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Dear Dr. Hart,

We have received the revisions for JPRAS-D-21-00959R1 and would like to thank you and your reviewers for your feedback and consideration of our manuscript. We have made revisions to the manuscript, per the reviewers' comments, which are highlighted and with red color change.

Comments:

Reviewer 2

I have made my intensive suggestions written in PDF in the attachment. Please see attached.

Appropriate changes have been made per suggestions. Thank you very much for the feedback.

Reviewer 3

This authors report demonstrates an objective assessment of surgical outcomes for facial rejuvenation patients using AI. Although preliminary and limit proof of concept, I consider the topic relevant to the readers.

Thank you very much for your time and consideration.
Sincerely,

Thanapoom Boonipat on behalf of the authors

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Using Artificial Intelligence to Analyze Emotion and Facial Action Units Following Facial Rejuvenation Surgery

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Short Running Title: Objective Facial Rejuvenation Analysis

Abstract:

Introduction:

There remains a lack of ~~standardization~~ standards in facial rejuvenation procedures, which may be attributed to the subjective measures used to determine surgical outcomes and success. The aim of this study was to evaluate the use of machine learning technology, i.e. FaceReader™, to objectively measure facial rejuvenation surgery outcomes. ~~This study evaluates the use of machine learning technology as an objective method to measure facial action units and emotional expression before and after facial rejuvenation surgery.~~

Methods:

Using a retrospective study design, we enrolled a cohort of patients undergoing high SMAS facelift with/without additional procedures during a one-year interval. The predictor variable was surgery done (pre- vs. postoperative). The outcome variables were 28 facial action units, happiness, and sadness emotions, detected by FaceReader™. Appropriate statistics were calculated at α = 0.05. ~~The sample consisted of fifteen patients who underwent facial rejuvenation surgery (high SMAS facelift in combination with possible browlift, blepharoplasty, fat grafting) and were evaluated before and after surgery. Repose images of the patient were analysed using the Noldus FaceReader™ software to measure the 28 action units and the happy and sadness emotion detected within each image.~~

Results:

The sample comprised of 15 patients (11 females, 15 Caucasians, mean age of 55.7 years). ~~Pre-operatively no patients had lip corner puller action unit activation. Post-operatively, 11/15 patients have activation of the lip corner puller action unit, changing in intensity from 1/4 to 3/4. This corresponded to an~~There was an average increase in detected happy emotion from 1.03% to 13.17% ($p>0.01$). Conversely, the average angry emotion detected decrease~~d~~s from 14.66% to 0.63% ($p<0.05$). ~~12.1% to 0.5%.~~ There were no other distinct action unit patterns across the operation.

Conclusion:

Despite a small sample size, the results of this study suggest that FaceReader™ can be used as an objective outcome assessment tool in patients undergoing high SMAS facelift with/without its adjuncts. ~~This study provides the first proof of concept for the use of a machine learning~~

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~~software application to objectively detect facial action unit changes and quantify facial expression before and after surgical facial rejuvenation.~~

Key words: FaceReader, Facial Rejuvenation Surgery, Artificial Intelligence Analysis, Facial Action Units

Introduction

Emotional expression is ~~a~~ fundamental ~~aspect to~~of human communication and connection. It includes ~~. Universal emotional expression by means of facial movements has seven categories:~~ sadness, happiness, anger, neutrality, surprise, fear, and disgust.[1] ~~These emotions have been systematically~~On one hand, it is linked to facial muscle action units functioning through the Facial Action Coding System (FACS), which can, on the other hand, be~~is~~ used to analyse facial expressions and emotions.[1,2]

Facial aging causes undesired emotional expression which can be surgically corrected. However, subjective surgical outcome measures may be biased. Such bias can be overcome by the use of objective measures, in this case, through emotional expressions post-surgery. ~~Surgical interventions can be employed to alter apparent undesired emotional expression due to facial aging. However, without an objective measure of surgical outcomes, the facial surgery profession largely relies on subjective analysis for the comparison of surgical techniques and success. Therefore, objective emotional expression can be a valuable unbiased metric of success.~~

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The purpose of this study was to objectively measure outcomes of facial rejuvenation using artificial intelligence (AI) and determine whether this measure was appropriate for evaluation of emotional expression.

~~In this paper, we examine the use of AI as a novel objective measure for surgical outcomes in facial rejuvenation patients. This research aims to examine the efficacy of our facial rejuvenation and to establish an objective measure of surgical outcomes with respect to emotional expression.~~

Methods

This was a retrospective study approved by the ~~After obtaining~~ institutional review board (IRB) and enrolled~~approval, a~~~~we retrospectively identified all~~ patients who underwent facial rejuvenation surgery comprising ~~(~~high SMAS facelift ~~with/without in combination with possible~~ browlift, blepharoplasty, and fat grafting at our department ~~)~~ in 2017**.** Pre- ~~We obtained pre-~~ and post-operative ~~images patient photographs were taken in repose, and of all patients in repose (n=15). Patients were instructed not to express any emotion in these photos.~~

images. ~~Images~~ were analysed using a commercially available facial expression recognition software package (FaceReader™, Noldus Information Technology BV, Wageningen, The Netherlands)~~.~~ ~~,~~ This analytic method has~~which~~ ~~was shown to have~~ an accuracy of 80% when tested against FACS.[3] FaceReader™ data included the proportion of each emotion expressed and associated facial action units intensity.

Appropriate statistical analyses were performed ~~Differences between paired continuous variables were assessed using the nonparametric Wilcoxon signed-rank test comparing facial emotions detected by FaceReader pre- and post-operatively. All statistical analysis was performed~~ using JMP (SAS Institute Inc., NC, USA) at α ~~A value of p <~~ = 0.05 ~~was considered statistically significant~~.

Results

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15 facial rejuvenation patients (11 females, 4 males ;15 all Caucasians) with a mean age of 55.7 years old (range ; 41-70 years old) years old, avg. 55.67 years old) were included. in the study. Other Cconcomitant procedures included 11 browlifts, 8 upper and lower blepharoplasties, 13 with fat grafting, and 3 with chin augmentations. Figure 1 shows an example of FaceReader analysis.

Facial analysis showed an increase in average perceived happiness from 1.03% to 13.17% ($p<0.01$) and a decrease in anger from 14.66% to 0.63% ($p<0.05$) in all patients pre- and post-operatively. (Figure 2) With additional procedures, the trends remain unchanged. When analysing patients with fewer concomitant procedures these trends were maintained. In the fivFivee patients underwent who only had a high SMAS facelift with upper or lower blepharoplasty, browlift, and/or fat grafting. ,—Their the average happiness emotion increased from 3.08% to 25.20% ($p<0.01$) and the average surprised emotion increased from 0.00% to 6.44% ($p<0.01$) in pre-operative and post-operative imagespost-operatively.

Facial action unit analyses correlated to emotional analyses. Pre-operatively, there was no detectable activation of the Lip Corner Puller, and the action unit of the zygomaticus major muscle essential for smile formation, in any patient.[4] The high SMAS facelift should raise the SMAS in the vector of the zygomaticus major, giving the patient a slight smile even at rest. As expected, after high SMAS facelift, 11/15 patients had activation of the Lip Corner Puller action unit ranging from 1/4 to 3/4 intensity. This was the most distinct and nearly universal change in all patients of all facial action units analysed.

Discussion

In this study, we demonstrated objective AI-based outcome measures of facial rejuvenation surgery. Our report demonstrates an objective assessment of surgical outcomes for facial rejuvenation patients using AI. Previous attempts evaluation methods, such as to analyse

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patient outcomes for aesthetic procedures (e.g., patient satisfaction surveys and , eye-tracking suffer from bias, etc.) are impacted by innate biases and contextual information.[4,5] AI advances have demonstrated could be promise as an objective and standardized technique forof surgical evaluation. Our aim wasWe used to employ FaceReader'sTM AI to overcome the 's capabilities to remove the innate errors associated with the aforementioned assessment drawbackss.

We found Our research demonstrated that FaceReaderTM was canable to quantify subjective measures, such as satisfaction, in a standardized standard wayfashion. Furthermore, the significant increase in perceived happiness in patients' faces in neutral pose can be interpreted as successful, demonstrated the efficacy of our facial rejuvenation. FaceReaderTM facial action unit analysis also allowed us to correlate the changes in perceived emotions with muscle functioning. Thus, the concurrent findings of increased Lip Corner Puller function and detected happiness further supports the efficacy of our facial rejuvenation.

An interesting outlook is to useInterestingly, AI software canto compare the results of multiple different surgical techniques because it does so objectively. to objectively compare outcomes and achieve better patient results.

Conclusion

Due to theThe growing popularity and availability of AI software such as FaceReaderTM, appear its efficacy must be assessed beneficial in for measuring aesthetic outcomes in facial surgeryfacial aesthetic surgery outcomes. The outputted numerical values for historically subjective measures such as perceived emotions provide a reliable and comparable measure which can avoid the inter- and intra-observer biases. Our future research will focus on the use of this technology to assess surgical outcomes. If surgical outcomes are unbiased with standardized evaluations, we believe the efficacy of facial aesthetic surgery will consequently improve. We hope to further use this technology to compare different surgical techniques for reversing facial

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~~wearing, with the aim to provide an objective measure for improving patient outcomes following facial surgical procedures.~~

Approved by Mayo Clinic IRB. IRB #:17-009087

Funding: None
Conflicts of interest: None declared
Ethical approval: Not required

Consent: Patient used in Figure 1 has provided written consent for photo publication

References

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Figure 1

Click here to access/download;Figure(s);Figure 1 Right.jpg

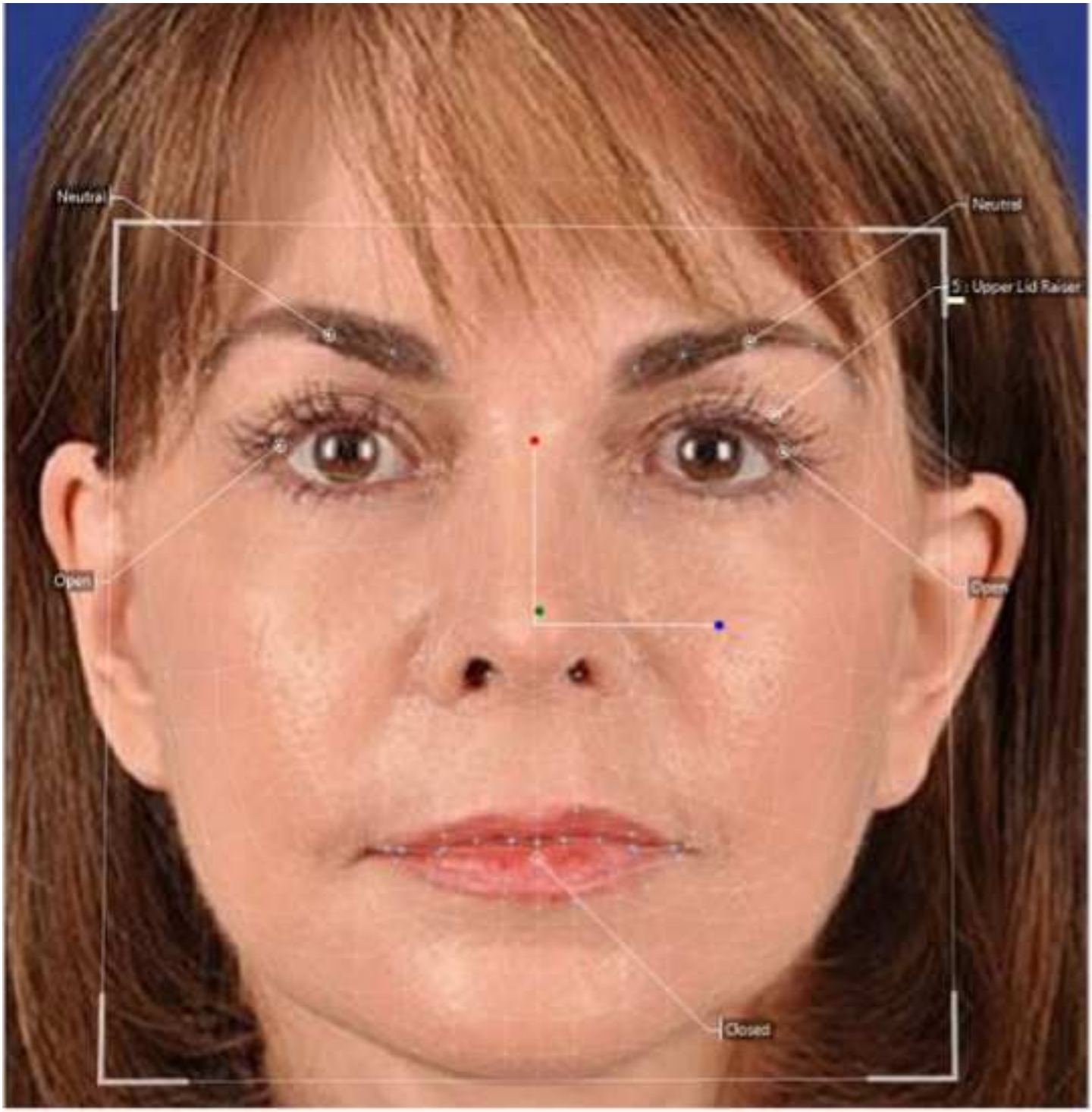

Figure 2

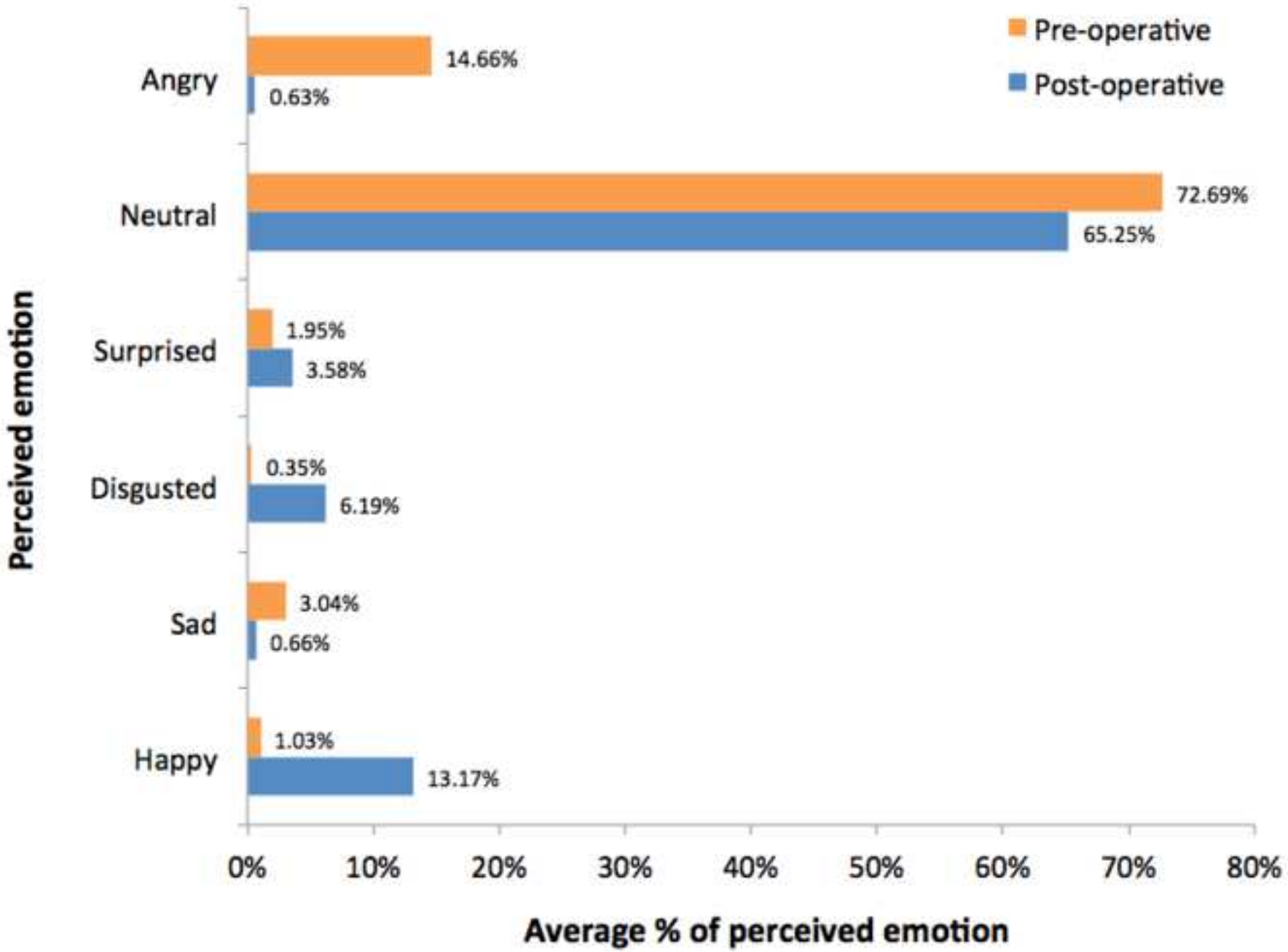

Figure Legend

Figure 1. Representative images of the FaceReader analysis. The facial images are overlayed with a virtual mesh with labelled action units with their respective functioning. Left: The example image demonstrates a pre-operative photo on the left and the corresponding post-operative photo on the right. The patient is a 49-year-old female who underwent high SMAS facelift with lateral temporal endoscopic browlift, bilateral canthopexy, and fat transfer to the lower eye lids, midface face, jawline, chin, and upper and lower lip.

Figure 2. Analysis of the perceived seven cardinal emotion averages in the 15 facial rejuvenation patients. Statistically significant emotions were determined to be the happy emotion and the angry in an inversely proportional manner. Pre-operative emotion was shown above the post-operative value within each emotion category.