Differences in Imaging Characteristics of HPV-Positive and HPV-Negative Oropharyngeal Cancers: A Blinded Matched-Pair Analysis

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ABSTRACT

BACKGROUND AND PURPOSE: Human papillomavirus–positive oropharyngeal cancers typically have younger age of onset, limited tobacco exposure, and more favorable prognosis than HPV-negative oropharyngeal cancers. We assessed whether HPV-positive and HPV-negative oropharyngeal cancers have consistent differences in pretreatment imaging characteristics.

MATERIALS AND METHODS: A retrospective review of 136 pretreatment CT examinations of paired HPV-positive and HPV-negative oropharyngeal cancers matched for T stage, tumor subsite, and smoking status was performed with the reviewing radiologist blinded to HPV status and clinical stage. Demographic/clinical characteristics and imaging characteristics of primary lesions and metastatic nodal disease were compared by use of Fisher exact testing. The McNemar $\chi^2$ test was used for the matched-pair analysis.

RESULTS: By imaging, HPV-negative tumors were more likely to demonstrate invasion of adjacent muscle (26% versus 6%, $P = .013$). HPV-positive primary tumors were more likely to be enhancing and exophytic with well-defined borders, whereas HPV-negative primary tumors were more likely to be isoattenuated and demonstrate ill-defined borders, though these results were not statistically significant. HPV-positive tumors were more likely to demonstrate cystic nodal metastases than HPV-negative tumors (36% versus 9%, $P = .002$).

CONCLUSIONS: In this matched and blinded analysis of the imaging differences between HPV-positive and HPV-negative oropharyngeal cancers, HPV-positive carcinomas often had primary lesions with well-defined borders and cystic nodal metastases, whereas HPV-negative primaries more often had poorly defined borders and invasion of adjacent muscle.

ABBREVIATIONS: HPV = human papillomavirus; SCCOP = squamous cell carcinomas of the oropharynx; EGFR = epidermal growth factor

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Whereas age-adjusted incidence of oral cavity, laryngeal, and hypopharyngeal carcinomas has predictably declined with decreased smoking prevalence, there has been a paradoxical increase in the age-adjusted incidence of oropharyngeal carcinomas secondary to the emergence of an epidemic of HPV-related squamous cell carcinomas of the oropharynx (SCCOP).1-5 HPV-positive SCCOP represents a unique demographic, molecular, and clinical entity with typically younger age of onset, limited tobacco exposure, and more favorable prognosis than HPV-negative SCCOP.6-10 The favorable prognosis among patients with HPV-positive SCCOP may be attributed in part to fewer somatic molecular alterations in HPV-positive cancers; HPV-positive smokers, however, appear to have a worse prognosis than HPV-positive nonsmokers, which may also be secondary to somatic molecular alterations in these cancers in smokers.6,11 It also appears that HPV-positive oropharyngeal carcinomas are a distinct histologic entity exhibiting basoloid, lymphoepithelial, and poorly differentiated histology as opposed to the keratinizing histologies seen in HPV-negative SCCOP.12

Although differences in the clinical characteristics, risk factors such as smoking and sexual behaviors, tumor pathways, and patient prognosis of HPV-positive versus HPV-negative SCCOP have been reported, distinctions between pretreatment imaging characteristics of HPV-positive and negative SCCOP have not
been thoroughly investigated.7 The most comprehensive examination of the imaging characteristics of HPV SCCOP was performed by Goldenberg et al,13 whose retrospective review of pretreatment CT examinations of SCCOP demonstrated an association of cystic nodal metastases with base of tongue and tonsillar primary cancers and an association of cystic nodal metastases with HPV-positive cancers. Furthermore, Goldenberg et al made a distinction between cystic and necrotic nodal metastases, suggesting that they are distinct imaging and pathophysiologic entities. Cystic nodal metastases were defined as having homogeneous fluid content without internal complex, irregular, or solid areas and an enhancing capsule <2 mm in thickness, whereas necrotic nodal metastases were defined as having thicker or more irregular walls with complex central low attenuation.13 Although the association of cystic nodal metastases with squamous cell carcinomas of the Waldeyer ring has been well established,14-17 our objective was to explore differences in the pretreatment imaging characteristics of HPV-positive and -negative oropharyngeal cancers.

MATERIALS AND METHODS

Patients with newly diagnosed oropharyngeal cancer who had been prospectively enrolled in a molecular epidemiology study conducted between May 1995 and June 2008 were matched on T-category, tumor subsite (base of tongue or tonsil), and smoking status (never, former, or current smoker). This research was approved by the institutional review board. Patients eligible for the current study met the following criteria: newly diagnosed, previously untreated SCCOP (base of tongue or tonsil), resident of the United States, and age 18 years or older. Exclusion criteria included treatment of head and neck malignancy (conventional surgical management, radiation therapy, or chemoradiation) before CT examination. Patients were also excluded if contrast-enhanced pretreatment CT imaging was not available for review in PACS. Each pair’s HPV status was determined by HPV in situ hybridization or HPV16 polymerase chain reaction testing. “Never-smokers” were defined as having smoked fewer than 100 cigarettes in their lifetime, with “former smokers” having quit smoking at least 1 year before their cancer diagnosis. “Current drinkers” were defined as having at least 1 alcoholic drink per week for at least 1 year and who were still drinking in this manner at the time of their presentation, whereas “former drinkers” were defined as those who had drunk alcoholic beverages in this manner in the past but had begun drinking less or stopped drinking at least 1 year before presentation.

Results of metatarsal imaging of paired patients with HPV-positive or HPV-negative SCCOP matched for T-category, tumor subsite, and smoking status was performed by a single neuroradiologist blinded to HPV status and clinical stage. T-category was determined clinically with clinical examination, direct laryngoscopy, and pretreatment imaging. All CT examinations were performed on 16- and 64-channel scanner systems (various software platforms; GE Healthcare, Milwaukee, Wisconsin). Images were obtained after administration of intravenous contrast, (125 mL, 60-second delay) from the aortic arch to the orbital roof with the following imaging parameters (tube current 100–600 mA, tube voltage 120 kVp, gantry rotation time 0.5–1 second, pitch 0.9, 1.25-mm image thickness). All patients with dental fillings had an additional stack of axial images obtained to angle away from the fillings. Although contrast bolus timing and volume of contrast may modify conspicuity of the interface between the primary lesion and surrounding soft tissues, in all cases contrast enhancement was sufficient to identify and adequately evaluate the primary tumor.

Demographic and clinical characteristics, imaging characteristics of primary lesion, and imaging characteristics of metastatic nodal disease were compared by means of Fisher exact testing. The McNemar χ² test was used for the matched-pair analysis. Variables compared for the primary lesion included visibility, well-defined versus ill-defined border, submucosal spread, invasion of adjacent muscle, enhancement, necrosis, and exophytic margins. Submucosal spread was defined as extension of mucosal lesion >1 cm in depth with infiltration of the submucosal fat plane and spread parallel to the mucosal surface. Variables compared for nodal metastases included radiologic N stage, presence of cystic nodes, necrotic nodes, metastatic spread to node of Rouver (lateral parapharyngeal lymph node), nodal enhancement, and extracapsular spread. Extracapsular spread was recognized by indistinct nodal margins, irregular nodal capsular enhancement, and infiltration into the adjacent perinodal fat or muscle. Cystic lymph nodes were defined as having a thin (<2 mm) enhancing capsule and homogeneous fluid content (>70% with HU <20), with no internal complexity.

RESULTS

Of 102 matched pairs (204 patients) initially identified, 34 matched pairs were excluded because for one or both members of the matched pair no pretreatment CT was available for review, yielding 68 matched pairs. Each pair’s HPV status had been determined by HPV in situ hybridization (38 pairs) or HPV16 polymerase chain reaction (30 pairs) testing.

The demographic and clinical characteristics of the patients with HPV-positive or HPV-negative SCCOP are presented in Online Table 1. Patients with HPV-positive and HPV-negative SCCOP were similar in demographics and clinical characteristics; however, there was a higher proportion of males in the group with HPV-positive SCCOP (P = .02, Online Table 1). Patients were excluded from analysis of the primary lesion (Table 1) if one or both members of the matched pair had a primary tonsillar tumor subsite with tonsillectomy before CT examination (7 matched pairs). Small primary tumors could not be visualized on CT imaging in 14 patients with HPV-positive SCCOP and in 10 patients with HPV-negative SCCOP (Table 1), and these patients were also excluded from further comparison of primary tumor imaging characteristics. HPV-negative tumors were more likely to demonstrate invasion of adjacent muscle (26% versus 6%, P = .013; Table 1) (Fig 1). HPV-positive tumors were more likely to have enhancing, exophytic primary lesions with well-defined borders by CT imaging (Fig 2), whereas HPV-negative tumors were more likely to have isointense primary lesions that demonstrated ill-defined borders, though these results did not reach statistical significance (Fig 3).

Patients were excluded from analysis of the metastatic nodal imaging (Table 2) if one or both members of the matched pair had prior excisional lymph node biopsy (9 matched pairs). In 6 pa-
Table 1: Imaging characteristics of patients with primary tumor among those with HPV+ oropharynx cancer and matched patients with HPV− oropharynx cancer

| Imaging Characteristic                                      | HPV+ (n = 61) | HPV− (n = 61) | P Value |
|-------------------------------------------------------------|---------------|---------------|---------|
| Primary lesion is visible                                   |               |               | .362    |
| Yes                                                         | 47 77.0       | 51 83.6       |        |
| No                                                          | 14 23.0       | 10 16.4       |        |
| Primary lesion is enhancing                                 |               |               | .182    |
| Yes                                                         | 37 78.7       | 34 66.7       |        |
| No                                                          | 10 21.3       | 17 33.3       |        |
| Primary lesion demonstrates necrosis                        |               |               | .651    |
| Yes                                                         | 8 17.0        | 7 13.7        |        |
| No                                                          | 48 83.0       | 44 86.3       |        |
| Primary lesion demonstrates well-defined border             |               |               | .067    |
| Yes                                                         | 35 74.5       | 29 56.9       |        |
| No                                                          | 12 25.5       | 22 43.1       |        |
| Primary lesion is exophytic                                 |               |               | .095    |
| Yes                                                         | 14 29.8       | 8 15.7        |        |
| No                                                          | 33 70.2       | 43 84.3       |        |
| Primary lesion demonstrates submucosal spread               |               |               | .667    |
| Yes                                                         | 26 55.3       | 26 51.0       |        |
| No                                                          | 21 44.7       | 25 49.0       |        |
| Primary lesion invades adjacent muscle                      |               |               | .013    |
| Yes                                                         | 3 6.4         | 13 25.5       |        |
| No                                                          | 44 93.6       | 38 74.5       |        |

FIG 1. HPV-negative SCCOP demonstrating deep muscular invasion involving the extrinsic muscles of the tongue with submucosal spread. Axial contrast-enhanced CT image shows a large and deeply invasive T4 base of tongue lesion, extending anteriorly into the oral tongue.

FIG 2. HPV-positive SCCOP with typically well-defined borders. Axial contrast-enhanced CT image shows a midline T2 base of tongue mass with well-defined margins (arrows). Level II left lymph node metastasis demonstrates extracapsular extension.

FIG 3. HPV-negative SCCOP demonstrating ill-defined borders. Axial contrast-enhanced CT image shows a mass in the left tonsil, with poorly defined borders, especially anteriorly.

DISCUSSION

In this blinded analysis of the CT imaging differences between HPV-positive and HPV-negative SCCOP, a greater percentage of HPV-positive SCCOP demonstrated primary tumors with well-defined borders whereas HPV-negative primary tumors demonstrated ill-defined borders and increased invasion of adjacent muscle. Despite the overall improved prognosis of HPV-positive SCCOP relative to HPV-negative SCCOP, we found no significant difference in incidence of extracapsular spread of nodal metastases, a well-established predictor of poor prognosis in squamous cell carcinoma of the head and neck. Our data are consistent with the findings of Goldenberg et al,13 which demonstrated increased incidence of cystic nodal metastases in HPV-positive SCCOP. These imaging differences between HPV-positive SCCOP compared with HPV-negative SCCOP are congruent with an understanding that HPV-positive SCCOP represent a
HPV-positive SCCOP demonstrating a cystic nodal metastasis. Axial contrast-enhanced CT image shows an obvious bulky midline left-sided base of tongue cancer (characteristically well-defined borders) and a predominantly cystic mass in level IIa.

Table 2: Imaging characteristics of nodal metastases among patients with HPV+ oropharynx cancer and matched patients with HPV− oropharyngeal cancer

| Imaging Characteristic | HPV+ (n = 59) | HPV− (n = 59) | P Value |
|------------------------|--------------|--------------|---------|
| Radiologic N stage     |              |              | .754    |
| N0                     | 6            | 10.2         | 9       | 15.3    | .754 |
| N1                     | 7            | 11.9         | 8       | 13.6    | .693 |
| N2                     | 45           | 76.3         | 42      | 71.2    | .149 |
| N3                     | 1            | 1.6          | 0       | 0       | .983 |
| Nodal metastases       |              |              | .693    |
| demonstrate extracapsular spread | 16         | 30.2         | 15      | 30.0    | .983 |
| Yes                    | 37           | 69.8         | 35      | 70.0    | .002 |
| No                     |              |              |         |         | .002 |
| Nodal metastases       |              |              | .474    |
| demonstrate cystic morphology | 19         | 35.8         | 5       | 10.0    | .474 |
| Yes                    | 34           | 64.2         | 45      | 90.0    | .474 |
| No                     |              |              |         |         | .474 |
| Nodal metastases       |              |              | .499    |
| demonstrate necrosis   | 37           | 69.8         | 41      | 82.0    | .499 |
| Yes                    | 16           | 30.2         | 9       | 18.0    | .499 |
| No                     |              |              |         |         | .499 |
| Nodal metastases       |              |              | .474    |
| demonstrate enhancement | 33        | 62.2         | 33      | 66.0    | .474 |
| Yes                    | 20           | 37.8         | 17      | 34.0    | .474 |
| No                     |              |              |         |         | .474 |
| Nodal metastases       |              |              | .754    |
| include node of Rouvier | 9           | 17.0         | 6       | 12.0    | .754 |
| Yes                    | 44           | 83.0         | 44      | 88.0    | .754 |

CONCLUSIONS

HPV-negative primary tumors demonstrated ill-defined borders and increased invasion of adjacent muscle, whereas HPV-positive SCCOP more frequently demonstrated primary tumors with well-defined borders and cystic nodal metastases. Given the rising incidence of HPV-positive SCCOP, radiologists should maintain a high index of suspicion for underlying malignancy when evaluating cystic neck masses in adult patients without significant tobacco or alcohol exposure.

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