, DOD = dead of disease and DWD = dead with disease, but not as first cause of death.

Material and methods

Material

Formalin fixed, paraffin-embedded biopsies from 129 patients with primary SCC of the tongue available at Umeå University Hospital and Naples, were included. Sixty-five were men and 64 women. The mean age was 63.4 years, ranging from 19 to 93 years. The project was approved by the local Ethical Committee (dnr 01-057, 03-201).

The majority of patient samples had previously been analysed for expression of p16 and HPV16 [8]. Follow up ranged between 1 and 179 months, with a mean of 46.6 months. All but seven patients had a follow up of 2 years or longer.

Status at the end of the study was staged as alive disease free, alive with disease, dead of disease, dead disease free or dead with disease, but not as first cause of death. Data on status were collected from the clinical files or, when not available there, from the Swedish Death Registry. For clinical data, see Table 1.
Immunohistochemistry and scoring

An antibody detecting podoplanin (D2-40; Abcam, Cambridge, UK) was diluted 1:25. Slides were pre-treated in TRIS-EDTA pH 8.0, and staining was performed in a Ventana staining machine according to the supplier’s recommendations. The percentage of tumour cells expressing podoplanin as well as the intensity of staining was assessed. The percentage of tumour cells expressing podoplanin was divided into six groups, where 0–4% = 1, 5–19% = 2, 20–39% = 3, 40–59% = 4, 60–79% = 5 and 80–100% = 6. Staining intensity in turn was described as negative = 0, weak = 1, intermediate = 2 or strong = 3. By multiplying the score for percentage of podoplanin-expressing tumour cells with the score for staining intensity, a quick score (QS) was calculated for each slide [9]. Scoring of slides was performed independently by three of the authors (NS, ELJ and KN) and cases of disagreement were reevaluated and discussed to provide a consensus score.

The number of lymph vessels in each sample was scored between 0 and 3, with 0 being no lymph vessels detectable, 1 = few, 2 = moderate numbers and 3 = many lymph vessels detectable, respectively.

qRT/PCR

Twenty-seven tongue SCCs, of which 23 had paired clinically normal tumour-adjacent tissue samples and 14 tongue biopsies from healthy controls were included in the mRNA analysis. For example, in the case of a SCC on the left border of the tongue, clinically normal tumour-adjacent tissue was taken from the right side of the tongue. For clinical data on the tumours, see Table 2. Paraffin-embedded samples from 10 of these tongue SCC were included in the analysis of podoplanin mRNA. 

| Nr | Sex | Age | Localisation | TNM |
|----|-----|-----|--------------|-----|
| 20 | Male | 61  | 1            | T1N0M0 |
| 35*| Female | 24 | 2            | T2N0M0 |
| 40 | Female | 81  | 3            | T4N2bM0 |
| 49*| Female | 52  | 3            | T4N2cM0 |
| 51*| Male | 74  | 1            | T2N0M0 |
| 56 | Female | 41  | 3            | T2N2bM0 |
| 58*| Male | 61  | 1            | T1N0M0 |
| 59*| Female | 68  | 1            | T2N0M0 |
| 61 | Male | 70  | 3            | T4aN0M0 |
| 65*| Female | 81  | 3            | T2N0M0 |
| 68 | Male | 62  | 1            | T2N0M0 |
| 70*| Male | 71  | 2            | T1N0M0 |
| 73 | Male | 81  | 3            | T4aN0M0 |
| 76 | Male | 59  | 3            | T4aN0M0 |
| 79 | Male | 61  | 2            | T1N0M0 |
| 82*| Female | 19  | 1            | T4N0M0 |
| 83*| Female | 64  | 2            | T1N0M0 |
| 85*| Female | 87  | 1            | T2N0M0 |
| 92 | Female | 63  | 2            | T2N0M0 |
| 98 | Male | 31  | 3            | T2N0M0 |
| 105 | Male | 64  | 2            | T1N0M0 |
| 111 | Female | 31  | 2            | T2N0M0 |
| 119 | Male | 66  | 2            | T2N0M0 |
| 124 | Male | 54  | 3            | T4N2bM0 |
| 131 | Female | 74  | 2            | T2N0M0 |
| 137 | Female | 71  | 2            | T2N0M0 |
| 138 | Male | 50  | 1            | T2N1M0 |

For tumour localisation 1 = tongue, 2 = border of tongue and 3 = over-growth into floor of mouth.

Tumours labelled with * also had paraffin samples included in the protein analysis. TNM = (Tumour), (Nodes), (Metastasis).

UBC, LAD1, RPS12 from PrimerDesign Ltd. For GAPDH and UBC the company does not give out sequences. LAD1 (For: CCTCCACCCGTCACACT, Rev: CTGCTGTAGTTCGCTGTGT), RPS12 (For: TGCTGTCGGAGGTTGAATGG, Rev:GCACACAA AGATGGCCGTGG).

Cycling conditions: enzyme activation at 95°C for 3 min, denaturation at 95°C for 15 s and annealing at 60°C for 60 s. The process was run for 40 cycles.

To normalize the values, a geometric mean from the reference genes GAPDH, UBC, RPS12 and LAD1 was used in the calculation of 2−ΔCq.

Statistical analysis

SPSS version 22 was used for statistical analysis, correlating results from scoring of podoplanin to clinical data. The Chi square test was used for calculation of p-values and a p-value <0.05 was considered statistically significant. Two- and 5-year survival were used in the survival analysis. Mann-Whitney test was used to analyse mRNA levels.
Results

Clinical data
At 2-year follow up, which was available for 122 of the 129 patients studied, 75 were alive and 47 dead. Considering age, 56% of patients ≤40 years were alive 2 years after diagnosis, in contrast to 73% of patients aged 41–65, but similar to 54% of patients >65 years. At 5 years (follow up available for 101 patients of whom 48% were alive), 39% of patients ≤40 years were alive, in contrast to 65% of those aged 41–65 years but similar to 37% of patients >65 (p = 0.009). For status at the end of the study, see Table 1.

Expression of podoplanin
Of the 129 tongue SCC samples, 8 (6%) were negative for podoplanin, 55 (43%) showed low expression (QS 1–5) and 66 (51%) showed high expression (QS 6–18) (Figure 1). A significantly higher percentage of tumours in patients aged ≤40 years (78%) showed high expression of podoplanin (QS = 6–18), compared to 56% and 41% of the 41–65 and >65-year-old patients, respectively (p = 0.027) (Table 1).

Looking at the whole group of patients, there was no significant association between expression of podoplanin (QS), N-status, T-status, gender or localisation. Lymph vessels were detectable in all but five samples, with 52% showing a moderate number. The five samples lacking detectable lymph vessels were also negative for podoplanin in the tumour tissue. Of the 94 samples with a lymph vessel score of 2 or 3, all but two expressed podoplanin. No significant association was seen between the presence of lymph vessels, age, gender, T- or N-stage or status at the end of the study (Table 1).

Levels of podoplanin mRNA
All 27 tumours analysed showed significantly higher levels of podoplanin mRNA compared to both healthy controls, and clinically normal tongue tissue adjacent to the tumours (p < 0.0001). In the group of tumour-adjacent tongue tissue, levels were also significantly higher compared to healthy normal tongue (p = 0.005). Inter-individual variation in podoplanin levels was seen in tumours, with the highest levels seen in two females, one 24 years old (no 35) and the other 41 years old (no 56) (Figure 2).
Podoplanin in tongue SCC

Tongue SCC is a severe disease, which shows an increase worldwide, especially among young people and particularly women [11]. The disease may have an unpredictable outcome and the known worse prognosis for young patients [8,12] was also clearly seen in the present material, where only 39% of patients ≤40 years were alive after 5 years compared to 65% of those aged 41–65 years.

One of the biggest challenges with tongue SCC is that 30% of clinically node negative tumours have occult lymph node metastasis at diagnosis [1]. However, without performing a staging neck dissection it is not possible to pinpoint these 30%. The tongue, with its well-developed lymphatic network, is ideal for easy spread of tumour cells and, as N-status is a factor of known prognostic significance, it would be valuable to identify at the time of diagnosis factors that can aid in, or precede development of, nodal spread.

A factor of potential importance in this aspect is the lymph vessel-specific glycoprotein podoplanin. Previous results concerning its role in tumour spread are contradictory, where some claim that it induces EMT [13] whereas others instead show that it forms filopodia and in that way induces collective cell migration [14].

Podoplanin expression has been reported in mucosa adjacent to SCC [15] and this has been interpreted to indicate that the protein is expressed early in the tumourigenic process [16]. Our results from mRNA analysis support this interpretation as levels of podoplanin in clinically normal tongue adjacent to tumour were significantly higher than those in normal tongue taken from healthy volunteers with no evidence of SCC or other disease. Levels in tongue SCC were also significantly higher compared to both groups. At the protein level, there was no tendency for lowered expression in later stages of the tumourigenic process. On the contrary, 61% of N1 tumours showed high podoplanin expression, judged as QS 6–18, compared to 51% of N0 tumours. Although the number of cases are low, none of the eight podoplanin negative tumours was T4, whereas seven of them were T1 and T2.

Our figures for podoplanin expression with 6% negative, 43% low expressing (QS 1–5) and 51% high expressing (QS 6–18) tumours are comparable to the findings of Yuan and coworkers [6]. In contrast to their findings and also to another study [16], we found no association between high expression of podoplanin and lymph node metastasis or prediction of poorer outcome. In Yuan’s material, 89% of the 28 N1 tongue SCC showed high levels of podoplanin, compared to 52% of our 33 N+ tumours. As the scales for evaluating percentage of podoplanin-expressing tumour cells differ between the two studies, it is not possible to fully compare these results. Bartuli et al [17] analysed a mixed group of 20 SCC, of which only 12 were located in the tongue compared to our group of 129 tongue SCCs. A limited group of 12 tumours may thus not be representative of the whole group of tongue SCCs.

As has been seen previously, patients ≤40 years are a specific group and, in this study, showed the significantly highest percentage of high podoplanin-expressing tongue tumours. Even if there was no difference in outcome for these young patients with
high podoplanin expression, it is noteworthy that this group, once again, differs from the majority of patients with tongue SCC, who are typically much older.

Concerning the number of lymph vessels, no association with any clinical factor was seen. It must, however, be emphasized that the calculation of lymph vessel number in diagnostic biopsy material is not optimal and not representative of all aspects of the whole tumour. Thus, the potential relevance of lymph vessel numbers cannot be excluded based on the present results.

In summary, we have measured podoplanin levels at both protein and mRNA level in tongue SCC and found significantly higher levels in tumours compared to normal tongue as well as to clinically normal tongue in the tumour vicinity. In contrast to other studies, we could not confirm the correlation seen between podoplanin levels and the presence or absence of lymph node metastases. However, we show that tongue SCC arising in patients ≤40 years of age has the significantly highest percentage of high podoplanin expressing tumours. The clinical value of this finding remains to be determined but suggests that targeting podoplanin with antibodies or lectins [18] could be particularly useful for the group of young patients with tongue SCC.

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Author contributions

NS collected samples, performed scoring, data analysis and writing of the manuscript; ELJ performed scoring; LB performed mRNA analysis; GC, LLM, GT, LC, GDO, RR, LL, MS, TW, KD and GL collected samples and clinical data; PIC, RF and KN supervised and coordinated the study and participated in writing of the manuscript. All authors were involved in writing the paper and had final approval of the submitted version.

References

1. Sano D, Myers JN. Metastasis of squamous cell carcinoma of the oral tongue. Cancer Metastasis Rev 2007; 26: 645–662.
2. Gall TM, Frampton AE. Gene of the month: E-cadherin (CDH1). J Clin Pathol 2013; 66: 928–932.
3. de Craene B, Berx G. Regulatory networks defining EMT during cancer initiation and progression. Nat Rev Cancer 2013; 13: 97–110.
4. Wicki A, Christofori G. The potential role of podoplanin in tumour invasion. Br J Cancer 2007; 96: 1–5.
5. Raica M, Cimpean AM, Ribatti D. The role of podoplanin in tumour progression and metastasis. Anticancer Res 2008; 28: 2997–3006.
6. Yuan P, Temann S, El-Naggar A, et al. Overexpression of podoplanin in oral cancer and its association with poor clinical outcome. Cancer 2006; 107: 563–569.
7. Foschini MP, Leonardi E, Eusebi LH, et al. Podoplanin and E-cadherin expression in preoperative incisional biopsies of oral squamous cell carcinoma is related to lymph node metastases. Int J Surg Pathol 2013; 21: 133–141.
8. Sgaramella N, Coates PJ, Strindlund K, et al. Expression of p16 in squamous cell carcinoma of the mobile tongue is independent of HPV infection despite presence of the HPV-receptor syndecan-1. Br J Cancer 2015; 113: 321–326.
9. Drette S, Saccani Jotti G, Dowsett M. A “quickscore” method for immunohistochemical semiquantitation: validation for oestrogen receptor in breast carcinomas. J Clin Pathol 1995; 48: 876–878.
10. Boldrup L, Coates PJ, Wahlgren M, et al. Subsite-based alterations in miR-21, miR-125b, and miR-203 in squamous cell carcinoma of the oral cavity and correlation to important target proteins. J Carcinog 2012; 11: 18.
11. Annertz K, Anderson H, Björklund A, et al. Incidence and survival of squamous cell carcinoma of the tongue in Scandinavia, with special reference to young adults. Int J Cancer 2002; 101: 95–99.
12. Lundqvist L, Stenlund H, Laurell G, et al. The importance of stromal inflammation in squamous cell carcinoma of the tongue. J Oral Pathol Med 2012; 41: 379–383.
13. Martin-Villar E, Megás D, Castel S, et al. Podoplanin binds ERM proteins to activate RhoA and promote epithelial-mesenchymal transition. J Cell Sci 2006; 119: 4541–4553.
14. Wicki A, Lehmbruck F, Wick N, et al. Tumor invasion in the absence of epithelial-mesenchymal transition: podoplanin-mediated remodeling of the actin cytoskeleton. Cancer Cell 2006; 9: 261–272.
15. Martin-Villar E, Scholl FG, Gamallo C, et al. Characterization of human PA2.26 antigen (Talpha-2, podoplanin), a small membrane mucin induced in oral squamous cell carcinomas. Int J Cancer 2005; 113: 899–910.
16. de Vicente JC, Rodrigo JP, Rodriguez-Santamarta T, et al. Podoplanin expression in oral leukoplakia: tumorigenic role. Oral Oncol 2013; 49: 598–603.
17. Bartuli FN, Luciani F, Caddeo F, et al. Podoplanin in the development and progression of oral cavity cancer: a preliminary study. Oral Implantol 2012; 5: 33–41.
18. Ochoa-Alvarez JA, Krishnan H, Pastorino JG, et al. Antibody and lectin target podoplanin to inhibit oral squamous carcinoma cell migration and viability by distinct mechanisms. Oncotarget 2015; 6: 9045–9060.