Submitted: 11 October, 2020 Accepted: 10 November, 2020 Published: 08 March, 2021 DOI:10.22514/sv.2020.16.0105

Open Access

Signa Vitae

ORIGINAL RESEARCH

Facial expression differences indicate pain improvement at the emergency department

Kuo-Cheng Wang[1,5], Chen-June Seak[2,5], Fu-Sheng Tsai[3], Cheng-Yu Chien[4], Chi-Chun Lee[3], Chip-Jin Ng[5], Bo-Cyuan Wang[6,7], Yi-Ming Weng[1,5,8,*]

[1]Department of Emergency Medicine, Prehospital Care Division, Tao-Yuan General Hospital, Taoyuan, Taiwan
[2]Department of Emergency Medicine, New Taipei City Municipal Tucheng Hospital (Built and Operated by Chang Gung Medical Foundation), New Taipei, Taiwan
[3]Department of Electrical Engineering, National Tsing Hua University, Hsinchu, Taiwan
[4]Department of Emergency Medicine, Ton-Yen General Hospital, Hsinchu, Taiwan
[5]Department of Emergency Medicine, Chang Gung Memorial Hospital,and Chang Gung University College of Medicine, Linkou, Taoyuan, Taiwan
[6]Department of Nursing, New Taipei City Municipal Tucheng Hospital (Built and Operated by Chang Gung Medical Foundation), New Taipei, Taiwan
[7]School of Nursing, College of Nursing, Taipei Medical University, Taipei, Taiwan
[8]Faculty of Medicine, National Yang-Ming University, Taipei, Taiwan

***Correspondence**
wengym33@gmail.com
(Yi-Ming Weng)

Abstract

Purpose: Pain is a major symptom for patients to seek medical services, but limited evidence supports the applicability and usage of facial expressions as a pain measurement strategy in the emergency department (ED). In this study, we explored possible differences in facial expressions before and after pain management and compared these differences with those in a self-reported pain scale. **Methods**: In this observational study, convenience sampling of patients admitted to the ED was conducted. Two video sessions of facial expressions were recorded for each participant, and participants rated their painon a self-reported numeric rating scale (NRS). A total of 25 facial parameters were extracted per frame. The main outcome measurements were the differences in facial parameters, and their correlation with changes in NRS scores was examined. **Results**: This study included 163 participants. A stronger reduction in NRS scores was associated with differences in systolic blood pressure (sBPr = 0.247, P = 0.011) and the following changes in facial features: eye opening (left: r = -0.210, P = 0.007; right: r = -0.206, P = 0.008), eye aspect ratio (left: r = -0.382, $P < 0.001$; right: r = -0.305, $P < 0.001$), and head rotation angle (r = 0.218, P = 0.005). Pain improvement (a difference of $\geq$ 4 in NRS scores) was associated with differences in BP (sBP, odds ratio [OR] = 0.973, 95% confidence interval [CI]: 0.949-0.998, P = 0.034; dBP, OR = 1.078, 95% CI: 1.026-1.113, P = 0.003), eye aspect ratio (Left: β = 5.613, 95% CI: 2.234-14.104, $P < 0.001$; Right: β = 2.743, 95% CI: 1.395-5.391, P = 0.003), and nasolabial fold variation (β = 0.548, 95% CI: 0.306-0.982, P = 0.043), after adjustment for variables. **Conclusions**: Intraindividual changes in facial expressions can be used to track clinically relevant differences in pain. Facial expressions alone cannot be used as a pain measurement strategy in the ED.

Keywords

Pain; Pain measurement; Analogue pain scale; Facial expression; Facial recognition

1. Introduction

Pain is an unpleasant feeling after experiencing trauma and is a major reason for seeking medical services [1–3]. Pain intensity is a major modifier of triage classification in emergency departments (EDs) [4–6]. Pain can be measured using several methods, including verbal rating scales, visual analog scales, numeric rating scales (NRSs), and face scales. Pain intensity is typically measured during triage through self-reporting on a 10-point NRS [7, 8]. Patients unable to understand the description of pain or communicate effectively may undergo an incomplete pain evaluation-particularly if they are elderly, very young, foreign, or unconscious [9, 10]. In addition, subjective ratings of pain raise concerns regarding stoic concealment or pain exaggeration [11].

Previous studies have attempted to measure pain by using behavioral assessments. For example, facial expressions of pain consist of a combination of emotions, including anger, fear, and disgust [12–14]. Identifying specific cues (e.g., brow lowering, eye closing, nose wrinkling, and mouth opening) can improve the subjective judgment of deception in pain expression [13, 14]. Facial action units, including brow lowering, orbital tightening, levator contraction, and eye closing, are considered prototypic expressions of pain [15]. The facial action detection technology had progressed from the first beginning as human coders to computers. Automatic tracking of facial landmarks became one of crucial development in this field. The accuracy and person independent facial landmark detection system is a major concern. A novel method is the Constrained Local Neural Field (CLNF). The CLNF capture more complex information and exploit spatial relationship between pixels. CLNF had shown outperforming across different conditions. Despite improvement of the face tracking technology, evidence supporting the efficacy of facial

This is an open access article under the CC BY 4.0 license (https://creativecommons.org/licenses/by/4.0/).

©2021 The Author(s). Published by MRE Press.

expression tracking for pain measurement in the emergency clinical setting is limited. The validity of previous findings in patients who cannot effectively communicate their pain is questionable.

Pain is a major symptom and major reason for patients to seek medical services, but limited evidence supports the applicability and usage of facial expressions as a pain measurement strategy in the ED. To facilitate pain measurement in the ED, the behavioral and physiological presentations of patients in pain should be investigated. The feasibility of using facial expressions as an indicator of pain in the ED is uncertain. In this study, we explored possible differences in facial expressions before and after pain management or treatment and compared these differences with those in self-reported NRSs. Moreover, the facial expressions with the highest correlation with clinically significant reductions in NRS pain scores were analyzed.

2. Methods

2.1 Study population

This study used convenience sampling to enroll patients who required pain evaluation during ED triage. Adult patients aged $\geq$ 18 years who were admitted to the ED due to complaints of headache, chest pain, abdominal pain, backache, painful limbs, or pain in other body parts at triage were included in this study. Patients $<$ 18 years old, those who had experienced trauma, referral patients, patients with prior treatment, patients who were lost to follow-up, and patients who were unwilling to participate in the study were excluded. Patients with critical illness or those needing emergency management were also excluded.

2.2 Study methods

2.2.1 Study protocol

Patients were triaged after registration in the ED. The primary investigators or research assistants explained the study objective to patients and asked them to sign an informed consent form while they waited for the physician at waiting area prior entering the examination room. The recording camera was set at a fixed location at a vacant room. All recruited patients were moved to this room. After informed consent was obtained, the first assessment and a video recording at least 30 seconds long were conducted in the resting state. The second assessment and recording session were performed after physician visits, at least 30-minute after the first session, in the same sitting and following the same protocol. Patients might receive pain treatment as prescription during the interval between the two sessions. The time point of each session was documented for each patient (i.e. 2016/7/20 11:16).

2.2.2 Assessment tools

The assessment included a basic description of the patients' pain, including location, duration, and intensity, and an NRS ranging from 0 (no pain) to 10 (worst pain imaginable) was used [6, 7]. NRS scores of 1-4, 5-7, and 8-10 were indicated mild, moderate, and severe pain, respectively [6, 7]. To standardize patients' attention, the research assistants acquired pain descriptions in a designated assessment room by using an HDR Handycam (Sony, Tokyo, Japan) mounted on a tripod to record the video. Patients received an indication to look at the camera and answer the questions prior to recording. The camera was positioned to allow consistent capturing of facial expressions between sessionsRecordings were stored in a hard drive for further processing. Other covariates were obtained from patients' electronic ED charts.

In this observational study, we conducted convenience sampling of patients admitted to the ED of a university-affiliated hospital during a 1-year period from May 2016 to April 2017. An HDR-CX405 Handycam (Sony, Tokyo, Japan) was used to track the changes in facial expression. This study was approved by the Ethics Committee of Chang Gung Medical Foundation, Taiwan (104-3625B). Informed consent was obtained from participants.

2.3 Data collection

2.3.1 Facial parameter extraction from videos

The development of facial feature detection algorithms has progressed. However, barriers, including poor lighting conditions and occlusions from extreme poses, still exist. The constrained local neural field (CLNF) model is a facial feature detection algorithm based on a point-distribution model; the positions of feature points in an image are determined by calculating the probability of aligned facial features. This algorithm was extended and its reliability was improved using a nonuniform regularized landmark mean shift fitting approach, optimizing the detection of a landmark's position [16, 17]. The CLNF method is an automated analytical method. The lowest error rate has been reported for the CLNF method with higher reliability than that of other methods [16].

In this study, we tracked the positions of 68 facial landmarks in each postprocessed recording by using the CLNF method. To identify the features of facial expressions of pain, the characteristics of such expressions were computed directly from the x and y positions of tracked key points instead of using action units (Fig. 1). Twenty-five facial parameters were extracted per frame to represent patients' facial expressions, which involved the eyebrows, eyes, mouth, nose, and head. To eliminate interindividual differences, we examined these features as ratios (divided by the distance from the nose tip to the root; Fig. 1), as follows:

Eyebrow distance ratio: The distance to the medial eyebrows divided by the distance to the lateral edge of the eyebrows (parameter 1).

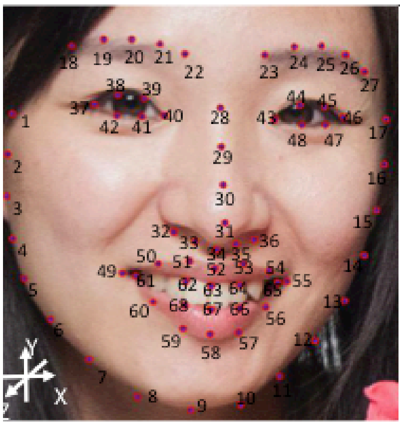
Eyebrow fall: The quadratic polynomial coefficients of the right and left eyebrows divided by the distance from the nose tip to the root (parameters 2-5).

Eye opening: The sagittal length of both eyes divided by the distance from the nose tip to the root (parameters 6 and 9).

Eye squinting: The sagittal length of the bilateral upper and lower eyelids to the medial-lateral canthus linedivided by the distance from the nose tip to the root (parameters 7, 8, 10, and 11).

Eye distance: The distance between the medial canthi divided by the distance between the lateral canthi (parameter 12).

Mouth height and width: The sagittal and horizontal lengths



NO.	Type	Explanation
P1	Eyebrow distance ratio	22,23 / 18,27
P2-5	Eyebrow fall	22,40 ,23,43 ,18,37 ,27,46 / 28,31
P6,9	Eye opening	38,42 , 45,47 / 28,31
P7,P8, P10,P11	Squint eyes	d(38, ∠↓37,40) ,d(42, ∠↓37,40) ,d(45, ∠↓43 ∠↓43,46) / 28,31
P12	Eye distance	40,43 / 37,46
P13,P14	Mouth height / width	52,58 , 49,55 / 28,31
P15,P16	Lip corner	40,49 , 43,55 / 28,31
P17,P18	Mouth variation	34,52 , 34,58 / 28,31
P19	Mouth aspect ratio	52,58 / 49,55
P20,P21	Eye aspect ratio	38,42 / 37,40 (45,47 / 43,46)
P22	Philtrum variation	31,52 / 28,31
P23	Nasolabial folds variation	32,36 / 28,31
P24,P25	Head pose, position	Calculate by Perspective-n-Point (PnP)

FIGURE 1. Twenty-five facial parameters were extracted per frame to represent the facial expressions of the patient.

of the lips divided by the distance between the medial canthi (parameters 13 and 14).

Lip corner: The distance between the medial canthi and the mouth angle of both sides divided by the distance from the nose tip to the root (parameters 15 and 16).

Mouth variation: The distance from the nose to the upper and lower lips divided by the distance from the nose tip to the root (parameters 17 and 18).

Mouth aspect ratio: The sagittal length between the lips divided by the horizontal length of the lips (parameter 19).

Eye aspect ratio: The sagittal length of both eyes divided by the medial-lateral canthus length (parameters 20 and 21).

Philtrum variation: The distance between the nose tip and upper lip divided by the distance from the nose tip to the root (parameter 22).

Nasolabial fold variation: The gap between the nasolabial folds divided by the distance from the nose tip to root (parameter 23).

Head pose and position: Head pose was estimated by calculating the movement between the head and the camera by using the perspective-n-point method based on the coordinates (parameter 24) and rotation angle (parameter 25).

In research on emotion recognition [18], neutral features were subtracted from emotional features to characterize significant differences in facial motion and enhance classification accuracy. Based on this concept, we defined the neutral condition as patients with a pain level of 0 and used the following function:

$$\text{Feature}_i = \frac{X_i - \text{mean}_{\text{neutral}}}{S_{\text{neutral}}} \quad (1)$$

2.3.2 Assessment of covariates

The patients' age in years, gender, chief complaint, body part affected, NRS or pain intensity scores during the two sessions, duration of video recording during the initial and follow-up sessions, and vital signs in ED triage (body temperature, heart rate, blood pressure, and respiration rate) were recorded for analysis. Analgesics provided, if any, to alleviate pain were identified. Information on admission to a ward or intensive care unit, surgery, and date of discharge from the ED was obtained from medical records.

2.4 Main outcome

The main outcome was the differences in 25 facial parameters, and their correlation with the changes in NRS pain scores before and after pain management was determined. Patients of pain improvement group with a difference of $\geq$ 4 in NRS scores were further identified to establish a model using crucial facial parameters after adjusting for variables.

2.5 Statistical analysis

The demographic characteristics of participants are presented as number (%) and mean (standard deviation (SD)) for categorical and continuous variables, respectively. Categorical variables were compared using chi-square tests. Continuous variables were compared using Student's t tests. A P value of < 0.05 was considered significant. Pearson's correlation analysis was used to examine the correlation between changes in NRS scores and differences in facial parameters between the two sessions. To identify indicators of pain, the associations between facial parameters and significant improvement in pain (a difference of $\geq$ 4 in the NRS score between the two sessions) were subjected to logistic regression analysis after adjustment for certain variables. NRS scores of 1-3, 4-6, and 7-10 were considered to indicate mild, moderate, and severe pain, respectively [6, 7]. Thus, significant improvement in pain was defined as a NRS pain score difference of 4 or more between the two sessions, which indicated a change in the category of pain severity (e.g., severe to moderate or moderate to mild). The data were analyzed using SPSS 13.0 for Windows (SPSS Inc., Chicago, IL, USA).

TABLE 1. Background characteristics of participants.

		All
		N = 163
Age, years; mean (SD)		51.9 (16.3)
Male, N (%)		96 (58.9)
Body part of pain, N (%)		
Head		10 (6.1)
Chest		14 (8.6)
Abdomen		87 (53.3)
Back		16 (9.6)
Limbs		20 (12.3)
Others		16 (10.0)
Pain level by NRS, mean (SD)		
Initial		6.4 (2.4)
Follow-up		3.7 (2.6)
Initial vital signs, mean (SD)		
HR, per min	Initial	86.0 (16.3)
	Follow-up	78.9 (15.5)
sBP, mmHg;	Initial	142.3 (22.5)
	Follow-up	130.4 (19.0)
dBP, mmHg;	Initial	91.0 (57.7)
	Follow-up	80.7 (11.3)
RR, per min	Initial	18.1 (1.6)
	Follow-up	17.8 (1.2)
Analgesics provision at ED, N (%)		112 (68.7)
Hospitalization, N (%)		49 (30.1)
Surgery, N (%)		18 (11.0)

Abbreviations: SD, standard deviation; HR, heart rate; sBP, systolic blood pressure; dBP, diastolic blood pressure; RR, respiratory rate; ED, emergency department.

3. Results

Among 241 participants, 163 completed both recording sessions and were enrolled in the study. Most of the study participants were men (58.9%); the mean age was 51.9 years (Table 1). Abdominal pain (53.3%) was the most common complaint at ED triage, followed by limb pain (12.3%). The mean duration of the interval between the two sessions was 68.6 (SD: 30.5) min. The initial and follow-up mean NRS scores were 6.4 and 3.7, respectively. Moreover, 112 (68.7%) participants had taken analgesics to alleviate pain, and 30.1% were admitted to the hospital, with a mean hospital stay of 2.5 (SD: 5.8). Surgery was conducted in 11.0% of participants. Mortality and admission to the intensive care unit did not occur. Only eight patients revisited the ED within 72 h after discharge, with three additional hospital admissions.

Table 2 shows the correlations between changes in NRS scores and differences in facial parameters and physiological parameters between the initial and follow-up sessions. A stronger reduction in NRS scores was associated with differences in systolic blood pressure (sBP; r = 0.247, $P = 0.011$) and changes in the following facial features: eye opening (left: r = -0.210, $P = 0.007$; right: r = -0.206, $P = 0.008$), eye aspect ratio (left: r = -0.382, $P < 0.001$; right: r = -0.305, $P < 0.001$), and head pose by rotation angle (r = 0.218, $P = 0.005$).

Fifty participants exhibited significant improvement in pain levels (i.e., a difference of $\geq$ 4 in NRS scores) between the two sessions (pain improvement group). The pain improvement group showed differences in (sBP, OR = 0.973, 95% confidence interval (CI): 0.949-0.998, $P = 0.034$; diastolic blood pressure, OR = 1.078, 95% CI: 1.026-1.113, $P = 0.003$), eye aspect ratio (left: $\beta = 5.613$, 95% CI: 2.234-14.104, $P < 0.001$; right: $\beta = 2.743$, 95% CI: 1.395-5.391, $P = 0.003$), and nasolabial fold variation ($\beta = 0.548$, 95% CI: 0.306-0.982, $P = 0.043$) after adjustment for initial pain level, gender, and age (Table 3). The scatter plots in Fig. 2 show the correlation of the differences in NRS scores with the differences in measurements of facial expressions.

4. Discussion

We found a significant correlation between the changes in NRS pain scores and the differences in facial parameters in the ED. Facial expressions of pain comprise various eye parameters and head rotation angles. Subgroup analysis indicated an association of additional parameters over the nose area with significant improvement in pain. Previous studies have emphasized the association between facial expressions and pain induced by stimuli or exercise [19–23]. The presentation of patients in prior studies might differ from that of patients in the ED. Our findings indicate that intraindividual changes in facial expressions can be used to track clinically relevant differences in pain. Facial expressions alone cannot be used as a pain measurement strategy in the ED.

This study identified facial parameters associated with pain in an ED population of a tertiary care center. These findings echo those of previous studies that have characterized features of the eyes, head posture, and nasolabial folds of patients in pain [13, 15, 24–26]. Thus, in addition to changes in the eyes, head posture, and nose area, activity in the brow and the activity in mouth areas are essential elements of facial expressions of pain. By contrast, we found a nonsignificant correlation of brow- and mouth-related parameters with changes in NRS scores. High-frequency mouth opening and residual eyebrow movement have been reported to be associated with the masking of pain expression [14]. Our findings suggest the importance of parameters related to the eyes, head angle, and nasolabial folds. In addition, lower blood pressure was associated with improved pain intensity. The

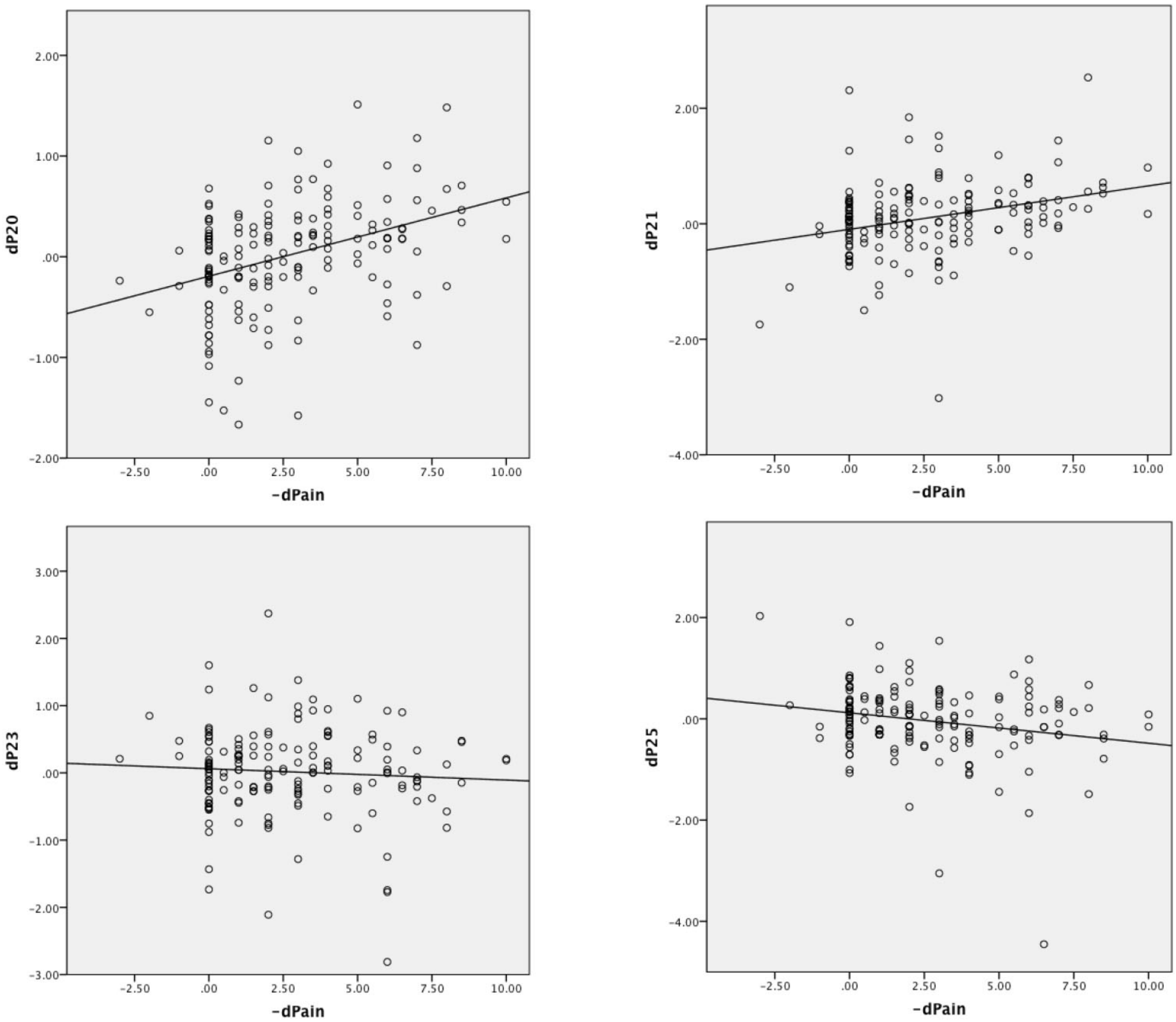


FIGURE 2. Scatter plots showing the correlations between changes in NRS scores and differences in measurements of facial expressions of pain (P20, 21: eye aspect ratio, P23: nasolabial folds, P25: head angle).

responses to pain stimuli involve the neuroendocrine system, which maintains adequate physiological function against the imbalance [27]. Acute pain tends to increase blood pressure through the activation of the sympathetic nervous system [28, 29]. Increased peripheral resistance, heart rate, and stroke volume all contribute to the increased resting blood pressure during pain stimulus [30]. Previous studies have proposed that hypertension-related acute pain modulation reduces pain sensitivity through hemostatic feedback [31]. The excitation of the central and peripheral nervous systems decreases with pain relief, followed by a decline in blood pressure.

Second, instead of recognizing facial action units, we computed features that characterize these expressions directly from the positions of tracked key points. Artificial intelligence and machine learning have been applied to the analysis of relevant action expression records [15, 32–35]. For example, Ashraf *et al.* used an active appearance model to identify frame-level pain [32], and Kaltwang *et al.* used a relevance vector regression model to discriminate between real and false pain [33]. Littlewort *et al.* reported that an automated facial coding system that involved machine learning could correctly identify real pain [34]. Another automatic continuous facial feature landmark tracking system enabled the monitoring of pain over time [35]. Action units use a layer combined with the computation of facial landmarks, which are easily communicated after being translated into different facial movements. This study analyzed several parameters by using primitive information to facilitate the transfer of the study results to a machine instead of post-processed action coding system.

Third, self-reporting is considered to be the primary pain measurement. A comprehensive assessment of pain includes the assessment of behavioral and physiologic presentations [36]. Although there were different starting points for self-reporting and distinct facial expressions for different types of pain stimuli, their association was evident in the presence of pain [37]. In addition to sensory discriminative factors, motivational affective and cognitive factors are important [38]. The interpretation of painful stimuli may be affected by culture, personality, experiences, environment, and emotional state [39, 40].

TABLE 2. Correlations between changes in NRS scores and differences in facial feature parameters and vital signs during two sessions (N = 163).

	r	*P*
Vital sign difference		
HR	-0.010	0.920
RR	0.082	0.413
sBP	0.247	**0.011**
dBP	0.160	0.101
Facial feature parameter		
Eye brows		
Eyebrows distance ratio (P1)	0.054	0.495
Distance of Lt Med. eyebrow to Med. Canthus (P2)	-0.078	0.325
Distance of Rt Lat. eyebrow to Lat. Canthus (P3)	-0.015	0.847
Distance of Rt Med. eyebrow to Med. Canthus (P4)	-0.009	0.907
Distance of Lt Lat. eyebrow to Lat. Canthus (P5)	-0.044	0.573
Eyes		
Lt eye sagittal length (P6)	-0.210	**0.007**
Rt eye sagittal length (P9)	-0.206	**0.008**
Lt Sagittal length of upper eyelid (P7)	-0.104	0.187
Rt Sagittal length of upper eyelid (P10)	-0.121	0.125
Lt Sagittal length of lower eyelid (P8)	-0.056	0.476
Rt Sagittal length of lower eyelid (P11)	-0.031	0.696
Distance of Med./Lat. Canthus (P12)	0.057	0.472
Lt sagittal/med.-lat. canthus length (P20)	-0.382	**< 0.001**
Rt sagittal/ med.-lat. canthus length (P21)	-0.305	**< 0.001**
Mouth		
Sagittal length of lips (P13)	-0.001	0.989
Horizontal length of lips (P14)	0.029	0.709
Distance of Lt eye to Lt mouth angle (P15)	-0.052	0.513
Distance of Rt eye to Rt mouth angle (P16)	-0.045	0.568
Distance of center of eyes to upper lips (P17)	-0.045	0.565
Distance of center of eyes to lower lip (P18)	-0.030	0.700
Sagittal/horizontal length of lips (P19)	-0.009	0.905
Nose		
Philtrum: distance of nose to upper lip (P22)	-0.008	0.916
Nasolabial folds variation (P23)	0.068	0.390
Head posture		
Head position (P24)	0.140	0.075
Head angle (P25)	0.218	**0.005**

Abbreviations: HR, heart rate; RR, respiratory rate; sBP, systolic blood pressure; dBP, diastolic blood pressure; Med., medial; Lat., lateral; Lt, left; Rt, right.

5. Limitations

The present study has several limitations. First, sampling and selection bias could not be ruled out because the study involved convenience sampling. Second, one in three patients refused to participate in this study. Third, this study was conducted with a limited number of participants from a university-affiliated hospital. Furthermore, the study population comprised patients with triage levels of 3 to 5, with few patients at levels 1 and 2. Patients with triage levels 1 and 2 patients were in

TABLE 3. Pain improvement group (N = 50)* showing differences in blood pressure, eye aspect ratio, and nasolabial fold variation.**

	OR	95% CI	*P*
Difference of sBP			
	0.973	0.949-0.998	**0.034**
Difference of dBP	1.078	1.026-1.133	**0.003**
Lt eye aspect ratio (P20)	5.613	2.234-14.104	**< 0.001**
Rt eye aspect ratio (P21)	2.743	1.395-5.391	**0.003**
Nasolabial folds variation (P23)	0.548	0.306-0.982	**0.043**

*Abbreviations: OR, odds ratio; CI, confidence interval; sBP, systolic blood pressure; dBP, diastolic blood pressure; Lt, left; Rt, right. *Pain improvement group: an NRS score improvement of ≥ 4. **Logistic regression analysis adjusted for initial pain level, age, and sex.*

critical condition and triaged according to modifiers other than NRS scores (e.g., unconsciousness, respiratory distress, and circulation collapse). Therefore, the study population may not be representative of all patients in pain; this limits the generalizability of our findings.

Several confounders, including the number of ED revisits after discharge, were not evaluated. Only revisit data for the ED of the study hospital were available. Some patients may have been lost to follow-up after discharge from the ED. Some patients may have left the ED without follow-up. Thus, some data on follow-up vital signs were missing. Nonetheless, we believe that the study reflected reality and provided adequate conclusions.

6. Conclusions

Using facial expressions to monitor the pain changes of a patient is a novel application of such technology in the ED. Gaps exist that prevent this method from being feasible in clinical practice, such as limitations related to facial recognition, multiface tracking, and data management process. Pain measurement in the ED should involve objective and automatic detectors either continuously or in a point-of-care style. In addition to the development of a feasible technological application, several aspects require further clinical research. First, outcome research is the most crucial field. As current technology is applied to daily ED care, the evolution of pain management should be observed. It will be interesting to check how clinical practice adjusted after revealing the results of dynamic facial expressions to the physicians and nurses in a timely manner. Second, a large database for subgroup analysis and cross-region comparison should be established. In subgroup analysis, patients who are unable to communicate their pain due to language barriers post physical/mental illness or those from different backgrounds should be included. In addition, the database would enable the exploration of the basics of pain expression and modulation under different causes of pain stimuli.

In short, we reported a significant correlation between changes in NRS pain scores and differences in facial parameters in ED patients. Facial parameters related to the eyes, head pose, and nasolabial folds were associated with changes in pain intensity. Our findings indicate that intraindividual changes in facial expressions can be used to track clinically relevant differences in pain. Facial expressions alone cannot be used as a pain measurement strategy in the ED.

ACKNOWLEDGEMENTS

This study was supported by grants from Chang Gung Memorial Hospital, Linkou, Taiwan (CMRPG3E1791) and the Ministry of Science and Technology, Taiwan (MOST 106-2221-E-007-027)

FUNDING

This study was funded by Chang Gung Memorial Hospital, Linkou, Taiwan (CMRPG3E1791).

CONFLICT OF INTEREST

The authors declare that they have no competing interests.

REFERENCES

[1] Debono DJ, Hoeksema LJ, Hobbs RD. Caring for patients with chronic pain: pearls and pitfalls. Journal of the American Osteopathic Association. 2013;113: 620-627.

[2] Turk DC, Dworkin RH. What should be the core outcomes in chronic pain clinical trials? Arthritis Research & Therapy. 2004; 6: 151-154.

[3] Apfelbaum JL, Chen C, Mehta SS, Gan TJ. Postoperative pain experience: results from a national survey suggesting postoperative pain continues to be undermanaged. Anesthesia and Analgesia. 2003; 97: 534-540.

[4] Bullard MJ, Unger B, Spence J, Grafstein E. Revisions to the Canadian Emergency Department Triage and Acuity Scale (CTAS) adult guidelines. Canadian Journal of Emergency Medicine. 2008; 10: 136-151. (In French)

[5] Ng CJ, Hsu KH, Kuan JT, Chiu TF, Chen WK, Lin HJ, *et al*. Comparison between Canadian triage and acuity scale and Taiwan triage system in emergency departments. Journal of the Formosan Medical Association. 2010; 109: 828-837.

[6] Ng CJ, Yen ZS, Tsai JC, Chen LC, Lin SJ, Sang YY, *et al*. TTAS national working group. Validation of the Taiwan triage and acuity scale: a

new computerized five-level triage system. Emergency Medicine Journal. 2011; 28: 1026-1231.
[7] Eriksson K, Wikstro¨m L, A rested K, Fridlund B, Brostr¨om A. Numeric rating scale: patients' perceptions of its use in postoperative pain assessments. Applied Nursing Research. 2014; 27: 41-46.
[8] Castarlenas E, S´anchez-Rodr´ıguez E, Vega Rde L, Roset R, Mir´o J. Agreement between verbal and electronic versions of the numerical rating scale (nrs-11) when used to assess pain intensity in adolescents. The Clinical Journal of Pain. 2015; 31: 229-234.
[9] Herr K, Titler M. Acute pain assessment and pharmacological management practices for the older adult with a hip fracture: review of ED trends. Journal of Emergency Nursing. 2009; 35: 312-320.
[10] Encandela JA. Social science and the study of pain since Zborowski: a need for a new agenda. Social Science and Medicine. 1993; 36: 783-791.
[11] Main CJ, Spanswick CC. Pain management: an interdisciplinary approach. Toronto: Churchill Livingstone. 2000.
[12] Hale C, Hadjistavropoulos T. Emotional components of pain. Pain Research & Management. 1997; 2: 217-225.
[13] Hadjistavropoulos HD, Craig KD, Hadjistavropoulos T, Poole GD. Subjective judgments of deception in pain expression: accuracy and errors. Pain. 1996; 65 : 251-258.
[14] Hill ML, Craig KD. Detecting deception in pain expressions: the structure of genuine and deceptive facial displays. Pain. 2002; 98: 135-144.
[15] Prkachin KM, Solomon PE. The structure, reliability and validity of pain expression: evidence from patients with shoulder pain. Pain. 2008; 139: 267-274.
[16] Baltrusaitis T, Robinson P, Morency LP. Constrained local neural fields for robust facial landmark detection in the wild. IEEE International Conference on Computer Vision Workshops. 2013; 354-361.
[17] Tzimiropoulos G, Alabort-i Medina J, Zafeiriou S, Pantic M. Generic active appearance models revisited, in Computer Vision-ACCV 2012. Springer. 2012; 650-663.
[18] Kulkarni S, Reddy N, Hariharan S. Facial expression (mood) recognition from facial images using committee neural networks. Nature Biomedical Engineering. 2009; 10: 16.
[19] Littlewort GC, Bartlett MS, Lee K. Automatic coding of facial expressions displayed during posed and genuine pain, Image and Vision Computing. 2009; 27: 1797-1803.
[20] Lu G, Yang C, Chen M, X Li. Sparse representation based facial expression classification for pain assessment in neonates, in Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD), 2016 12th International Conference on. IEEE. 2016; 1615-1619.
[21] Kaltwang S, Rudovic O, Pantic M. Continuous pain intensity estimation from facial expressions. Advances in Visual Computing. 2012; 368-377.
[22] Aung MS, Kaltwang S, Romera-Paredes B, Martinez B, Singh A, Cella M, *et al*. The automatic detection of chronic pain-related expression: requirements, challenges and the multimodal emopain dataset. IEEE Transactions on Affective Computing. 2016; 7: 435-451.
[23] Olugbade TA, Aung M, Bianchi-Berthouze N, Marquardt N, Williams AC. Bi-modal detection of painful reaching for chronic pain rehabilitation systems, in Proceedings of the 16th International Conference on Multimodal Interaction. Association for Computing Machinery. 2014; 455-458.
[24] Lucey P, Cohn JF, Matthews I, Lucey S, Sridharan S, Howlett J, *et al*. Automatically detecting pain in video through facial action units, systems, man, and cybernetics, part b: cybernetics. IEEE Transactions on. 2011; 41: 664-674.
[25] Rathee N, Ganotra D. A novel approach for pain intensity detection based on facial feature deformations, Journal of Visual Communication and Image Representation. 2015; 247-254.
[26] Werner P, Al-Hamadi A, Niese R, Walter S, Gruss S, Traue HC. Towards pain monitoring: facial expression, head pose, a new database, an automatic system and remaining challenges. British Machine Vision Conference. 2013; 119-1.
[27] France CR, Froese SA, Stewart JC. Altered central nervous system processing of noxious stimuli contributes to decreased nociceptive responding in individuals at risk for hypertension. Pain. 2002; 98: 101-108.
[28] Fagius J, Karhuvaara S, Sundlof G. The cold pressor test: effects on sympathetic nerve activity in human muscle and skin nerve fascicles. Acta Physiologica Scandinavica. 1989; 137: 325-334.
[29] Nordin M, Fagius J. Effect of noxious stimulation on sympathetic vasoconstrictor outflow to human muscles. Journal of Physiology. 1995; 489: 885-894.
[30] Maixner W, Gracely RH, Zuniga JR, Humphrey CB, Bloodworth GR. Cardiovascular and sensory responses to forearm ischemia and dynamic hand exercise. American Journal of Physiology. 1990; 259: R1156-R1163.
[31] Dworkin BR, Filewich RJ, Miller NE, Craigmyle N, Pickering TG. Baroreceptor activation reduces reactivity to noxious stimulation: implications for hypertension. Science. 1979; 205: 1299-1301.
[32] Ashraf AB, Lucey S, Cohn JF, Chen T, Ambadar Z, Prkachin MK, *et al*. The painful face-pain expression recognition using active appearance models. Image and Vision Computing. 2009; 27: 1788-1796.
[33] Kaltwang S, Rudovic O, Pantic M. "Continuous pain intensity estimation from facial expressions," in Advances in Visual Computing. Springer. 2012; 368-377.
[34] LittlewortGC, Bartlett MS, Lee K. Automatic coding of facial expressions displayed during posed and genuine pain. Image and Vision Computing. 2009; 27: 1797-1803.
[35] Lucey P, Cohn JF, Prkachin KM, Solomon PE, Chew fS, Matthews I. Painful monitoring: automatic pain monitoring using the unbc-mcmaster shoulder pain expression archive database. Image and Vision Computing. 2012; 30: 197-205.
[36] Carr DB, Jaco AK, Cahpman CR, Ferrell B, Field HL, Heidrich G. Acute pain management: operative or medical procedures and trauma. US Public Health Service, Agency for Health Care Policy and Research. 1992; 11: 391-414.
[37] Kunz M, Mylius V, Schepelmann K, Lautenbacher S. On the relationship between self-report and facial expression of pain. Journal of Pain. 2004; 5: 368-76.
[38] Kenshalo DR. The skin senses: proceedings of the first International Symposium on the Skin Senses, held at the Florida State University in Tallahassee, Florida. Sensory, motivational and central control determinants of chronic pain: a new conceptual model. Charles C Thomas 1968; 423-439.
[39] Skevington SM. Psychology of pain. Chichester, UK: Wiley. 1995; 18.
[40] Craig AD. Pain mechanisms: labeled lines versus convergence in central processing. Annual Review of Neuroscience. 2003; 26: 1-30.

How to cite this article: Kuo-Cheng Wang, Chen-June Seak, Fu-Sheng Tsai, Cheng-Yu Chien, Chi-Chun Lee, Chip-Jin Ng, et al. Facial expression differences indicate pain improvement at the emergency department. Signa Vitae. 2021;17(2):111-118. doi:10.22514/sv.2020.16.0105.