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Quantitative Measures of Facial Expression for Patients with Head and Neck Cancer*

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Abstract— **In addition to changes in facial morphology, head and neck cancer treatment can impact the facial expression. Quantification of changes in facial expression, particularly of smiling, would enable a deeper understanding of the relationship between physical changes and psychosocial adjustment in patients being treated for facial cancer. This study proposes 48 quantitative facial expression measures, which consist of the length normalized distances and slopes between 27 manually annotated fiducial points on standard 2D clinical photographs of patients with head and neck cancer. Using the proposed measures, the maximum intensity of smiling for patients with head and neck cancer prior to their treatments was compared to that of a sample from a healthy population. A total of 7 facial expression measures captured statistically significant differences between patients with head and neck cancer and healthy individuals. These measures suggest that patients with head and neck cancer are less expressive than people without head and neck cancer. This study is the first attempt to quantify the facial expression of patients with head and neck cancer and to build a foundation for studying how surgical interventions may affect their facial expressions. Moreover, this study lays the groundwork for future investigation of the relationship between facial expression and psychosocial adjustment in cancer patients.**

I. Introduction

Patients with head and neck cancer often undergo treatment that affects their facial function as well as their appearance. Such treatments can have a negative effect on their quality of life negatively because the face is a highly visible part of the body.

In addition to surgical changes in facial morphology, treatment of head and neck cancer can impact facial expression. Quantification of changes in facial expression, particularly of smiling, would enable a deeper understanding of the relationship between physical changes and psychosocial adjustment for patients.

Human facial expressions have been studied extensively in computer vision. In the computer vision literature, the main focus has been on recognition/classification of given facial expressions in order to develop better human computer interaction algorithms [3].

The study of facial expressions in clinical research has been mainly focused on how patients with neuropsychiatric disorders such as schizophrenia (e.g., [4]) form facial expressions. Moreover, few prior studies were based on *quantitative* analysis of facial expressions. Verma et al. [5] proposed a geometric feature-based method to quantitatively analyze facial expressions from 2D photographs. They divided the face into several regions and computed a non-rigid deformation from each region of the face with no expression (or neutral) to the corresponding region of the expressive face. From the same research group, quantitative facial expression analysis methods have been proposed for different imaging modalities such as video and 3D surface imaging [6, 7]. Although their quantitative methods showed promising results for patients with schizophrenia, their methods depend on the changes in facial regions (e.g., eye or nose region) rather than distances/ratios between facial landmarks (fiducial points). Since facial region based methods are more difficult to interpret than distance/ratio based methods and they require complex computation to provide quantitative expression analysis results, they are less likely to be adopted for clinical use. In addition, we need to have a new set of quantitative measures for patients with head and neck cancer since the consequences of head and neck cancer and those of neuropsychiatric disorders are different.

In this study, we propose quantitative facial expression measures that are clinically intuitive and suitable for longitudal study. Our quantification method consists of 48 expression measures computed from the length normalized distances and slopes between 27 fiducial points on standard 2D clinical photographs of patients with head and neck cancer. The proposed expression measures were based on a previous study showing promising results for the recognition of facial expressions [1]. The proposed measures were evaluated by comparing the maximum intensity of smiling for the *pre-operative* (prior to either reconstructive surgery alone or oncological resection followed by reconstructive surgery) patients with head and neck cancer and that of healthy individuals.

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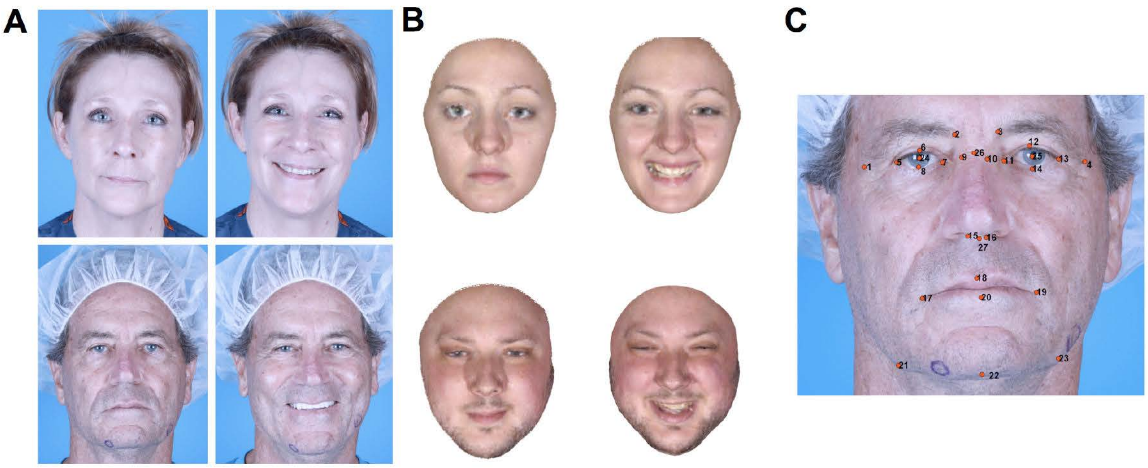

Figure 1. **A:** Example *pre-operative* facial photographs of patients with head and neck cancer. First and second column of images show the patients with neutral facial expression and peak smile, respectively. **B:** Example 2D texture images of BU-3DFE dataset. First and second column of images show healthy individuals with neutral facial expression and peak smile, respectively. **C:** Illustration of 27 facial fiducial points.

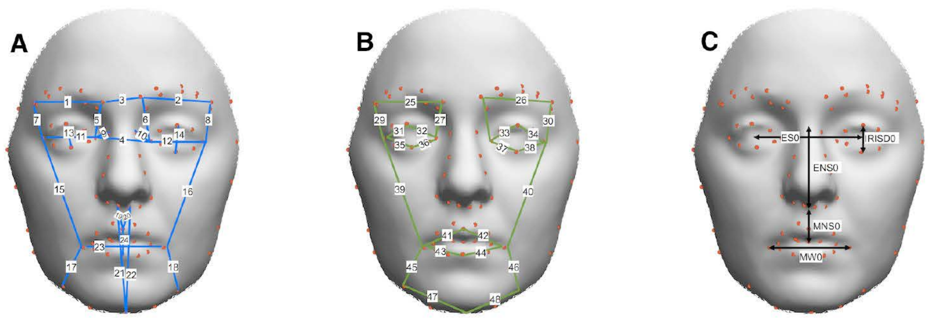

Figure 2. Illustration of 24 distance features (A), 24 slope (B) features [1] and 5 facial animation parameter units (FAPUs) (C) [2] used in this study. 24 distance features were divided corresponding one of 5 FAPUs by facial regions, which are eye (ES0 or IRISD0), nose (ENS0 or MNS0), and mouth (MNS0 or MW0).

II. Materials and Methods

A. Datasets

The first image dataset of this study consists of patients with head and neck cancer aged 21 or older who were scheduled for facial reconstructive surgery from July 2010 to November 2012 at The University of Texas MD Anderson Cancer Center. Data was collected under the approval of the Institutional Review Board (IRB). A Canon EOS REBEL Tli (Canon, USA) was used to obtain *pre-operative* anterior posterior (AP) facial photographs of 95 patients (34 female and 65 male). Patients who have limited ability to form a facial smile due to a very large tumor or the effect of prior cancer treatment were excluded from the study. The patients' age ranged from 18 to 89 years (mean: 62). Each patient was first asked to pose with a neutral facial expression and then to smile with two different levels of intensity: 1) mild and 2) peak, when his/her facial photographs were taken (Fig 1.A).

The Binghamton University 3D facial expression database (BU-3DFE) [8] was used as the second dataset of this study. This dataset consists of 3D facial images of 100 subjects (56 male and 44 female) depicting 7 facial expressions: angry, happy, disgust, fear, sad, surprise. The age distribution of this dataset is from 18 to 70 years but most of the subjects are on the younger end of that range as most subjects were university students. Each facial expression includes 4 intensity levels in addition to a single level neutral expression. Each 3D facial image can be decomposed to 2D texture and depth images and we utilized the 2D texture image (Fig 1.B) for the study. Among 7 facial expressions, we used the images of happy and neutral expression, since this study is interested in comparing the maximum intensity of smiling between *pre-operative* patients with head and neck cancer and healthy individuals.

B. Quantitative Measures of Facial Expression

In this study, we adopted the method introduced by Tang and Huang [1] to compute the quantitative expression measures. In their work, they used 24 length normalized distance features and 24 slope features on 3D facial images of the BU-3DFE, and showed promising results for the recognition of the given facial expression. Fig 2.A and B illustrate those 48 facial features used in the prior study. A detailed description of each facial feature can be found in [1]. To take into account the differences across individuals in face size, the normalization was done on distance features by dividing those by 5 facial animation parameter units (FAPUs): 1) eye separation (ES0), 2) iris diameter (IRIS0), 3) eye-nose separation (ENS0), 4) mouth-nose separation (MNS0), and 5) mouth width (MW0) (Fig 2.C) [1, 2]. Table 1 shows the distance feature numbers and their corresponding FAPUs to normalize those distance features. Since slope features are unit-less, the normalization was applied only to distance features.

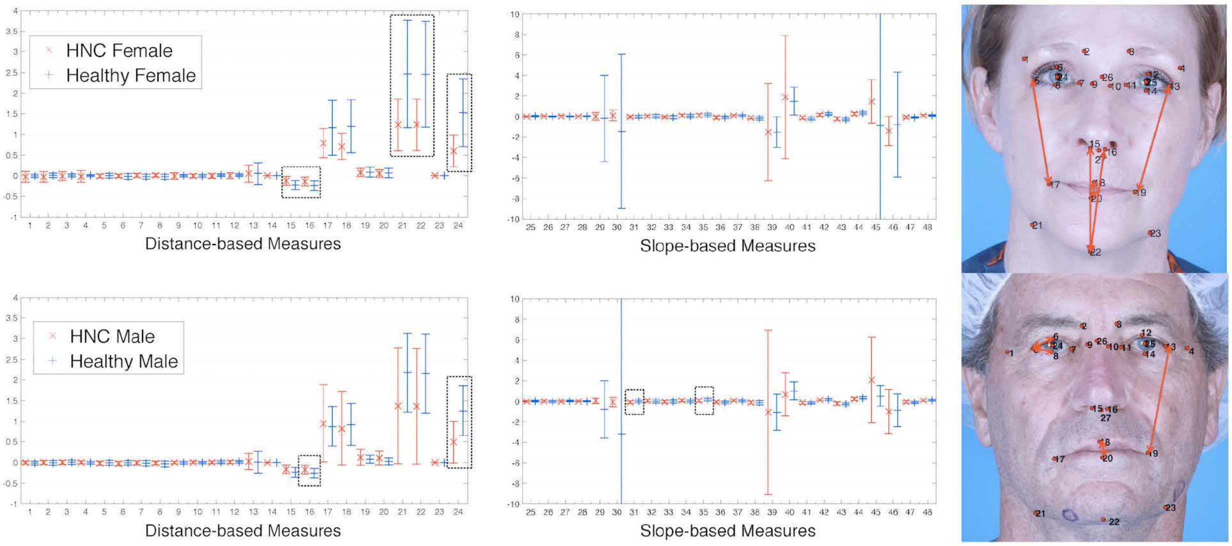

Figure 3. This figure illustrates the quantitative expression measures that showed statistically significant differences between the patients with head and neck cancer (HNC) at the *pre-operative* stage and healthy indivduals. The first and second columns show the mean of each measure and the upper and lower bounds by its +/- standard variation from the mean. Among all meaures, statistically significant measures are bounded by the dashed box. For the most cases, there were no statistically significant difference between the head and neck cancer patients and healthy individuals. All statistically significant expression measures are the distance-based measures except the measures of the patient's right eye (the slope-based measures). The distances between the tip of eye and mouth are usually reduced when people smile. Analysis result showed that those lengths for head and neck cancer patients are less reduced than those of healthy individuals. Although a few slope-based expression measures showed statisticial significance, their absolute values are around 0, which means there is almost no change in angle before and after forming a smile.

The first author (J. Lee) of this study manually annotated 27 facial fiducial points on the first image dataset following the definition of Farkas [9] and the illustration shown in Tang and Huang [1] (Fig 1.C). For BU-3DFE, this study used the subset of fiducial points provided with the dataset (red dots in Fig 2.A and B). To make the fiducial points of BU-3DFE comparable to our dataset, we projected those points to the xy-plane of Cartesian coordinate space and used the resulting location in the xy-plane for the study. Then 24 distance features and 24 slope features were obtained from those fiducial points. Although this study used manually annotated fiducial points, this step could be automated in the future using existing fiducial point detection algorithms (e.g., [10]).

TABLE I. DISTANCE FEATURES AND CORRESPONDING FAPUS FOR NORMALIZATION

Distance Feature Numbers	Normalized by
1 – 4, 9 – 12	ES0
5 – 8, 15, 16	ENS0
13, 14	IRISD0
17 – 22, 24	MNS0
23	MW0

The quantitative measures of facial expression were then computed as follows,

$$f_{i,PE} - f_{i,NE},\ i = 1,2,\ldots,48 \quad (1)$$

where f represents expression features, *PE* and *NE* stand for peak and neutral expression, respectively. For BU-3DFE, we referred to the images depicting the highest expression intensity level (i.e., intensity level 4) as the PE images.

C. Statistical Analysis

The hypothesis of this study is that patients with head and neck cancer at the *pre-operative* stage show limited intensity in their facial expressions, particularly in smiling, compared to healthy individuals. This trend for patients with head and neck cancer is expected since: 1) the tumor itself may hinder forming a smile and 2) they are facing many serious concerns such as dying and disfiguring surgeries as well as the potential for functional impairment.

As previous studies have indicated that there is a gender difference in posing facial expressions [11], we compared the quantitative analysis results by gender. However, we did not stratify our data further by age since previous studies showed that there is no age effect in posing facial expressions (e.g., [12]). Moreover, since facial expression, especially smiling, is considered to be universal [13], we didn't divide our dataset into different race/ethnic groups.

A two-sample student's t test was applied to each facial expression measure pair to evaluate our hypothesis. Since multiple t-tests were conducted, we corrected the significance level using Bonferroni's correction. The resulting significance level after the correction was 0.001.

III. RESULTS

There were a total of 7 facial expression measures that showed statistically significant differences between patients with head and neck cancer at the *pre-operative* stage and healthy individuals.

Female patients showed statistically significant differences in a total of 5 facial expression measures, which are the distances between tip of eye and mouth, the distances from each nostril to chin, and the distance between the upper and lower lip (Fig 3. First row). These measures are all distance-based expression measures. None of the slope measures showed a statistically significant difference between the two groups. The values of those 5 distance-based expression measures are typically reduced, i.e., the length between related fiducial points in *PE* is shortened than that in *NE*. Our results indicated that the values of those 5 distance-based expression measures of female patients are less reduced than those of healthy women.

Male patients showed statistically significant differences in a total of 4 facial expression measures, which are the distance between left tip of eye and nose, the distance between upper and lower lip, right-upper and lower slope measures on right eye (Fig 3. Second row). A similar trend for the distance-based expression measures was found; the values of those 2 measures are less reduced than those of healthy men. In the case of those 2 slope-based measures, the values of the measures for both groups are similar; the measure values are around 0, which means that those slopes do not change much when they form a smile. This trend also was found for the other slope-based measures. Hence, those 2 slope-based measures have less meaning than the distance-based measures. Although the value of the other 3 distance-based measures that showed statistical significance for the female case were not statistically significantly different between the male patients and the healthy male groups, their *p-value*s were closed to the significance level cut-off (i.e., 0.001). This shows that male and female patients have similar trends in smiling as quantified by distance-based expression measures.

IV. Discussion and Conclusion

In this study, we proposed 48 quantitative facial expressions measures computed from 27 manually annotated fiducial points on 2D clinical photographs of patients with head and neck cancer. The quantitative expression measures were computed by calculating the change of the facial feature value between the peak smile and neutral expression. Facial features for this study consist of the length normalized distances and the slopes (or angles) between those 27 fiducial points. Using the proposed measures, the maximum intensity of smiling for patients with head and neck cancer at the *pre-operative* stage was compared to that of healthy individuals. We identified a total of 7 quantitative facial expression measures (5 distance-based and 2 slope-based measures) that capture statistically significant differences between either male or female patients with head and neck cancer and a gender-matched sample of a healthy population. The value of the above expression measures indicated that patients with head and neck cancer are less expressive when they form a smile compared to healthy individuals. The result of this study is promising as these measures quantitatively capture facial expression, such as smiling for patients with head and neck cancer.

This study lays a foundation for investigating an important facet of the cancer treatment consequences, which is change in facial expression. Previous studies were limited to the patients with neuropsychiatric disorders. Using the proposed measures and existing psychosocial instruments, we can quantitatively track changes in smile intensity across cancer treatment and relate such changes to patient's psychological functioning. This will allow us to understand better how physical changes due to cancer treatment relate to psychosocial adjustment and quality of life.

Areas for future work building on this study include: 1) automation of fiducial point detection using existing algorithms to facilitate the process of quantification of smile intensity, 2) investigating changes in smile intensity of patients over the course of their cancer treatment, and 3) relating it to patients' psychosocial functioning.

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