2010

FACIAL EXPRESSION DISCRIMINATES BETWEEN PAIN AND ABSENCE OF PAIN IN THE NON-COMMUNICATIVE, CRITICALLY ILL ADULT PATIENT

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Facial Expression Discriminates Between Pain and absence of Pain

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December 3, 2010

Facial expression discriminates between pain and absence of pain in the non-communicative critically ill adult patients.

A dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at Virginia Commonwealth University

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Acknowledgment

The author wishes to thank several people. I would like to thank my husband, Faiq, for his love, support and patience over the years it has taken me to finish my research. I would like to thank my parents for their unending love and support. I would also like to thank Dr. Mary Jo Grap for her mentorship and direction with this project. I would like to thank the Dissertation Committee members for their direction with this project. Special thanks to Dr. Cohn and his team at Department of Psychology, University of Pittsburgh, PA for all the support and training they provided. Last but not least, I would like to thank the staff, patients, and their families in the Medical Respiratory and Surgical Trauma Intensive Care Units at Virginia Commonwealth University Health System (VCUHS) in Richmond, Virginia for participating in this study.

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ABSTRACT

BACKGROUND: Pain assessment is a significant challenge in critically ill adults, especially those unable to communicate their pain level. At present there is no universally accepted pain scale for use in the non-communicative (cognitively impaired, sedated, paralyzed or mechanically ventilated) patient. Facial expressions are considered among the most reflexive and automatic nonverbal indices of pain. The facial expression component of pain assessment tools include a variety of facial descriptors (wincing, frowning, grimacing, smile/relaxed) with inconsistent pain intensity ratings or checklists of behaviors. The lack of consistent facial expression description and quantification of pain intensity makes standardization of pain evaluation difficult. Although use of facial expression is an important behavioral measure of pain intensity, precise and accurate methods for interpreting the specific facial actions of pain in critically ill adults has not been identified.

OBJECTIVE: The three specific aims of this prospective study were: 1) to describe facial actions during pain in non-communicative critically ill patients; 2) to determine facial actions that characterize the pain response; 3) to describe the effect of patient factors on facial actions during the pain response.

DESIGN: Descriptive, correlational, comparative.

SETTING: Two adult critical care units (Surgical Trauma ICU-STICU and Medical Respiratory ICU-MRICU) at an urban university medical center.

SUBJECTS: A convenience sample of 50 non-communicative critically ill intubated, mechanically ventilated adult patients. Fifty-two percent were male, 48% Euro-American, with mean age 52.5 years (±17. 2).

METHODS: Subjects were video-recorded while in an intensive care unit at rest (baseline phase) and during endotracheal suctioning (procedure phase). Observer-based pain ratings were gathered using the Behavioral Pain Scale.[1] Facial actions were coded from video using the Facial Action Coding System (FACS)[2;3] over a 30 second time period for each phase. Pain scores were calculated from FACS action units (AU) following Prkachin and Solomon[4] metric.

RESULTS: Fourteen facial action units were associated with pain response and found to occur more frequently during the noxious procedure than during baseline. These included areas of brow raiser, brow lower, orbit tightening, eye closure, head movements, mouth opening, nose wrinkling, and nasal dilatation, and chin raise. The sum of intensity of the 14 AUs was correlated with BPS (r=0.70, P<0.0001) and with the facial expression component of BPS (r=0.58, P<0.0001) during procedure. A stepwise multivariate analysis predicted 5 pain-relevant facial AUs [brow raiser (AU 1), brow lower (AU 4), nose wrinkling (AU 9), head turned right (AU 52), and head turned up (AU53)] that accounted for 71% of the variance (Adjusted R^2=0.682) in pain response (F= 21.99, df=49, P<0.0001). The FACS pain intensity score based on 5 pain-relevant facial AUs was associated with BPS (r=0.77, P<0.0001) and with the facial expression component of BPS (r=0.63, P<0.0001) during procedure. Patient factors (e. g., age, gender, race, and diagnosis, duration of endotracheal intubation, ICU length of stay, and analgesic and sedative drug usages, and severity of illness) were not associated with the FACS pain intensity score.

CONCLUSIONS: Overall, the FACS pain intensity score composed of inner brow raiser, brow lower, nose wrinkle, and head movements reflected a general pain action in our study. Upper facial expression provides an important behavioral measure of pain which may be used in the clinical evaluation of pain in the non-communicative critically ill patients. These results provide

preliminary results that the Facial Action Coding System can discriminate a patient's acute pain experience.

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CHAPTER 1

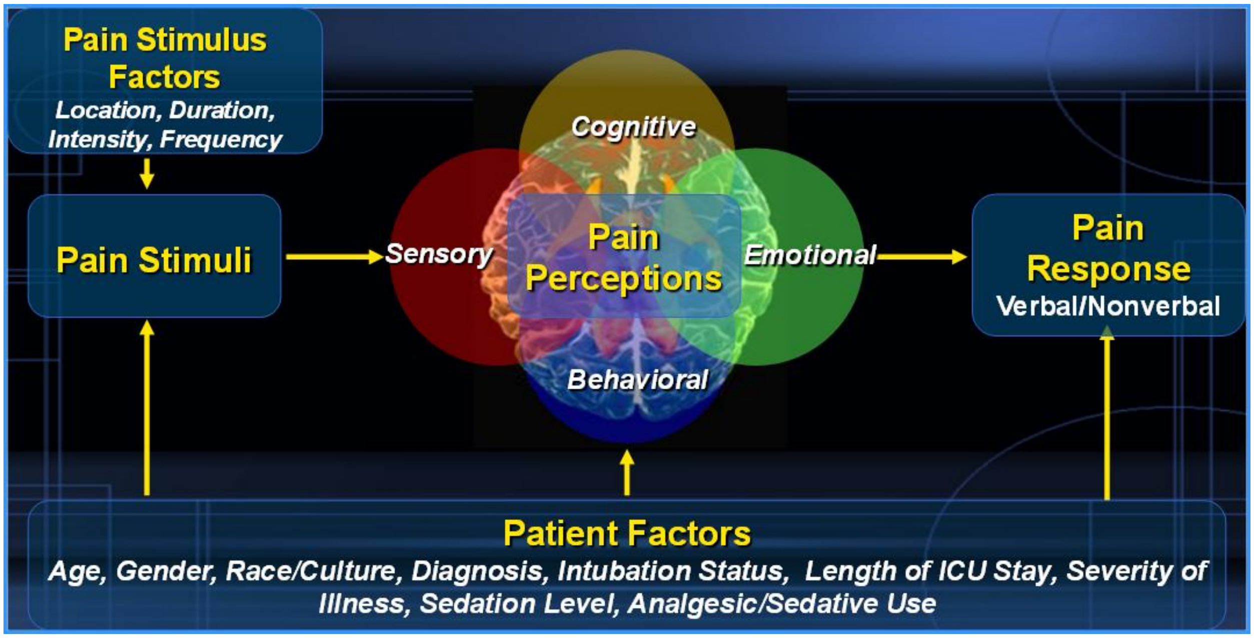
INTRODUCTION

Pain is a complex multidimensional concept that is difficult to define. Individual pain experiences influence cognitive, emotional, and behavioral responses. Pain is a subjective experience that is described as "the unpleasant sensory and emotional experience associated with actual or potential tissue damage."[1] The most reliable and valid indicator of pain is the patient's self-report.[2-4] In the critically ill many factors may alter oral communication including tracheal intubation, reduced level of consciousness, sedation, and paralyzing drugs.[4-8]These patients may be unable to report pain[9] and are at great risk of inadequate pain management. International Pain Guidelines require that pain be assessed in "all patients" and that tools to evaluate pain should be specific to the age and disease state of the patient and to the site of pain.[10-15] When patients cannot adequately express themselves, observable indicators have been labeled as 'pain behaviors.'[9;16-19] A common pain behavior used in behavioral pain tools is facial expression.

A theoretical model of the relationships among pain concepts is shown in Figure 1 and was developed by the first author of this study. The model is based on the gate-control theory,[20] nonrestrictive operant model,[21] the cognitive-behavioral model,[22] the biobehavioral model,[23] and the UCSF symptom management model[24] specifically the symptom experience dimension. The model (Figure 1) includes three major constructs: pain stimuli, pain perceptions and pain behaviors.

Briefly, the *pain stimuli* is a noxious stimulus of varying degree in location, duration, intensity and frequency exciting pain nerve receptors sensitive to tissue damage. *Pain perceptions* refer to the complex interactions between sensory, behavioral, emotional, and cognitive components in response to the painful stimuli. The sensory component refers to

Figure 1: Theoretical Model



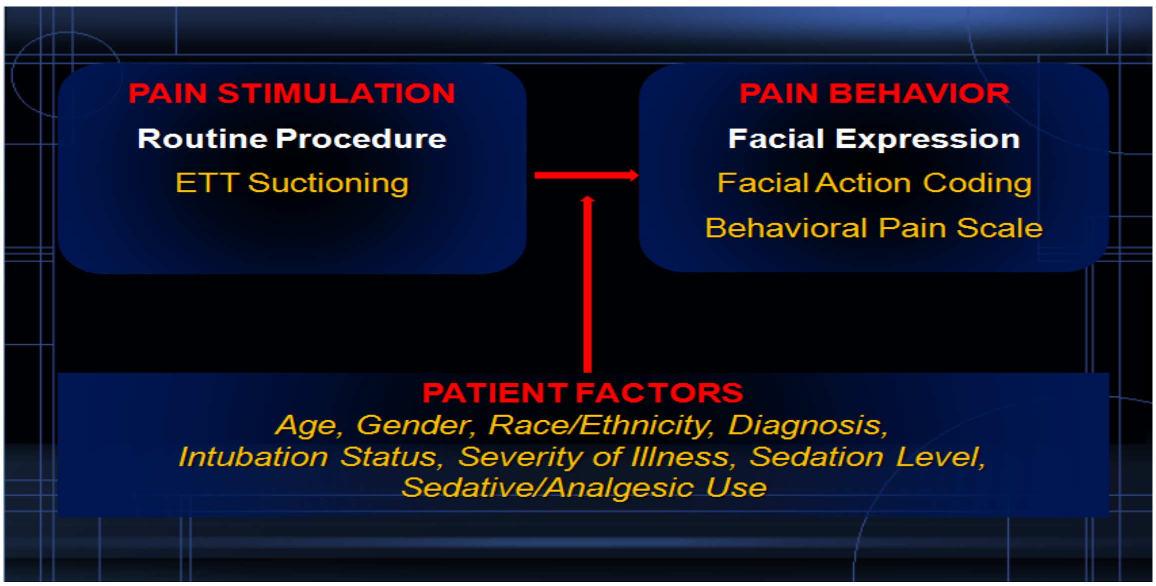
sensations perceived even if the patient is no longer capable of demonstrating behavioral response to pain, such as critically ill patients who are sedated. The behavioral component refers to a response, such as facial expression, to a noxious stimulus. The emotional component encompasses sensations such as fear, surprise, or anger. The cognitive component involves a higher cognitive process of attaching meaning to the perceived stimuli. This component is shaded gray in the proposed model because it is often difficult to assess in a patient who is unable to orally report pain. Finally, *pain responses* are the expressions of the pain experience displayed by verbal signs (self report or sounds such as ouch, groans) and nonverbal signs (facial expression including grimacing and aversion or withdrawal behaviors or physiological symptoms). In critically ill patients who cannot express themselves all three constructs maybe affected by patient factors such as age, gender, race/ethnicity, diagnosis, intubation status, severity of illness, sedation/pain level, and sedative/analgesic use.

In order to enhance understanding of facial expressions to evaluate pain and foster better decision-making among nurses, a comprehensive review of literature to analyze the evidence related to facial expression and pain assessment tools in the critically ill non-communicative patients is presented in Chapter 2.[25] Identification of the optimal pain scales for non-communicative (cognitively impaired, sedated, paralysed or mechanically ventilated) patients have been the focus of several studies.[26-28] Pain intensity may be quantified using behavioral-physiological scales in the non-communicative patients but healthcare workers' bias may influence perceptions of the patient's suffering. [17;29-31] In a recent critical review, Li et al.[26] identified psychometric properties of six objective pain measures that were developed to assess pain in non-communicative critically ill patients. The facial expression component of these tools varies in their behavioral descriptors and scoring ranges. Each tool describes wincing, frowning, and grimacing differently with a different intensity of pain score. The facial expression component in most of these tools was derived from previously described instruments,[9;32-34] chart review,[8] focus groups interviews,[35] or nurses' intuitive knowledge of pain.[32]

However, tools currently available to assess pain in the non-communicative critically ill patient are not universally accepted and provide a wide range of descriptors of facial expressions. Therefore, accurate assessment of nonverbal pain behaviors such as facial expression, especially in the critically ill, is important. The facial descriptors identified in the pain assessment tools are often of the upper face (eyes and brow) and a comprehensive investigation of facial expressions in this region is presented in Chapter 3.

Experts [26] suggest that more research is needed to identify facial indicators that reflect pain-related distress. These studies should identify changes in facial pain behavior that may occur with aging, the use of sedatives, and the presence of an endotracheal tube, nasogastric tube and/or their securing devices. Systematic identification of facial expression which is comprised of distinct facial action movement during pain is therefore crucial. The theoretical model described above provides the framework to study one type of nonverbal pain behavior, facial expression that consists of specific facial actions and guides the research model (Figure 2) proposed for the study described in Chapter 3.

Figure 2: Research Model



The specific aims of this prospective study were: 1) to describe facial action during pain in non-communicative critically ill patients; 2) to determine facial action that characterize the pain response; 3) to describe the effect of patient factors (e. g., age, gender, race, and diagnosis, duration of endotracheal intubation, ICU length of stay, and analgesic and sedative drug usages, sedation level, and severity of illness) on facial action during the pain response.

A descriptive, prospective and multivariate design was initiated to explore the specific facial action during pain in non-communicative critically ill intubated, mechanically ventilated adult patients in medical and surgical ICU. A convenience sample of 50 non-communicative critically ill intubated, mechanically ventilated adult patients was recruited. Fifty-two percent were male, 48% Euro-American, with mean age 52.5 years (±17. 2). Endotracheal suctioning was used to elicit pain response. Subjects were video-recorded while at rest (baseline phase) and during endotracheal suctioning (procedure phase). Observer-based pain ratings were gathered using the Behavioral Pain Scale (BPS),[33] which consists of three categories: facial expression, upper limb movement, and compliance with ventilation with a total score ranging from 3 to 12 with scores greater than 6 requiring pain intervention. The facial expression component of BPS is scored as increasing in pain intensity as follow: relaxed =1, partially tightened (i.e., brow lowering) =2, fully tightened (i.e., eyelid closing) =3 and grimacing =4.

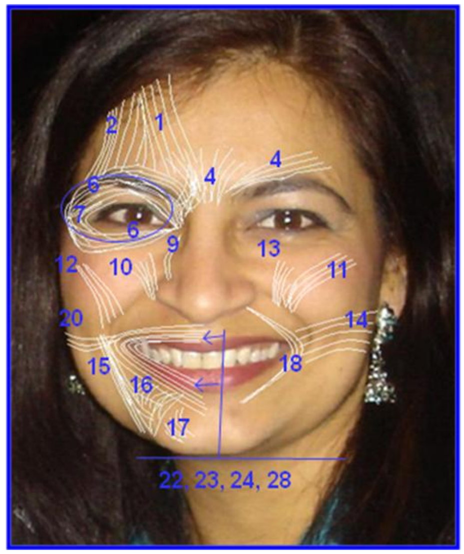
To identify facial action, the Facial Action Coding System (FACS)[36;37] developed by Ekman and Friesen,[36;37] was used to code distinct muscle movements or a group of muscles moving as a unit of the face using slow action video and stop-frame feedback through the Observer XT 8.0 (Noldus, Inc) program. Each facial action units (AUs) is identified by a number and name (for example, AU 43 – Eye closure) (Figure 3).

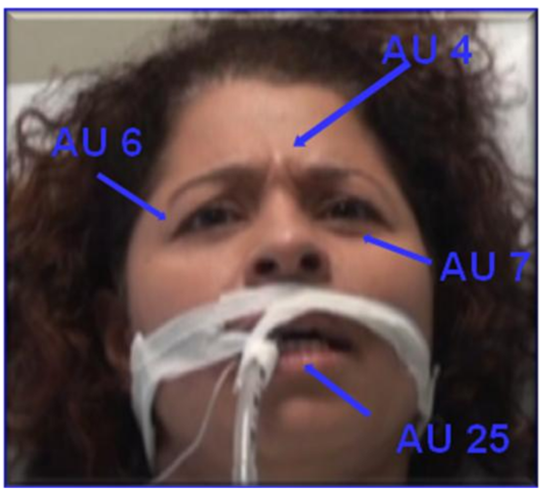
Facial AUs were coded on a frame-by-frame basis from video using the FACS over a 30 second time period for each phase. Pain scores were calculated from FACS action units (AU) following Prkachin and Solomon[38] metric. Fourteen facial AUs were associated with pain response and found to occur more frequently during the noxious procedure than during baseline. These included brow raiser, brow lower, orbit tightening, eye closure, head movements, mouth opening, nose wrinkling, and nasal dilatation, and chin raise. The sum of intensity of the 14 AUs was correlated with BPS (r=0.70, P<0.0001) and with the facial expression component of BPS (r=0.58, P<0.0001) during procedure.

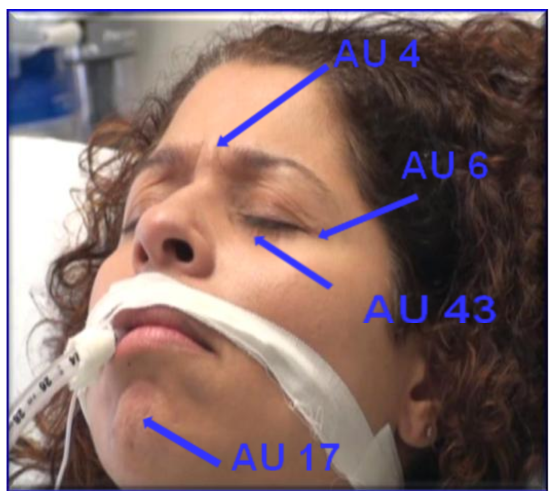
Figure 3: Facial Action Unit corresponding to underlying facial muscles

Facial Action Units commonly occurring during pain response

Description	Action Unit
Brow lower	(AU4)
Cheek raised	(AU6)
Lid tightened	(AU7)
Nose wrinkle	(AU9)
Upper lip raiser	(AU10)
Lip corner puller	(AU12)
Lip stretcher	(AU20)
Lip presser	(AU24)
Lips parted	(AU25)
Jaw drop	(AU26)
Mouth stretched	(AU27)
Eyes closure	(AU43)







Common AUs during pain response

A stepwise multivariate analysis predicted 5 pain-relevant facial AUs [brow raiser (AU 1), brow lower (AU 4), nose wrinkling (AU 9), head turned right (AU 52), and head turned up (AU53)] that accounted for 71% of the variance (Adjusted R^2=0.682) in pain response (F= 21.99, df=49, P<0.0001). The FACS pain intensity score based on 5 pain-relevant facial AUs was associated with BPS (r=0.77, P<0.0001) and with the facial expression component of BPS (r=0.63, P<0.0001) during procedure. Patient factors (e. g., age, gender, race, and diagnosis, duration of endotracheal intubation, ICU length of stay, and analgesic and sedative drug usages, and severity of illness) were not associated with the FACS pain intensity score.

Overall, the FACS pain intensity score of brow raiser, brow lower, nose wrinkle, and head movements reflected a general pain action in our study. Upper facial expression provides an important behavioral measure of pain which may be used in the clinical evaluation of pain in the non-communicative critically ill patients. This study contributes new knowledge to the identification of facial expression, an important behavioral measure of pain in the clinical evaluation of pain in the non-communicative critically ill patient. The study provides preliminary results that the FACS can discriminate patient's acute pain experience. These data are the first in identifying the appropriate terms to use in behavioral pain scales when evaluating facial expression. Terms presently used such as ''frowning,'' ''grimacing,'' "wincing," "smile/relaxed" may not be specific or descriptive enough to direct the clinician to look for the most appropriate facial action during pain. The FACS pain intensity scores may guide the quantification of pain and may make standardization of pain evaluation more feasible.

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CHAPTER 2

FACIAL EXPRESSION IN PAIN REVIEW

Title: Facial Expression and Pain in the Critically Ill Non-Communicative Patient: State of Science Review.

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Summary

The aim of this review is to analyse the evidence related to the relationship between facial expression and pain assessment tools in the critically ill non-communicative patients. Pain assessment is a significant challenge in critically ill adults, especially those who are unable to communicate their pain level. During critical illness, many factors alter verbal communication with patients including tracheal intubation, reduced level of consciousness and administration of sedation and analgesia. The first step in providing adequate pain relief is using a systematic, consistent assessment and documentation of pain. However, no single tool is universally accepted for use in these patients. A common component of behavioural pain tools is evaluation of facial behaviours. Although use of facial expression is an important behavioural measure of pain intensity, there are inconsistencies in defining descriptors of facial behaviour. Therefore, it is important to understand facial expression in non-communicative critically ill patients experiencing pain to assist in the development of concise descriptors to enhance pain evaluation and management. This paper will provide a comprehensive review of the current state of science in the study of facial expression and its potential application into clinical practice.

Keywords: pain assessment, facial expression, pain, critically ill, non-communicative, Facial Action Coding System.

Introduction

Pain assessment is a significant challenge in critically ill adults, especially those who are unable to communicate their pain level. In 1968, Margo McCaffery defined pain as, "whatever the experiencing person says it is, existing whenever the experiencing person say it does."[1] Unfortunately in critical care, many factors alter verbal communication with patients including endotracheal intubation, reduced level of consciousness, sedation, and administration of paralysing drugs. There is no question that critically ill patients experience acute pain manifested by the patient's underlying disease, invasive procedures, catheters and drains, endotracheal tubes, suctioning, wound care, and turning or other preexisting disease processes.[2-12] The International Pain Guidelines require that pain be assessed in "all patients" and that tools to evaluate pain should be specific to the age and disease state of the patient and to the site of pain.[13-18] The first step in providing adequate pain relief for patients is systematic and consistent assessment and documentation of pain. Identification of the optimal pain scales for non-communicative patients have been the focus of several studies. To date, however, no one tool is universally accepted for use in these patients.

When patients cannot express themselves, observable indicators, both physiological and behavioural, have been labeled as 'pain behaviours.'[2;19-23] Since the term 'pain behaviour' was first described by Fordyce [24] as a one-dimensional construct of chronic pain, there have been several attempts to develop systems for assessing pain behaviour.[2;4;6;23;25-27] One of the most frequently used pain behaviour incorporated in a variety of pain scales for the non-communicative patients is facial expression.[7;28-35] Although use of facial expression is an important behavioural measure of pain intensity, precise and accurate methods for interpreting the facial expression of pain in critically ill adults has not been identified. Therefore, this review will provide an analysis of the use of facial expressions in non-communicative critically ill patients and the variation of facial expression descriptors used in pain assessment tools.

Pain in Critically Ill Patients

Pain is a complex multidimensional concept that is difficult to define. Individual pain experiences influence cognitive, emotional, and behavioural responses. Pain is a subjective experience that is described as "the unpleasant sensory and emotional experience associated with actual or potential tissue damage."[36] The most reliable and valid indicator of pain is the patient's self-report.[37-39] In numerous studies, it has been reported that seriously ill patients experience pain and some patients can recall their dissatisfaction with pain control.[40-47] The Study to Understand Prognoses and Preferences for Outcomes and Risks of Treatments (SUPPORT)[45] evaluated the pain experience of seriously ill hospitalized patients and their satisfaction with control of pain. Of the 9,105 patients admitted to five US teaching hospitals, 5,176 patients provided interviews of their pain experience. The SUPPORT results indicated that seriously ill, hospitalized patients demonstrated a high prevalence of pain. Specifically, approximately 50% of patients reported pain and 14.9% reported extremely severe pain or moderately severe pain occurring at least half of the time, and nearly 15% of those patients with pain were dissatisfied with its control.

In a more recent study, Topolovec-Vranic et al.[46] described patients' perspective of pain management in the ICU. The study included 52 patients who had recollection of their ICU stay and agreed to complete the Patient Pain Management Questionnaire. They compared patient satisfaction with pain management before and after implementation of the Nonverbal Pain Scale (NVPS). Although the "worst" level of pain was reduced after use of the NVPS (8.5 vs 7.2 on

10 point scale, P=0.04), the reported level of pain was still very high. Gelinas et al.[44] found that more than 50% of 99 intubated conscious patients reported pain whilst at rest and 80% during nociceptive exposure such as turning. In critically ill adults, Ahlers et al.[47] found that nurses tended to report patient's pain higher 16% of the time and as lower 12% of the time when compared to patient self-report.

Unconscious or sedated patients cannot communicate their level of pain using numeric pain rating scales (NRS) (0-to-10) and are therefore at risk for being inadequately medicated for pain.[48;49] Furthermore, optimal sedation/analgesia is difficult to achieve in the critically ill and data shows that nurses adjust sedation/analgesia based on a wide range of information, including subjective assessments related to patient amnesia and comfort needs, need for prevention of self-injurious behaviour, and efficiency of care.[50-54] Inaccurate pain assessments and resulting inadequate treatment of pain in critically ill adults can lead to significant physiologic consequences such as increased myocardial workload which can lead to myocardial ischemia or impaired gas exchange which can result in respiratory failure.[55] Therefore, it is imperative that health care providers assess pain accurately in the non-communicative critically ill patients.

Pain assessment in the non-communicative/unconscious patient

The first step in providing adequate pain relief for patients is systematic and consistent assessment and documentation of pain.[22;56] Identification of the optimal pain scales for non-communicative (cognitively impaired, sedated, paralysed or mechanically ventilated) patients have been the focus of several studies. To date, however, no one tool is universally accepted for use in the non-communicative patient.[39;57] Pain intensity may be quantified using behavioural-physiological scales in the non-communicative patients but healthcare workers' bias may influence perceptions of the patient's suffering.[20;21;58;59] Puntillo et al.[41] found that the pain behaviours most frequently reported by nurses in the critically ill abdominal or thoracic surgery patients (n=105) were grimacing, frowning, or wincing (34%); vocalisation (24%); and restlessness (19%); no movement (38%).

The 2004 Thunder Project II, developed by the American Association of Critical-Care Nurses Task Force, identified behaviours displayed during procedures in 5,957 critically ill adult patients at 169 sites.[4] In this comprehensive examination of procedural pain-related behaviours, patients (n = 4,278) who reported pain during a procedure (turning, suctioning, wound care, device removal) displayed five behaviours: grimacing (43%), rigidity (27%), wincing (24%), shutting of eyes (34%), and verbalisation of complaints (24%). In addition, they showed that patient's age and ethnicity or amount of sedation did not contribute to behavioural activity during a procedure. The presumption that sedation would decrease behavioural activity was not supported.

To identify pain behaviours in critically ill intubated patients, Gelinas et al.[6] conducted a retrospective review of 183 pain episodes that occurred in the first 72 hours after the patients were intubated. Pain behaviours such as facial expressions, agitation, movement, compliance with ventilator, etc, were identified in nurses' notes 73% of the time, whilst physiologic indicators (BP, HR, arrhythmia) were found only 24% of the time. Specifically, facial expressions were identified 6% of the time, whereas, body movement occurred 59 % of the time. These studies[4;6;7;31] led to the development of pain assessment tools in the non-communicative critically ill patients.

Adult Behavioural Pain Assessment Tools

In a recent critical review, Li et al.[60] identified psychometric properties of six objective pain measures that were developed to assess pain in non-communicative critically ill patients. A common component of these behavioural pain tools is facial expressions. However the descriptors used to identify facial expression in these tools varies across tools. The most common tools in use today that include facial expression are summarised in Table 1.

The facial expression component of these tools varies in their behavioural descriptors and scoring ranges. Each tool describes wincing, frowning, and grimacing differently with a different intensity of pain score. The development of facial expression component in most of these tools were derived from previously described instruments,[2;33;61;62] chart review,[6] focus groups interviews,[63] or nurses' intuitive knowledge of pain.[61]

The Pain Assessment and Intervention Notation Algorithm (PAIN)[2] checklist of behavioural and physiological indicators of pain was derived from research literature and content validity was established by a panel of experts in critical care practice and pain. The Pain Behaviour Assessment Tool (PBAT)[4] was then adapted from the PAIN tool and Children's Hospital Eastern Ontario Pain Scale (CHEOPS).[62] Even though, the PBAT's was extensively researched for reliability and validity of the facial expressions component of the tool, many of the research used was based on pediatric studies. Both the PAIN and PBAT algorithm were developed not as a scoring instrument but an observation tool to identify specific pain-related behaviours in patients who could respond to questions and were able to use a numeric rating scale of pain intensity.

The Post-Anaesthesia Care Unit Behavioural Pain Rating Scale (PACU BPRS)[61] and Nonverbal Pain Scale (NVPS)[28] were adopted from previously established tools.[34;64] These tools were pilot tested in a specialised population of the Post Anaesthesia Care Unit and Burn Trauma

Table 1: Pain Assessment Tools used in the Non-communicative Patients		
Scale	**Facial Behavior Descriptors and Scoring**	**Validity and Reliability Studies for Facial Behavior Component**
The Pain Assessment and Intervention Notation (PAIN) Algorithm	**Checklist** • Grimacing, frowning, wincing • Drawn around mouth and eyes • Wrinkled forehead • Teary/crying	**Puntilo, et al.**[2] • Validated by performing five pain assessments for the presence or absence of the pain behaviors post-op patients using behavioral indicators, the 0 to 10 numeric rating scale of pain intensity and patient self-report pain rating (n=31). • Facial pain behavioral most frequently reported were grimacing, frowning, or wincing (34%); drawn around mouth and eyes (9%); and wrinkled forehead (16%), and teary/crying (4%). • Content validity established by a panel of experts clinicians. • No inter-rater reliability reported.
Pain Behavior Assessment Tool (PBAT)	**Checklist** • Grimace • Frown • Wince • Eyes closed • Eyes wide open with eyebrows raised • Looking away in opposite direction of the pain • Grin/smile • Mouth wide open to expose teeth and tongue • Clenched teeth exposing slightly open mouth • None • Unable to assess • Other	**Puntillo, et al.**[4] • Validated in 5957 subjects (169 sites) comparing behaviors before and during the procedure (turning, central venous catheter insertion, wound drain removal, wound care, tracheal suctioning, and femoral sheath removal). More behaviors exhibited during procedural pain ($p < .001$). • Facial behaviors exhibited during procedural pain: Grimace 42.8%, Eyes closed 33.7%, and Wince 23.7%, (n = 4,278)
PACU Behavioral Pain Rating Scale (BPRS)	• Does not frown forehead or grimace 0 • Slight frowning and grimacing 1 • Moderate frowning and grimacing 2 • Constant frowning and grimacing 3	**Mateo, et al. (English version)**[61] • Validated during a ten minutes observations of pain behaviors within the first hour after arrival at the PACU (n = 30 patients). • Content validity established by panel of experts • Internal consistency of scale (Cronbach α =.92). • Interrater reliability for each category of the scale (r=0.71 to 1.0). • Frowning or grimacing correlated to self-reported pain (r=0.69, p<0.05) **Persson, et al. (Swedish version)**[65] • Test the reliability of the Swedish version by performing test–retest and interrater reliability in clinical conditions of postoperative pain after arrival at the PACU (n=49). • Test–retest reliability between 2 observers showed good agreement in frowning or grimacing (k=0.274, 69.3 % Concordance) • Interrater reliability between 2 observers showed high concordance for frowning or grimacing (Cronbach α=.0.615, 90% concordance observer 1 & 2); (Cronbach α =.0.621, 91% for observers 1 & 3)(n=11)

Table 1: (Continued)		
Scale	**Facial Behavior Descriptors and Scoring**	**Validity and Reliability Studies for Facial Behavior Component**
Nonverbal Pain Scale (NVPS)	• No particular expression or smile 0 • Occasional grimace, tearing, frowning, wrinkled forehead 1 • Frequent grimace, tearing, frowning, wrinkled forehead 2	**Odhner, et al.**[28] • Validated by comparing NVPS and the FLACC (n=59) • Strongest inter-scale correlations were seen between NVPS and FLACC: facial assessment components (r=0.78, p<0.0001) • Internal consistency : NVPS - Cronbach α =0.78; FLACC Cronbach α =0.84 • Interrater reliability for both the FLACC and the NVPS reported as good.
Face, Legs, Activity, Cry, Consolability Observational Tool (FLACC)	• No particular expression or smile 0 • Occasional grimace or frown, withdrawn or disinterested 1 • Frequent to constant quivering chin, clenched jaw 2	**Merkel, et al.**[34] • Test the reliability of FLACC tool by measuring changes in scores in response to administration of analgesics in postoperatively after the child was awake and arousable (n=89). • Validity showed higher preanalgesia scores than postanalgesia scores (p<0.001). • Positive correlation between Objective Pain Scale (OPS) and FLACC scores (r=0.80; p<0.001). • Positive correlation (r=0.41, p<0.005) between FLACC scores and PACU nurses' global rating of pain. • Interrater reliability: 2 observers (r=0.94; p<0.001) and 69% agreement between observers, (Kappa=0.52) for facial expression.
Behavioral Pain Scale (BPS)	• Relaxed 1 • Partially tightened (e.g., brow lowering) 2 • Fully tightened (e.g., eyelid closing) 3 • Grimacing 4	**Payen, et al.**[33] • Validated during 3 assessments at rest and during a procedure [nonnociceptive (central venous catheter dressing change or compression stocking) and nociceptive (suctioning or turning)] in 30 mechanically ventilated patients (301 observations). BPS scores increased during painful procedure (p < .01). • Principal component first factor analysis accounted for 55% of the variance in pain expressions, with coefficients of r= .789 for facial expression. • Interrater reliability between a pair of evaluators (nurse and nurse's aide) [weighted kappa coefficient =0.74 (P < .01)]. **Aissaoui, et al.**[66] • Validated during rest and painful procedures (tracheal suction and peripheral venous cannulation) (n=30). • BPS scores increased during painful procedures, (p< 0.001). • Principal component first factor analysis accounted for 65% of the variance in pain expressions, with coefficients of r= .90 for facial expression. • Intraclass correlation coefficient for facial expression was 0.91(95% CI, 0.88–0.93). • Intraclass correlation coefficient (ICC) to evaluate inter-rater reliability was high (0.95).

Table 1: (Continued)		
Scale	**Facial Behavior Descriptors and Scoring**	**Validity and Reliability Studies for Facial Behavior Component**
		***Young, et al.**[67] • Validated during painful (repositioning) and non-painful (eye care) procedures (n=44). • Internal consistency: Cronbach α = 0.64. • Inter-rater reliability between two raters tested in 11 patients: good agreement (82% to 91%) for pre-procedure assessments; lower agreement post-procedure, with agreement after eye care assessments ranging between 64% and 73% and agreement after repositioning ranging between 36% and 46%.
Critical Care Pain Observation Tool (CPOT)	• Relaxed, neutral: No muscular tension observed 0 • Tense: Presence of frowning, brow lowering, orbit tightening, and levator contraction 1 • Grimacing: All of the above facial movements plus eyelid tightly closed 2	***Gelinas, et al. (French version)**[7] • Validated during 3 assessments (rest, noxious procedure (turning), and recovery) in 105 cardiac surgery patients. Significant increase in CPOT scores during turning ($p < .001$). • Interrater reliability between two raters were moderate to high at all assessments (Weighted kappa coefficients ranged from 0.52 – 0.88). • Criterion validity for mean CPOT scores according to patients' self-reports of the presence or absence of pain during the second testing period was significant ($p \leq 0.005$). • Discriminant validity for the differences in scores on the Critical-Care Pain Observation Tool measured at rest before the procedure (T1, T4, and T7) and during the procedure (T2, T5, and T8) was significant ($p<0.001$). • Content validity of the CPOT was established with 4 physicians and 13 critical care nurses. ***Gelinas, et al. (English Version)**[68] • Validated during nociceptive procedure (turning) and non-nociceptive procedure (noninvasive blood pressure) before, during, and 20 minutes after the procedures. CPOT scores increased during turning (n=55, $p \leq .001$). • Intraclass correlation coefficients (0.80 to 0.93) high in all six assessments.

*Facial Expression component not separately evaluated or reported.

Unit, respectively. The PACU BPRS has four of the original eight categories for assessing three types of pain (acute, chronic and progressive pain) that were developed by Chambers and Pric.[64] The four dimensions (restlessness, tense muscles, frowning or grimacing; and patient sounds) range from none to severe (0 to 3) with total pain score ranging 0-12.

The NVPS consists of five dimensions (face, activity, guarding, physiological I and II). Each dimension ranges from 0 to 2 with total pain score ranging 0-10. The face and activity dimension of NVPS was patterned after the face, legs, activity, cry, consolability (FLACC)[34] pain assessment tool. The FLACC was developed by clinicians to provide a simple, consistent method to identify, document, and evaluate pain in the paediatric population. One of the major limitations of the FLACC tool is the applicability of cry and consolability which are not appropriate for the critically ill, intubated adults. Thus, the NVPS used only the face and activity dimensions of FLACC tool.

The Behavioural Pain Scale (BPS)[33] was developed to assess pain in the mechanically ventilated patients. The BPS consists of three dimensions (facial expressions, upper limbs movement, and compliance with ventilation) ranging from 1 to 4 points with total pain score ranging 3-12. The scoring of each facial expression from 1 (no response) to 4 (full response) was based on assumptions that these behaviours reflect increases in pain intensity in the critically ill as well.[33] The facial expressions were derived from Prkachin's[69] study of specific facial muscle actions related to pain states. Prkachin used the Facial Action Coding System[70] to measure facial actions during painful and pain-free periods on healthy adult volunteers. He divided facial expressions of pain into four groups by graded pain intensity: brow lowering, tightening and closing of the eye lids and nose wrinkling/upper lip raising. Payen, et al.[33] modified these facial expressions (Table 1) in the BPS to make it easy for the paired evaluators to rate.

A more recently developed tool, the Critical Care Pain Observation Tool (CPOT) [7] includes components of facial expressions that were derived from previous established tools, such as the PACU BPRS,[61] PAIN Tool[2], and Behavioural Pain Scale (BPS).[33] The CPOT consist of 4 components with 0-2 rating for each behaviour: facial expression, body movements, muscle tension, and compliance with the ventilator for intubated patients or vocalization for extubated patients.

In summary, facial expressions have not been rigorously tested in any of the above tools. If facial expressions are an essential component of pain evaluation tools, then scoring should be based on objective data related to facial expression during pain in the critically ill. Tools in use today include a wide range of facial expression descriptors such as no facial response, relaxed, smile to most extreme wince, frown, and grimacing. Experts[60] suggest that more research is needed to identify facial indicators that reflect pain-related affective distress, to identify changes in facial pain behaviour that may occur with ageing to determine the effects of sedatives and the presence of an endotracheal tube and/or its securing device have on facial expressions of pain. Systematic identification of facial expression during pain is therefore crucial.

Study of Facial Expressions

The face reveals a wealth of information about human behaviour and emotions. The most frequently used pain behaviour in pain evaluation scales for patients who cannot orally communicate is facial expression.[7;28-35] Facial expression has been studied for centuries, dating back to Charles Darwin's "The Expression of Emotions in Man and Animals"[71] reporting observations and detailed explanations of why particular facial expressions occur with particular emotions.[71;72] Ekman et al.,[73-78] experts in facial expressions studies, conducted extensive crosscultural studies in determining if facial expressions are universal or specific to each culture. They demonstrated that observers' judgments of anger, disgust, fear, sadness, happiness and surprise made by preliterate people as isolated as New Guineans[74] were no different than judgments made by college students in eight literate cultures around the world.[76] They concluded that regardless of age, gender, and race/ethnicity, facial expressions are evidence of universal expressions across cultures with variation due to the expression itself, and in what the expression signifies to the person showing the expression and to others.[78] Their studies led to the development of the Facial Action Coding System (FACS),[70] which identifies distinct facial muscle movements during an emotional response. These facial muscle movements are typically identified through the use of slow action video and stop-frame feedback.

The basic elements of FACS are 44 action units (AUs). Each AU represents the movement of a single facial muscle or a group of muscles, which move as a unit. The 44 AUs can be reliably identified by trained FACS coders and can also be reliably graded on a 5-point scale for intensity (degree of muscle excursion). Once the pain expressions are identified, data on number of expressions per minute over the course of each condition can be derived.[70] The FACS has been shown to be highly reliable in many studies and shows a distinct pattern of facial actions that are characteristic of pain.[30;35;69;79-84] Facial Action Coding is a complex manual process but advances in automated face analysis using computer vision are being developed.[85] Cohn et al.[85] reported high concurrent validity with automated face analysis by feature point tracking and manual FACS in the brow, eye, and mouth regions.

Facial expression in pain

Facial expression specific to pain has been studied[69;80;81;83;86-89] using the Facial Action Coding System (FACS) developed by Ekman and Friesen (1978). Several facial actions that correlated with pain that have been identified include lowered brows, raised cheeks, tightened eyelids, a raised upper lip or opened mouth, and closed eyes (Figure 1).[69;80;83] In the general population, Craig and Patrick identified facial expressions of acute pain-related facial activity (brow lowering, narrowing of the eye aperture from below, raising the upper lip, and blinking).[81;87] They used the FACS to identify facial activity associated with exposure to one noxious stimulus in healthy adults and identified six action units (AU) categories that occurred more frequently during exposure to the noxious stimulus than during a baseline experience.

Prkachin[69] focused on pain behaviour of healthy adults (n=41), specifically facial expression during three different types of pain stimulus (electric shock, cold, pressure, and muscle ischemia). He identified four actions during pain, increasing in intensity or duration across all modalities using the FACS: brow lowering (AU4), tightening and closing of the eye lids (AU6/AU7), and nose wrinkling/ upper lip raising (AU9/AU10). Hadjistavropoulos et al.[90] examined the validity of non-verbal measures in detecting pain amongst seniors who were experiencing movement-related exacerbations of musculoskeletal pain and documented the utility of behavioural coding of pain-related body/limb movements (e.g., bracing and guarding). The results demonstrate that FACS not only discriminates between pain and absence of pain but can also provide information about the variability of the pain experience.[19;90]

In another study to evaluate gender differences in facial expressiveness to pain, Kunz et al.[91] used FACS, focusing on 4 AUs: brow lowering (AU 4), tightening of the orbital muscles surrounding the eye (AUs 6/7), nose wrinkling/upper lip raising (AUs 9/10), and eye closure

Figure 1: Facial expression correlated with pain using the Facial Action Coding System

Description	Action Unit
Brow lower	AU4
Cheek raised	AU6
Lid tightened	AU7
Nose wrinkle	AU9
Upper lip raiser	AU10
Lip corner puller	AU12
Lip stretcher	AU20
Lip presser	AU24
Lips parted	AU25
Jaw drop	AU26
Mouth stretched	AU27
Eyes closure	AU43
Blink	AU 45

Neutral Expression — Pain Expression

(AU 43). They found that in young and pain-free individuals (male n=20, female n=20) that men and women were equally facially expressive during tonic heat stimulation at non-painful and at painful intensities. These observations are similar to previous findings of lack of gender differences in the facial expressiveness of pain.[69;80]

FACS provides an objective assessment of facial reactions that are most reflexive and automatic nonverbal indices of pain. Even though, facial expressions have been identified in infants, children, adults, and the elderly using FACS, there is little empiric evidence of its' utility in the critically ill patients. More research is needed to identify facial expressions during pain in the critically ill patients.

Conclusion

Pain assessment is a significant challenge in critically ill adults, especially those who are unable to communicate their pain level. Unfortunately in critical care, many factors alter verbal communication with patients including tracheal intubation, reduced level of consciousness, sedation, and administration of paralysing drugs. Therefore, accurate assessment of nonverbal pain behaviours such as facial expression, especially in the critically ill, is important. Facial expressions provide a critical behavioural measure for the study of emotion, cognitive processes, and social interaction.[78] Understanding facial expressions may assist in the development of strategies to enhance pain assessment tools. Tools currently available to assess pain in the non-communicative critically ill patient are not universally accepted and provide a wide range of descriptors of facial expressions. Interestingly, most of the facial descriptors identified in the pain assessment tools are of the upper face (eyes and brow) and using the Facial Action Coding System to study facial expressions in this region may be feasible since other facial areas (mouth, nose) are often distorted by the presence of an endotracheal or nasogastric tubes. Specifically, Facial Action Coding data may provide empirical evidence to use facial expressions accurately in assessment tools that are appropriate, practical, reliable, and valid across patient populations.

Conflict of interest

The authors declare that they have no conflict of interest.

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CHAPTER 3

Facial Expression Quantifies Pain Response in Critically Ill Intubated Adult Patients

Facial Expression Quantifies Pain Response in Critically Ill Intubated Adult Patients

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Sources of support for this research: NIH F31 NR010433

ABSTRACT

OBJECTIVE: The three specific aims of this prospective study were: 1) to describe facial action during pain in non-communicative critically ill patients; 2) to determine facial action that characterize the pain response; 3) to describe the effect of patient factors on facial action during the pain response.

DESIGN: Descriptive, correlational, comparative.

SETTING: Two adult critical care units (Surgical Trauma ICU-STICU and Medical Respiratory ICU-MRICU) at an urban university medical center.

SUBJECTS: A convenience sample of 50 non-communicative critically ill intubated, mechanically ventilated adult patients. Fifty-two percent were male, 48% Euro-American, with mean age 52.5 years (±17. 2).

METHODS: Subjects were video-recorded while in an intensive care unit at rest (baseline phase) and during endotracheal suctioning (procedure phase). Observer-based pain ratings were gathered using the Behavioral Pain Scale. Facial behavior was coded from video using the Facial Action Coding System (FACS) over a 30 second time period for each phase. Pain scores were calculated from FACS action units (AU) following Prkachin and Solomon metric.

RESULTS: Fourteen facial actions were associated with pain response and found to occur more frequently during the noxious procedure than during baseline. These included areas of brow raiser, brow lower, orbit tightening, eye closure, head movements, mouth opening, nose wrinkling, and nasal dilatation, and chin raise. The sum of intensity of the 14 AUs was correlated with BPS (r=0.70, P<0.0001) and with the facial expression component of BPS (r=0.58, P<0.0001) during procedure. A stepwise multivariate analysis predicted 5 pain-relevant facial AUs [brow raiser (AU 1), brow lower (AU 4), nose wrinkling (AU 9), head turned right (AU 52), and head turned up (AU53)] that accounted for 71% of the variance (Adjusted R^2=0.682) in pain response (F= 21.99, df=49, P<0.0001). The FACS pain intensity score based on 5 pain-relevant facial AUs was associated with BPS (r=0.77, P<0.0001) and with the facial expression component of BPS (r=0.63, P<0.0001) during procedure. Patient factors (e. g., age, gender, race, and diagnosis, duration of endotracheal intubation, ICU length of stay, and analgesic and sedative drug usages, and severity of illness) were not associated with the FACS pain intensity score.

CONCLUSIONS: Overall, the FACS pain intensity score of inner brow raiser, brow lower, nose wrinkle, and head movements reflected a general pain action in our study. Upper facial expression provides an important behavioral measure of pain which may be used in the clinical evaluation of pain in the non-communicative critically ill patients. These results provide preliminary results that the Facial Action Coding System can discriminate a patient's acute pain experience.

Keywords: Facial Expression, pain assessment, non-communicative, Intensive Care Unit

Introduction

Critically ill patients experience acute pain that may be associated with routine care (suctioning, turning, wound care, invasive procedures, endotracheal tubes) or their underlying disease processes.[1-5] In critical care, many factors may alter oral communication including tracheal intubation, reduced level of consciousness, sedation, and paralyzing drugs. Patients who cannot communicate may be unable to report pain and are at great risk of inadequate pain management.[3;6-8] There is no "gold standard" to assess pain in the critically ill patients.[9-11] A variety of assessment tools have been used to evaluate pain in this population and when patients cannot communicate their level of pain using speech, written, and eye or hand motions, observable indicators have been identified.[1;3;12-18] In several comprehensive reviews,[2;8;19-22] pain assessment tools (Table 1) commonly used in non-communicative critically ill adult patients have been evaluated. These tools generally consist of objective measures which include behavioral dimension (facial expression, body movement, verbal response, ventilator compliance). Facial expressions are considered among the most reflexive and automatic nonverbal indices of pain.[23] The facial expression component includes a variety of specific facial descriptors (e. g., wincing, frowning, grimacing, smile/relaxed) with various pain intensity ratings (Table 1). The lack of consistent facial expression description and quantification of pain intensity makes standardization of pain evaluation difficult. Prkachin and Solomon,[24] in an outpatient context, proposed that four facial actions, brow lower, orbit tightening, nose wrinkling, and eye closure carry the bulk of pain information. The Prkachin and Solomon[24] scale to our knowledge, has not been applied with critical care patients. Although use of facial expression is an important behavioral measure of pain intensity, precise and accurate methods for interpreting the specific facial actions of pain in critically ill adults have not been identified.

Table 1: Pain Measurement Tools and Facial Behavior Descriptors for the Non-communicative Patients

Scale	Facial Behavior Descriptors and Scoring	Score
Behavioral Pain Rating Scale (BPRS) *Mateo, et al. (English version)*[13] *Persson, et al. (Swedish version)*[25]	• Does not frown forehead or grimace • Slight frowning and grimacing • Moderate frowning and grimacing • Constant frowning and grimacing	**Score** 0 1 2 3
The Pain Assessment and Intervention Notation (PAIN) Algorithm *Puntilo, et al.*[12]	• Grimacing, frowning, wincing • Drawn around mouth and eyes • Wrinkled forehead • Teary/crying	
Behavioral Pain Scale (BPS) *Payen, et al.*[15]	• Relaxed • Partially tightened (e.g., brow lowering) • Fully tightened (e.g., eyelid closing) • Grimacing	**Score** 1 2 3 4
Nonverbal Pain Scale (NVPS) *Odhner, et al.*[14]	• No particular expression or smile • Occasional grimace, tearing, frowning, wrinkled forehead • Frequent grimace, tearing, frowning, wrinkled forehead	**Score** 0 1 2
Pain Behavior Assessment Tool (PBAT) *Puntillo, et al.*[1]	• Grimace • Frown • Wince • Eyes closed • Eyes wide open with eyebrows raised • Looking away in opposite direction of the pain • Grin/smile • Mouth wide open to expose teeth and tongue • Clenched teeth exposing slightly open mouth • None • Unable to assess • Other	
Critical Care Pain Observation Tool (CPOT) *Gelinas, et al. (French version)*[16] *Gelinas, et al. (English Version)*[17]	• Relaxed, neutral: No muscular tension observed • Tense: Presence of frowning, brow lowering, orbit tightening, and levator contraction • Grimacing: All of the above facial movements plus eyelid tightly closed	**Score** 0 1 2

A system to recognize and represent the muscular activity in facial appearance has been developed to distinguish all possible facial movement. This comprehensive system, Facial Action Coding System (FACS),[26;27] developed by Ekman and Friesen,[26] has been used in the study of pain expression. The system provides objective, anatomically based description of facial action units. The basic elements of FACS are 44 action units (AUs). Each AU represents the movement of a single facial muscle or a group of muscles moving as a unit (Figure 1). Several facial actions have been identified that correlate with pain in generally healthy patient populations (Table 2). The FACS identifies distinct muscle movements of the face which are identified through the use of slow action video and stop-frame feedback. Most frequently reported pain-related facial responses that significantly increase during noxious stimulation include lowered brows, raised cheeks, tightened eyelids, a raised upper lip or opened mouth, and closed eyes.[28-31] In ambulatory patients, these facial responses have been shown to be consistent and are considered “core” actions of pain.[30] Because facial expression is commonly used to evaluate pain in the non-communicative patient, the systematic evaluation of facial action during pain in the critically ill patients is paramount.

While FACS has been used to study facial actions in infants, children, and adults, including the elderly, little empiric evidence exists of its’ utility in non-communicative critically ill patients. The specific aims of this prospective study were: 1) to describe facial action during pain in non-communicative critically ill patients; 2) to determine facial action that characterize the pain response; 3) to describe the effect of patient factors (e. g., age, gender, race, and diagnosis, duration of endotracheal intubation, ICU length of stay, and analgesic and sedative drug usages, sedation level, and severity of illness) on facial action during the pain response.

Figure 1: Facial Action Units during baseline and noxious procedure

Action	Description	Baseline	Procedure
AU 1	Inner brow raise		
AU 2	Outer brow raise		
AU4	Brow lower		
AU6	Cheek raised		
AU7	Lid tightened		
AU9	Nose wrinkle		
AU10	Upper lip raiser		
AU43	Eyes closure		
AU 45	Blink		
AU12	Lip corner puller		
AU 17	Chin raiser		
AU20	Lip stretcher		
AU24	Lip presser		
AU25	Lips parted		
AU26	Jaw drop		
AU27	Mouth stretched		
AU 61	Eyes left		
AU 62	Eyes right		
AU 63	Eyes up		
AU 64	Eyes down		
AU 73	sudden jerk		

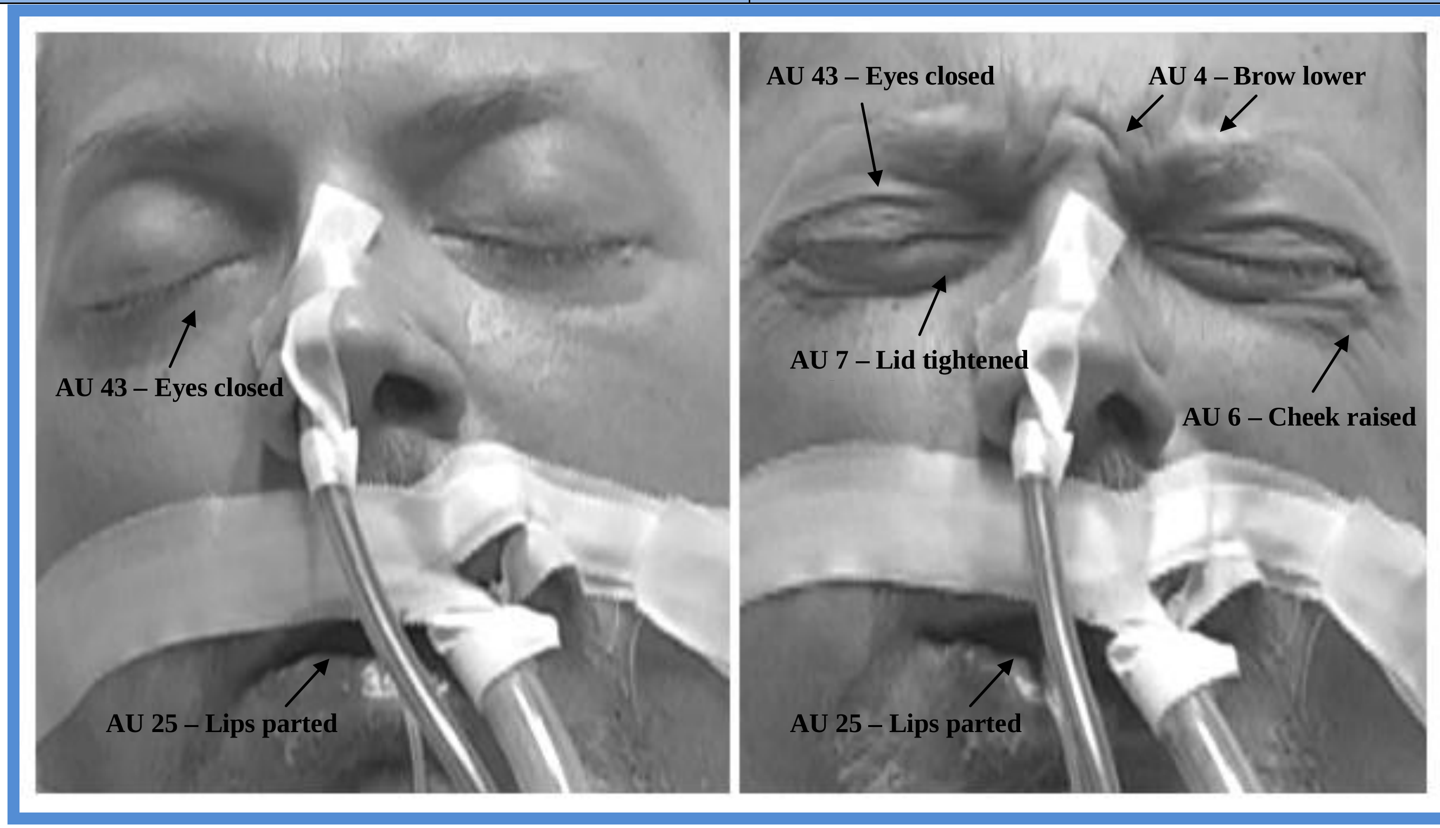

Table 2: Studies of Facial Actions Units associated with pain in adults

Study	Population	Procedure	Action Units
Craig et al. (1985)	72 college students; mean age 18.65 ±1.58	Cold pressor test	AU 6, 7, 10, 12, 25, 26, 27, 43, 45
Patrick & Craig (1986)	30 females; age range 17-28	Electric shock	AU 4, 6, 10, 45
Prkachin 1992	41 college student; mean age: 20 ± 2.02	Electric shock, cold pressor test, mechanical pressure, muscle ischemia	AU 4,6, 7, 9, 10, 43
Hadjistavropoulos et al. (2000)	58 frail elders with cognitive impairment post hip replacement; mean age 76.6 ±8.1	Sit, stand, walk, and recline	AU 1, 2, 4, 6, 7, 9, 10, 12, 17, 18, 20, 24, 25, 26, 27, 43, 45
Hadjistavropoulos et al. (2002)	82 post surgical knee replacement patients; mean age 73.1 +- 7.6	Reclining, Standing, Knee bending	AU 1, 2, 4, 6, 12, 17, 18, 20, 24, 25, 26, 43, 45
Kunz et al. (2004)	40 college students; mean age 24 ±3.2	Electrical shock and mechanical pressure	AU 1, 2, 4, 6, 7, 9, 10, 12, 17, 25, 26, 27, 45
Lints-Martindale et al. (2007)	27 Alzheimer's disease patients, mean age 78 ±4 and 36 cognitively intact, mean age 78 ±4	Electrical-thermal and mechanical pressure	AU 4, 7, 25, 26, 43, 45, 61, 62, 63, 64, 73
Kunz et al. (2007)	42 patient with dementia; mean age 76.7 ±7.3 and 54 healthy control; mean age 74.2 ±5.6	Mechanical pressure	AU 1, 2, 4, 6, 7, 9, 10, 17, 25, 26, 27, 45
Kunz et al. (2008)	40 college students; mean age 24.1 ±3.2 and 61 elderly students; mean age 72.3 ±5.6	Electrical shock and mechanical pressure	AU 1, 2, 4, 6, 7, 9, 10, 12, 14, 25, 26, 27, 43, 45
Prkachin and Solomon (2009)	129 patients with shoulder pain; mean age 42.23 ±14.48	Passive range of motion	AU 4, 6, 7, 9, 10, 12, 20, 25, 26, 27, 43

METHODS

Setting and Sample

The sample was comprised of 50 non-communicative, intubated, mechanically ventilated patients admitted to Virginia Commonwealth University Health System (VCUHS) in Richmond, Virginia, a 983-bed university medical center. The subjects were recruited from two adult critical care units (Surgical Trauma ICU-STICU; Medical Respiratory ICU-MRICU). The units provided data about both medical and surgical diagnoses so that broad application of the findings was possible, as well as comparison of findings across diagnoses and age groups. Patients were excluded if they had persistent neuromuscular disorders (such as cerebral palsy and Parkinson's disease), head trauma or stroke, or were receiving neuromuscular blockade as these conditions may affect facial expressions and study measurements.

Measurement of Key Variables

Pain level. To determine the subject's pain level, the Behavioral Pain Scale (BPS),[15] an observer-based pain ratings scale commonly used in intubated patients unable to communicate,[7;15;32] was recorded at baseline and during noxious procedure. Interrater reliability was established prior to study enrollment between the PI and another expert nurse.

The BPS has three categories: facial expression, upper limb movement, and compliance with ventilation with a total score ranging from 3 to 12 with scores greater than 6 requiring pain intervention. The facial expression component is scored as increasing pain intensity as follow: relaxed =1, partially tightened (i.e., brow lowering) =2, fully tightened (i.e., eyelid closing) =3 and grimacing =4. The facial expressions are based on previous work by Prkachin et al.[30] who used the FACS[26] to measure facial actions on healthy adult volunteers. Prkachin et al.[30] identified four core AUs: brow lowering, orbit tightening, closing of the eye lids, and nose wrinkling/upper lip raised. These AUs were simplified in the BPS as partially tightened, fully tightened, and grimace. The BPS demonstrated good validity when used during noxious and non-noxious stimulation in mechanically intubated patients and had inter-rater reliability ranging from 0.50 -0.71.[15;33]

Facial action. Facial actions were evaluated using the FACS.[26] The FACS is used with slow action video and stop-frame feedback. The FACS has been shown to be highly reliable in a variety of studies and shows a distinct pattern of facial actions that are characteristic of pain.[23;24;28-30;34-36] The basic elements of FACS AUs can be reliably identified by trained FACS coders and can also be reliably graded on a 5-point scale for intensity (degree of muscle excursion). In this study, AU frequency, duration, and intensity scoring was coded using the Observer XT 8.0 program (Noldus Information Technology, Wageningen, Netherlands). Coding was performed by the principal investigator (PI) who is a certified FACS coder.[26] A second coder also proficient in FACS coding, established interrater reliability by scoring 10% of the randomly selected videos (211 frames) during procedure. The two coders had to agree on occurrence of AUs within a span of 0.2 second of each other.

Subject characteristics. Subject characteristics (e. g., age, gender, race, and diagnosis, duration of endotracheal intubation, ICU length of stay, and analgesic and sedative drug usages, sedation level, and severity of illness) may affect pain. On study enrollment, subject demographics such as age, gender, and race and ethnicity background, diagnosis (reflecting type of critical illness and population; i.e. surgical or medical), duration of endotracheal intubation and length of ICU stay based on date of ICU admission to date of enrollment, and total amount of sedative/analgesic usage over the past 24 hours prior to the noxious procedure, were collected. Analgesia and sedative doses were converted to equivalents for analysis, as described in

Cammarano et al.[37] The dosages of all opioids were converted to equivalent units (mg) of fentanyl, based on relative potency. All doses of benzodiazepines were converted to equivalent units (mg) of lorazepam, based on relative potency.

In addition, individual patient differences related to severity of illness may also affect pain response. Patients who have greater severity of illness may require greater amounts of opioids and sedatives to facilitate mechanical ventilation, optimize oxygenation and ensure hemodynamic stability.[11] Severity of illness was documented based on the 24 hours prior to enrollment, using the Acute Physiology, Age, and Chronic Health Evaluation (APACHE III) scoring method.[38] The APACHE is based on the concept that the pretreatment risk of death of an acutely ill patient is determined by type of disease, physiologic reserve, and severity of disease.[39] The total score (0 to 299) consists of sub-scores: vital sign/lab, pH/pCO_2, neurological, age, and chronic health. Scoring is done using the worst values for the first ICU day. The APACHE III scoring system has been validated and widely used to stratify patients into well defined groups[40;41] and to ensure that research treatment and control groups have equivalent severity of illness. [40-43]

The level of sedation may affect the patient's ability to express pain behaviorally, including through facial expression. The Richmond Agitation Sedation Scale (RASS)[44] used in this study was developed at VCUHS, and is a 10 point scale, ranging from -5 (unarousable) to 0 (calm and alert) to +4 (combative), based on observation of specific patient behaviors. It has been validated against a visual analogue scale of sedation and agitation and tested for inter-rater reliability in 5 adult ICUs.[44] Additional reliability and validity was demonstrated in a prospective cohort study of 38 medical ICU patients for reliability testing (46% receiving mechanical ventilation) and an independent cohort of 275 patients receiving mechanical ventilation for validity testing.[45] The

RASS demonstrates excellent inter-rater reliability (weighted κ=0.91) and criterion(r=0.91, P<0.001), construct (5 methods tested), and face (92% agreement) validity and is the first sedation scale to be validated for its ability to detect changes in sedation status over consecutive days of ICU care (P<0.001), against constructs of level of consciousness and delirium,[45] and correlated with the administered dose of sedative and analgesic medications (both P<0.001).[45;46] The RASS was recorded at baseline and during noxious procedure. Interrater reliability was established prior to study enrollment between the PI and another expert nurse.

Procedures

The study was approved by VCU's institution review board and consent for study participation was obtained from the subject's legally authorized representative (LAR).

Endotracheal suctioning, a routine medical procedure used in critical care setting, was used in this study as the noxious stimuli to elicit a pain response because it has been shown to be a noxious event.[47-52] In a study by Puntillo et al.,[53] the mean pain intensity score for endotracheal suctioning (4.0) was comparable to other common procedural pain caused by wound care (4.4), wound drain removal (4.7), and turning (4.9). Puntillo et al.[1] reported that patients with procedural pain were 3 times more likely to have increased facial responses than patients without procedural pain. These facial responses are listed in Table 1 (Pain Behavior Assessment Tool).[1] Additionally, in a more recent study, subjects (n=755) who could self-report pain indicated greater pain response during the endotracheal suctioning (*Mean*= 4.0, S. D. = 3. 3) than prior to tracheal suctioning (*Mean*= 2.1, S. D. = 2. 8).[5] The authors reported that the most frequently observed pain behavioral response during endotracheal suctioning were grimace (52%), clenched fists (24%), rigid (23%), and wince (22%). Patients were suctioned based only on their clinical needs.

A digital video camcorder (Canon GL2) secured on a tripod was placed at the foot of the patient's bed, zoomed to the patient's face and neck to capture video for FACS coding. Subjects were video recorded for approximately 1 hour to capture both a baseline period and an episode of suction. At a later time, video was analyzed for FACS coding during two phases: pre-suctioning phase when subject appeared most comfortable (baseline) and during the endotracheal suctioning (procedure). The time segment for FACS coding was standardized to 30 seconds for each phase. This time frame was based on preliminary findings that suctioning episodes in this setting ranged from 6-28 seconds (*Mean*=13.33, SD=4.8). Using the criteria established by the developer of FACS, each 30 second phase was coded separately for all possible AUs for their frequency of occurrence, duration of expression (in seconds) and intensity of expression (on a 5 point scale).[26] The BPS was documented at baseline and during the endotracheal suctioning procedure and RASS was documented at baseline and 2 minutes post procedure.

Data Analysis

Data were analyzed using the Observer XT 8.0 Program (Noldus Information Technology, Wageningen, Netherlands) and JMP 8.0 Statistical Program (SAS Institute, Cary, NC). The three specific aims of this prospective study were: 1) to describe facial action during pain in non-communicative critically ill patients; 2) to determine facial action that characterize the pain response; 3) to describe the effect of patient factors (e. g., age, gender, race, and diagnosis, duration of endotracheal intubation, ICU length of stay, and analgesic and sedative drug usages, sedation level, and severity of illness) on facial action during the pain response.

To achieve aim #1, descriptive statistics and ANOVA were used to determine the difference between AUs activated during baseline compared to those activated during the noxious procedure using the FACS.

To achieve aim # 2 in determining facial action that best describe the pain response, several data reduction strategies were first used to identify AUs that were pain relevant. A sequence of analyses as reported in previous studies[23;54;55] was used to determine AUs that occurred at least once during either the baseline or procedure phases in any of the 50 subjects. Then those AUs occurring 5 times or less during either phase were eliminated from subsequent consideration because of their rarity. Facial AUs that have been cited in previous literature as pain-relevant and that reached level of significance ($P \leq 0.05$) in our study were included for further analysis. We used stepwise multivariate analysis to develop a model that best describes the FACS pain score based on pain-relevant facial AUs. To identify an overall FACS pain intensity score, we used the criteria established by Prkachin and Solomon[24] who identified four core facial expressions (brow lower, orbit tightening, levator contraction, and eye closure) indicative of pain response and summed their intensity score to define overall pain score. Each AU intensity was coded on a 5-point intensity scale, ranging from 1 = minimal action/trace to 5 = maximum action. Peak intensity was recorded for pain relevant AUs.

To achieve aim #3, descriptive statistics and multivariate analysis were used to describe the effect of patient factors on facial action during the pain response. Specifically, we tested the relationship between FACS pain intensity score based on pain relevant AUs and patient factors (e. g., age, gender, race, and diagnosis, duration of endotracheal intubation, ICU length of stay, and analgesic and sedative drug usages, sedation level, and severity of illness). All tests were done at statistical significance of $\alpha < 0.05$.

RESULTS

Subjects

Fifty subjects were enrolled in the study (Figure 2) and were representative of medical and surgical populations in the ICU. Demographic characteristics of the sample are shown in Table 3. The majority of subjects were male and subjects were evenly divided between African American and white with a mean age of 52. 5 years. The primary reason for ICU admission was respiratory failure. There were no differences between subjects from the two ICUs based on demographic characteristics (i.e., gender, race/ethnicity, and age, duration of endotracheal intubation (LOI), length of stay (LOS), APACHE III, RASS, and BPS).

Figure 2: Study Flow Chart

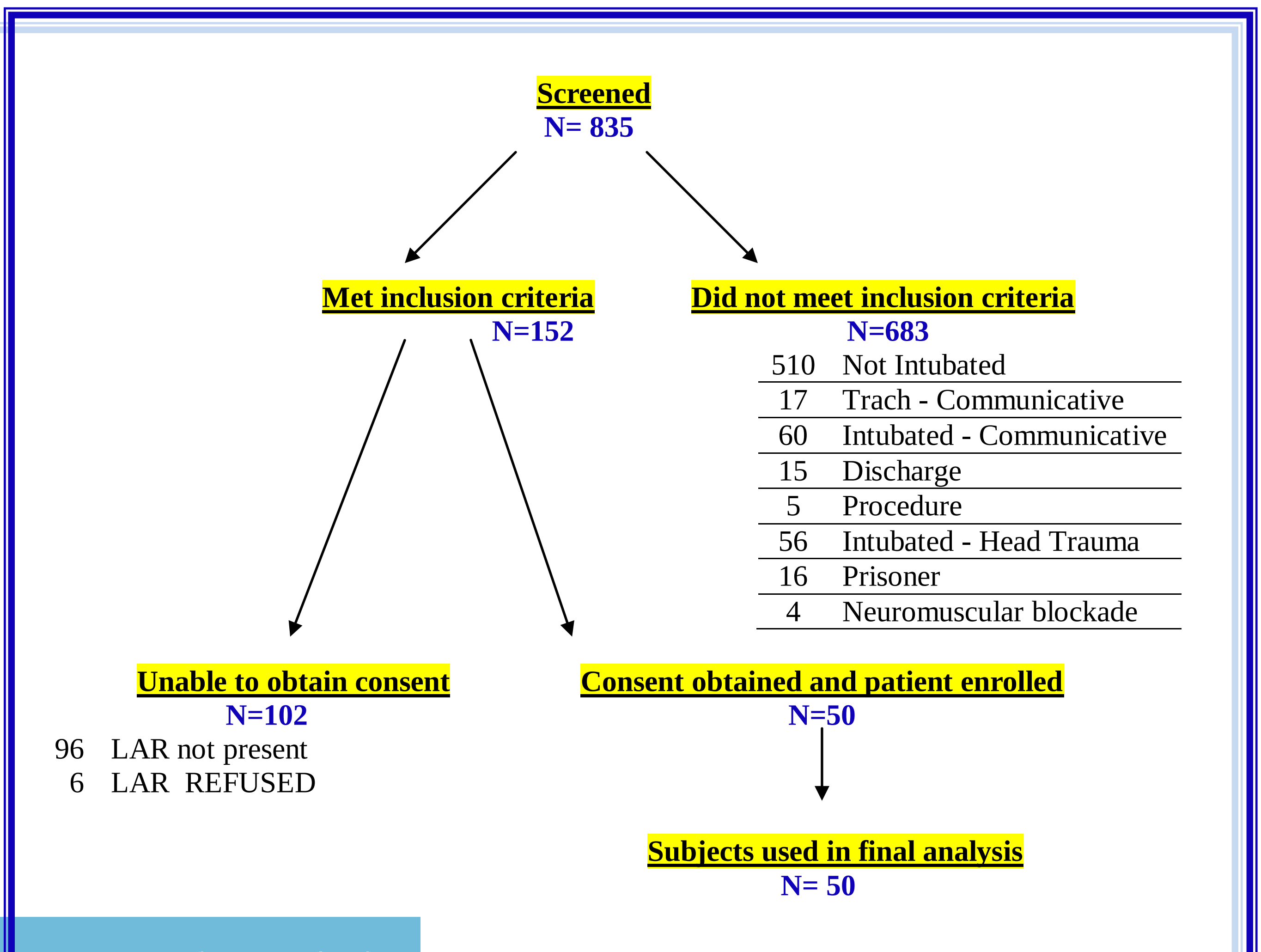

TABLE 3: Characteristics of sample and major variables (N=50)

Variable		Frequency	%
Gender			
Male		26	52
Female		24	48
Ethnicity			
Black or African-American, not Hispanic		24	48
White, not Hispanic		24	48
American Indian or Alaskan Native		1	2
Asian		1	2
Subject per Unit			
MRICU		27	54
STICU		23	46
Diagnosis			
Respiratory Failure		25	50
Surgery		12	24
Transplant		4	8
MVA		5	10
Septic Shock		2	4
Other		2	4
Suctioning Episode			
1		42	84
2		8	16
	Mean	**SD**	**Range**
Age (year)	52.48	17.2	18 - 85
Duration of intubation (days) §	5.1	3.9	1 - 17
ICU Length of stay (days) ϕ	5.74	3.7	1 - 17
Suctioning duration (Seconds)	13.33	8.1	5.99 - 28.13
APACHE III	92.8	26.0	37 - 140
RASS			
Baseline	-2.42	1.64	-5 - +2
Procedure	-2.24	1.81	-5 - +2
BPS****			
Baseline	3.28	0.61	3 - 5
Procedure	6.36	1.86	3 - 11
Analgesia			
Fentanyl (mcg)	1662.12	1316.5	0-4910
Morphine (mg)	1.9	10.8	0-75
Dilaudid (mg)	2.0	10.7	0-72
Benzodiazepine			
Ativan (mg)	1.0	4.0	0-20
Versed (mg)	53.5	66.6	0-268
Other			
Propofol (mg)	659.5	1689.0	0-8304
Precedex (mcg)	113.0	578.3	0-3600

APACHE III = Acute Physiology, Age, and Chronic Health Evaluation; §Length of intubation=day of intubation to the time of study enrollment.
ϕICU length of stay=day of admission to ICU to the time of study enrollment.
*p < 0.05; ** p< 0.01; *** p<0.001; **** p< 0.0001

Pain Level

As expected, pain was elicited by endotracheal suctioning as evidence by the increase in pain score using the BPS. The overall pain level was higher during the noxious procedure than during baseline (F= 123.89, df=99, P<0.0001) using the BPS. During the baseline time period, the facial expression component of the BPS indicated that 92% of the subjects (n=46) had 'relaxed' facial expressions and an overall mean BPS of 3.28. During the procedure, 46% of the subjects had BPS facial expressions that were 'partially tightened,' 24% were 'fully tightened,' and 18% were 'grimacing' and a mean BPS of 6.37.

Specific Aim 1: Facial actions

The primary aim of this study was to describe facial actions during pain in non-communicative critically ill patients. Thirty of the 44 facial AUs were activated during the baseline and/or the procedure and are summarized in Table 4. Fourteen of these AUs showed a significant difference in activation between baseline and procedure ($p \leq 0.05$) of which 10 AUs have been cited in previous studies of healthy subjects [inner brow rained (AU 1), outer brow raise (AU 2), brow-lowering (AU 4), cheek-raising (AU 6), eyelid tightening (AU 7), eye closure (AU 43), lips parting (AU 25), jaw dropping (AU 26), nose wrinkling (AU 9) and chin raiser (AU17)].[26;28;30;55;56]

The facial AUs activated during pain found in this sample and the difference from baseline for frequency of activation, duration, and peak intensity are shown in Table 5. Although during pain, specific AUs were activated, these same AUs did not necessarily have the greatest duration or intensity. Overall, brows lower (AU 4) and orbit tightening (AU 6/7) showed the most difference in frequency of activation, duration of occurrence and strongest intensity (P<0.0001) between baseline and procedure. In addition, all AUs were significantly different in intensity (P

Table 4: Activation of Facial Action Units during baseline and noxious stimulus (N=50)

		BASELINE			PROCEDURE			
FACS Name	**Action Units**	**No. of times activated**	**Mean Activation Per Subject**	**Std Dev**	**No. of times activated**	**Mean Activation Per Subject**	**Std Dev**	***P-value***
Upper Face								
Inner brow raised	AU1	2	0.04	0.20	31	0.62	1.31	**0.0025**
Outer brow raised	AU2	2	0.04	0.20	20	0.4	1.16	**0.033**
Brow lower	AU4	8	0.16	0.51	88	1.76	1.66	**<0.0001**
Upper Lid Raiser	AU5[¶]	0	0	0.00	5	0.1	0.71	0.3198
Cheek raised	AU6	3	0.06	0.31	25	0.5	0.95	**0.0025**
Lid tightened	AU7	29	0.58	1.13	141	2.82	2.95	**<0.0001**
Eyes closure	AU43	56	1.12	0.59	82	1.64	1.52	**0.0267**
Blink	AU45	17	0.34	2.12	48	0.96	2.55	0.1894
Head Position								
Head Turn Left	AU51	9	0.18	0.75	10	0.2	0.45	0.8717
Head Turn Right	AU 52	3	0.06	0.31	20	0.4	0.86	**0.0098**
Head Turn Up	AU 53	3	0.06	0.24	43	0.86	1.20	**<0.0001**
Head Tilt Left	AU 55[¶]	0	0	0.00	1	0.02	0.14	0.3198
Head Forward	AU 57	1	0.02	0.14	11	0.22	0.55	**0.0137**
Eye Position								
Eyes right	AU 62[¶]	0	0	0.00	2	0.04	0.28	0.3198
Eyes up	AU 63[¶]	0	0	0.00	7	0.14	0.57	0.0865
Lip Parting and Jaw Opening								
Lips parted	AU 25	36	0.72	0.70	62	1.24	1.06	**0.0047**
Jaw drop	AU 26	18	0.36	0.72	41	0.82	1.41	**0.0427**
Lower Face								
Nose wrinkle	AU 9	0	0	0.00	15	0.3	0.68	**0.0023**
Lower Lip Depress	AU 16[¶]	0	0	0.00	2	0.04	0.20	0.1562
Chin Raiser	AU 17	1	0.02	0.14	23	0.46	1.15	**0.0083**
Lip Pucker	AU 18	1	0.02	0.14	8	0.16	0.51	0.0642
Lip stretcher	AU 20[¶]	1	0.02	0.14	9	0.18	0.66	0.0972
Lip presser	AU 24[¶]	1	0.02	0.14	3	0.06	0.24	0.3123
Miscellaneous								
Tongue Show	AU 19[¶]	1	0.02	0.14	3	0.06	0.24	0.3123
Jaw Clencher	AU 31[¶]	0	0	0.00	1	0.02	0.14	0.3198
Blow	AU 33[¶]	0	0	0.00	1	0.02	0.14	0.3198
Puff	AU 34[¶]	0	0	0.00	1	0.02	0.14	0.3198
Nasal Dilatation	AU 38	0	0	0.00	32	0.64	2.08	**0.0318**
Head shake back and forth	AU84[¶]	0	0	0.00	1	0.02	0.14	0.3198
Total number of AUs activation		**192**	**3.84**	**4.66**	**736**	**14.72**	**8.88**	**<0.0001**

Pain related AUs are marked in boldface as reported in previous studies.

Significant results are marked in boldface.

[¶]AUs occurring in 5% or less for all 50 subjects over the 2 phases were eliminated from subsequent consideration because of their rarity.

Table 5: Facial Action Units Frequency, Duration, and Intensity during pain response§

Facial Action Units	Total Frequency		Total Duration (Seconds)		Highest Intensity	
	Difference	P-value	Difference	P-value	Difference	P-value
Inner brow raised AU1	0.58	0.0025	1.70	0.0769	0.86	0.0006
Outer brow raised AU2	0.36	0.0330	0.90	0.3156	0.56	0.0159
Brow lower AU4	1.6	<0.0001	10.14	<0.0001	2.72	<0.0001
Cheek raised AU6	0.44	0.0025	1.87	0.0090	1.12	0.0003
Lid tightened AU7	2.24	<0.0001	4.89	<0.0001	1.84	<0.0001
Eye closure AU43	0.52	0.0267	-3.42	0.0065	0.08	0.6739
Lips parted AU 25	0.52	0.0047	4.57	0.4585	0.82	0.0039
Jaw drop AU 26	0.46	0.0427	0.42	0.8630	0.7	0.0114
Nose wrinkle AU 9	0.3	0.0023	1.15	0.0080	0.72	0.0009
Chin Raiser AU 17	0.44	0.0083	1.91	0.0077	0.66	0.0023
Nasal Dilatation AU 38	0.64	0.0318	0.72	0.0190	0.46	0.0042
Head turn right AU 52	0.34	0.0098	1.55	0.0870	0.48	0.0064
Head turn up AU 53	0.8	0.0000	4.83	<0.0001	1.34	<0.0001
Head turn forward AU 57	0.2	0.0137	0.82	0.0137	0.56	0.0091
Sum of AUs	9.44	<0.0001	32.04	<0.0001	12.92	<0.0001

§Difference = Procedure – Baseline

Specific Aim 2: Facial actions and pain response

The fourteen facial AUs that were associated with pain response are described in Table 6. These AUs varied in frequency, duration or intensity of correlation with the BPS. For example, only brow raiser and mouth opening AUs were moderately correlated with BPS while brow lower, orbit tightening and head turned up correlated with duration and BPS. Meanwhile, the intensity of all the 8 AUs represented in the frequency and duration categories were correlated with BPS. In addition, chin raiser, nasal dilation, and head turned forward had no association with BPS for frequency, duration, or intensity. The sum of intensity of the 14 AUs was correlated with BPS (r=0.70, P<0.0001) and with the facial expression component of BPS (r=0.58, P<0.0001) during procedure.

To predict which facial AUs accounted for the majority of pain response, we entered all 14 AUs in the stepwise method model. Table 7 illustrates a final model which included 5 pain-relevant facial AUs that accounted for 71% of the variance (Adjusted R^2=0.682) to predict pain response (F= 21.99, df=49, P<0.0001). Using the criteria established by Prkachin and Solomon,[24] we summed the intensity of these 5 AUs to define FACS pain intensity score:

$$Pain = AU1 + AU4 + AU9 + AU52 + AU53$$

Based on the 5-point intensity scale used to code each AU, the possible FACS pain intensity score ranged from 0-25. The FACS pain intensity score was higher during the procedure (*Mean*=6.72) than baseline (*Mean*=0.60) (F= 105.95, df=99, P<0.0001). In addition, the FACS pain intensity score was highly correlated with BPS (r=0.77, P<0.0001) and with the facial expression component of BPS (r=0.63, P<0.0001) during procedure.

Table 6: Correlation of Facial Action Units and BPS for frequency, duration, and intensity during pain response

Facial Action Units	Frequency		Duration		Intensity	
	Correlation	P-value	Correlation	P-value	Correlation	P-value
Inner brow raised AU1	**0.31**	0.0312	0.21	0.1339	**0.42**	0.0024
Outer brow raised AU2	**0.32**	0.0244	0.16	0.2775	**0.33**	0.0193
Brow lower AU4	0.10	0.4789	**0.54**	0.0001	**0.72**	<0.0001
Cheek raised AU6	0.06	0.6838	**0.33**	0.0210	**0.45**	0.0010
Lid tightened AU7	0.05	0.7557	**0.30**	0.0343	**0.45**	0.0009
Eye closure AU43	0.16	0.2661	-0.21	0.1453	-0.09	0.5500
Lips parted AU 25	0.24	0.0893	-0.08	0.5940	**0.40**	0.0038
Jaw drop AU 26	**0.37**	0.0090	0.19	0.1924	**0.36**	0.0114
Mouth opening AU25/26	**0.38**	0.0068	-0.02	0.8718	**0.40**	0.0038
Nose wrinkle AU 9	0.14	0.3224	0.10	0.4947	0.21	0.1346
Chin Raiser AU 17	-0.01	0.9202	0.17	0.2438	0.12	0.4203
Nasal Dilatation AU 38	-0.09	0.5415	0.01	0.9578	-0.03	0.8232
Head turn right AU 52	**0.44**	0.0012	0.27	0.0601	**0.40**	0.0038
Head turn up AU 53	0.10	0.5021	**0.30**	0.0356	**0.29**	0.0431
Head turn forward AU 57	0.16	0.2743	0.24	0.0875	0.12	0.3995
Sum of AUs	**0.36**	0.0112	0.26	0.0714	**0.70**	<0.0001

Table 7: Facial action units predicting pain response

Term	Estimate	Std Error	t Ratio	Prob>|t|
Inner brow raised AU1	0.29	0.09	3.09	0.0034*
Brow lower AU4	0.70	0.10	7.12	<0.0001*
Nose wrinkle AU 9	0.17	0.10	1.71	0.0939
Head turn right AU 52	0.44	0.14	3.19	0.0026*
Head turn up AU 53	0.16	0.10	1.60	0.1157

Specific Aim 3: Patient factors

Facial action units and patient factors. There was no association between FACS pain intensity score and patient factors (e. g., age, gender, race, and diagnosis, duration of endotracheal intubation, ICU length of stay, and analgesic and sedative drug usages, and severity of illness).

Facial action units and sedation level. As might be expected, subjects were more aroused during the noxious procedure than during baseline but there was no difference in scores (P =0.6041). During baseline, 56% of the subjects were in a moderate to unarousable state (deep sedation), 36% arousable to awake state, and 8% in an agitated state as compared to noxious procedure 50%, 40%, and 10%, respectively. No subject was observed to be in a highly agitated or combative state. The FACS pain intensity score was highly correlated with RASS (r=0.63, P <0.0001) during pain indicating greater the pain level and higher the arousal state.

DISCUSSION

Pain assessment remains a challenge in non-communicative critically ill patients whose pain experience is inferred from observation of behaviors and other physiological measures. This is the first study focusing on facial expressions during pain in the non-communicative critically ill adult patient. Furthermore, we investigated the relationship among facial expression, pain level, sedation level, and other patient factors.

The subjects were representative of medical and surgical ICU populations. Most were adequately sedated with light to moderate levels of sedation and able to briefly awaken with eye contact or movement to voice but were unable to follow commands.

Facial actions during pain response

Prkachin and Solomon[24] have identified four core facial action that contain the majority of pain information. These include brow lower, orbit tightening, nose wrinkling, and eye closure. These expressions have been associated with pain in other analyses of facial expression using different modalities (i.e., experimental pain or clinical pain; Table 2) generally in healthy volunteers. Our study extended their work to describe facial expression in non-communicative critically ill patients. Similarly, we found facial action units, specifically brow lower, orbit tightening, nose wrinkling, and eye closure. However, we also identified brow raiser, mouth opening, head position, and nasal dilatation expressions to be frequently seen during pain.

Core facial action in non-communicative critically ill patients

Brow lowering and orbit tightening. Facial expression of pain appeared to occur most often in the upper face (brow lower and orbit tightening) especially in terms of duration and intensity. Although the frequency of these expressions was not great during pain, this may be related to the difficulty in identifying these AUs due to peri-orbital edema. But once they occurred and were seen, their duration and intensity was strong during pain.

Nose wrinkle. Although nose wrinkle is generally a common expression of pain reported in otherwise healthier subjects, it was infrequently seen in this population and not strongly associated with pain in our sample. However, identification of nose wrinkle was frequently compromised (32% of the subjects) due to obstruction of the nose bridge with tape holding a nasogastric tube in place or tape securing the endotracheal tube.

Eye closure. FACS coding for eye closure (AU 43) is scored base on a subject's eyes open at onset and change in the degree of lid closing is coded. Most studies (Table 2) have found that subjects close their eyes during pain. However, in a study by Hadjistavropoulos,[23] eye closure varied as a function of activity in post-surgical knee replacement subjects who kept their eyes open to maintain balance while performing physiotherapy activities. In our study, majority of the subjects had their eyes closed at onset with longer duration of closure. The difference in increased frequency of eye closing during procedure was due to some subjects attempt to open their eyes. The intensity of eye closure was unchanged because it is coded on the degree of upper eyelid lowering that, at level 5 (maximum intensity), eyes are closed for more than 2 seconds. This coding assumes that the eyes are generally open and then close as a pain response. However in this sample, there was no difference in intensity of eye closure with or without pain and no association of eye closure with pain level. This is likely due to the level of sedation used in these patients. Although many subjects were arousable, the majority had their eyes closed due to sedation or their disease process and were unable to maintain eye opening so that a difference in this expression could be noted. Given this unique situation in this population, eye closure may not be informative with respect to pain assessment in the critically ill.

Additional facial action non-communicative critically ill patients

Brow raiser. The brow raiser facial expression is not quite as often reported in healthy subjects, but it occurred in high frequency in our sample, although with short duration and low intensity. The initial response to pain may arouse the subject and cause the eye brow to go up but quickly came down simultaneously as brows were lowered with great intensity. Brow raiser may be a useful pain relevant facial expression as it was significantly associated in frequency and intensity with pain.

Mouth opening. Mouth opening (lip parting and jaw drop) has been associated with pain in many studies and although not considered a core facial expression by Prkachin and Solomon[35] but was also found with pain in our study. However, it is important to note that majority of the subjects had their mouth open because of the presence of an endotracheal tube in the mouth and no difference was found in duration with and without pain.

Head position. Interestingly, head position (AU 52=turn right, AU53=turn up and AU57=forward) has not been described as a pain expression in previous studies but it was associated with pain in our study. All the subjects in our study were in supine position in bed and tended to move their head back or side to side as cough was stimulated with suctioning.[57] Even though head position was moderately correlated with pain level and more so with coughing episodes, this finding may not be generalizable and may require observations with other elicitors.

Nasal dilatation. Nasal dilation has not been reported in previous studies as a facial expression of pain, although there was an increase frequency of occurrence during procedure in our sample. It had the lowest frequency, duration, and intensity and did not correlate with pain level. Therefore nasal dilatation may not be an important facial action unit of pain in this population.

Facial actions during pain and patient factors

Level of sedation certainly affects facial expression. Those who had greater levels of arousal showed greater intensity of brow raiser, brow lower, orbit tightening, nose wrinkle, and mouth opening and head turning accounted for higher overall FACS pain intensity scores. Our findings are consistent with previous studies[30;58;59] showing that facial expression frequency, duration and intensity do not differ by gender. Similar to healthy subjects in previous study,[55] facial expressions of pain did not differ based on age in our study.

Based on our findings, the FACS pain intensity score of inner brow raiser, brow lower, nose wrinkle, and head movements reflected a general pain expression in the non-communicative critically ill patients.

LIMITATIONS

The study was conducted in two ICUs in a single institution. Although the units were well representative of medical surgical populations in critical care setting, the findings may not be generalized to every type of medical or surgical population. An important limitation of this study was that we used one noxious condition, no stimulus control, and with an assumption of absence of pain at baseline. Even though we used endotracheal suctioning, to elicit pain response, it has been shown to be comparable to other common procedure which causes pain in critically ill patients.

The data collection and video coding were conducted by the PI who was highly qualified and trained in FACS coding. Although this may have enhanced consistency in coding, it can also introduce bias such that PI can give possible meaning to facial behaviors. Therefore, biasing effects were minimized by recording BPS and FACS at separate times and coding each action units individually. In addition, inter-rater reliability was done on FACS coding as well as BPS and RASS. FACS coding is extremely time-consuming and requires comprehensive coding to avoid the possibility of overlooking meaningful actions and requires comparison coders. However, with future advances in automated face analysis using computer, pain detection through interactive video systems in diverse populations may become practical in clinical practice.[60;61]

CONCLUSION

In summary, our findings suggest that facial expressions of pain do not diminish in non-communicative critically ill patients. Upper facial actions (brow raiser, brow lower, and orbit tightening) appear to be the most frequently activated expressions in this population and have the potential to serve as a valid alternative to self-report ratings in the non-communicative critically ill patients. As shown in other clinical studies of healthy adults,[23;54] discrete facial action appeared to be reliable and useful measure of pain expression. In addition, development of an automated method of facial display analysis by feature point tracking has high concurrent validity with manual FACS coding.[60] Cohn et al.[60] found in the cross-validation set, average recognition accuracy for 15 action units in the brow, eye, and mouth regions that were comparable to the level of interobserver agreement achieved in manual FACS coding. These results provide evidence that the automated FACS could be beneficial in the development of a clinical tool for pain assessment in the critically ill non-communicate patients. These data are the first in identifying the appropriate terms to use in behavioral pain scales when evaluating facial expression. Terms presently used such as ‘‘frowning,’’ ‘‘grimacing,’’ “wincing,” “smile/relaxed” are not specific or descriptive enough to direct the clinician to look for the most appropriate facial action during pain. Second, the FACS pain intensity scores could guide in the quantification of pain score and may make standardization of pain evaluation more feasible. Further studies should validate these data so that clinicians can focus on facial expressions that have the greatest opportunity to reflect pain in the non-communicative critically ill patient.

ACKNOWLEDGEMENTS:

The authors thank the staff, patients, and their families in the Surgical Trauma ICU and Medical Respiratory ICU at Virginia Commonwealth University Health System (VCUHS) in Richmond, Virginia for participating in this study. The authors also would like to thank the staff at Department of Psychology, University of Pittsburgh, PA for providing training and reliability coding.

FUNDING:

Funding for this research was provided by the National Institutes of Health / National Institute of Nursing Research (F31 NR010433).

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52. Grap MJ, Glass C, Corley M, Parks T. Endotracheal suctioning: ventilator vs manual delivery of hyperoxygenation breaths. Am.J.Crit Care 1996;5:192-97.

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57. Branson RD. Secretion management in the mechanically ventilated patient. Respir.Care 2007;52:1328-42.

58. Kunz M, Gruber A, Lautenbacher S. Sex differences in facial encoding of pain. J.Pain 2006;7:915-28.

59. Craig KD, Hyde SA, Patrick CJ. Genuine, suppressed and faked facial behavior during exacerbation of chronic low back pain. Pain 1991;46:161-71.

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Mamoona Arif – Rahu, Phd, RN, CCRN

Curriculum Vita

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Place of Birth

Mamoona R. Arif-Rahu was born on June 13, 1970, in Karachi, Pakistan. She moved to United States of American in 1982 and since then lived in Virginia. She is an American citizen.

Education

2010	Ph.D. Program, Biobehavioral clinical research, Virginia Commonwealth University
1999	Master's of Science in Nursing, Advanced Clinical Nursing, George Mason University
1999	Clinical Research Associate, Georgetown University
1995	Bachelor's of Science in Nursing, Community Health Nursing, George Mason University
1994	Associate in Applied Science in Nursing, Registered Nurse, Northern Virginia Community College.

Experience

2008 – Present VCU Health System Richmond, VA
Nurse Clinician, Supplemental Staff

Provide leadership in multiple clinical practice areas and assures quality patient care through expert clinical practice, education, consultation and research, and use of innovations to solve clinical problems and instituting change. In collaboration with the nurse manager, accountable for establishing and maintaining standards of care.

Responsibilities: Coordination of department Orientation Program; multiple unit-specific education and competencies, and monitoring of performance improvement initiatives. Development of Nursing Intensity Rating Tool.

Committee Representatives: Supplemental Staff Professional Practice Council, Supplemental Staffing Education Committee, Nursing Quality Outcome Council, Critical Care Committee, Critical Care Practice Council, Progressive Care Practice Council, Education Leadership Council, Certification Task Force, and Nurse Intensity Rating Tool Task Force.

2004 – 2008 VCU Health System Richmond, VA

Nurse Clinician, Medical Respiratory ICU

Critical Care areas: 18 beds Medical Respiratory ICU.
Provide leadership in clinical practice and assures quality patient care through expert clinical practice, education, consultation and research, and use of innovations to solve clinical problems and instituting change. In collaboration with the nurse manager, accountable for establishing and maintaining standards of care.

Responsibilities: Coordination of Unit Based Orientation Program; unit-specific education and competencies; ongoing in-services; Writing new or revision of Policies and Procedures to meet current evidence based standards: Sedation Protocol, Weaning Protocol, Central Venous Access, Withdrawal of Life Support Guidelines, etc.

Committee Representatives: Critical Care Council, Critical Care Practice Council, Medicine Practice

Council, Education Leadership Council, Documentation Task Force, Acuity Task Force, Unit Based Committees: Steering, Clinical Practice Committee, and Education Committee

2005 VCU Health System Richmond, VA
Clinical Instructor for 2nd Degree BSN Program

Facilitated Fall clinical rotations of nursing students during their senior practicum experience at VCU Health Care Systems.

2004 George Mason University Fairfax, VA
Clinical Instructor for 2nd Degree BSN Program

Facilitated two summer clinical rotations of nursing students during their senior practicum experience at INOVA Fair Oaks Hospital, Invoa Alexandria Hospital, and Invoa Mt. Vernon Hospitals.

2002 – 2003 Inova Mount Vernon Hospital Alexandria, VA
Clinical Nurse Specialist, Critical Care Services

Critical Care areas: 20 beds ICU, 21 beds ER, and 32 beds Intermediate Care Unit.
Provide leadership in clinical practice and assures quality patient care through expert clinical practice, education, consultation and research, and use of innovations to solve clinical problems and instituting change. In collaboration with the nurse manager, accountable for establishing and maintaining standards of care.

Responsibilities: Development of ICU/ER/IMCU Internship Program; unit-specific education and competencies; ongoing in-services; Writing new or revision of Policies and Procedures to meet current evidence based standards: High Risk Medications, Code Blue, Standard Drip Concentration, and Management of patient on peripheral thrombolytics, etc. Development of Triage and Trauma education program. Development of Unit Practice Council on all three units. Development of Wound Fair.

Chair of Code Blue Committee. Implemented new standards and guidelines. Formulated Code Blue Team responsibilities. Implemented new forms for code documentation.

Committee Representatives: Critical Care, Infection Control, Advance Clinical Ladder, Patient Safety, Research Based Practice Committee, Nursing Leadership, Non-invasive Cardiology Committee, Cardiology Leadership Committee, Wound Management, Unit Practice Council – all three units.

2000 – 2002 Northern Virginia Community Hospital Arlington, VA
Clinical Nurse Specialist, Critical Care Services

Critical Care areas: 14 beds ICU, 9 beds ER, and 20 beds Pulmonary Rehab Services.
Provide leadership in clinical practice and assures quality patient care through expert clinical practice, education, consultation and research, and use of innovations to solve clinical problems and instituting change. In collaboration with the nurse manager, accountable for establishing and maintaining standards of care.

Responsibilities: Development of ICU Internship Program; unit-specific education and competencies; ongoing in-services; self-study packets on AAA, Carotid Endarterectomy, ECG. Revision of Policies and Procedures to meet current evidence based standards: Code Blue, Central Venous Catheter Management, Blood Culture, ICU Testing, CRRT, Propofol Drip, High Risk IV Drugs Administration and Patient Education.

Chair of Code Blue Committee. Implemented new standards and guidelines. Formulated Code Blue Team responsibilities. Implemented new biphasic defibrillators training and new forms for code documentation.

Committee Representatives: Critical Care, Quality Council, Infection Control, Pain Management, Nursing Policy and Procedure, Hospital Policy and Procedure, Wound Management, Product Evaluation, Standards.

1998 – 2003 INOVA Fairfax Hospital Fairfax, VA
Medical Surgical Intensive Care Unit – ICU 1

Provide comprehensive health care to critically ill patients, utilizing standard of care and practice. Responsible for invasive hemodynmic monitoring and mechanical ventilation management. Primary focus of care: Immediate post-op recovery of liver transplant patient and high risk kidney/ pancreas transplant patient; Cardiovascular dysfunction; Post Cardiac Resuscitation care; MI, CHF, Cardiac dysrhythmias, CA, Hemodynamic instability; respiratory dysfunction; ARDS; COPD, Pneumonia; high pregnancy/OB/ GYN complications; Neurovascular dysfunction; CVA; brain tumors, Ventilator dependent patients.

Committee Representatives: Staff Development, Nursing Congress, and Research.

1996 – 1998 INOVA Fairfax Hospital Fairfax, VA
Medical Surgical Unit – Tower 8

Primary Nursing, Infectious Diseases and Medical Surgical Unit. Provide primary bedside nursing care to diverse patient population. Primary focused of care: HIV/AIDS, Respiratory infections, CHF, CAD, Renal, Hepatic, and GI diseases.

Committee Representatives: Patient Education Council Committee, Editor/Publisher of Nursing Newsletter for the Unit.

1994 - 1996 Fairfax Nursing Center Fairfax, VA
Charge/Staff Nurse: Long Term Care Facility

Supervision of 200-bed facility with 12 staff members. Worked on a Skill Care Unit. Provided nursing care to elderly population including rehabilitative, restorative, and palliative care.

Licensure and Certification

Registered Nurse, Commonwealth of Virginia.

Certification in Critical Care Nurse (CCRN). American Association of Critical Care Nurse.

Advanced Cardiac Life Support (A.C.L.S.)

Basic Life Support (BLS) Instructor

Preceptor

2006 Preceptor for Graduate Advance Nursing Student in the Role of CNS, Viringia Commonwealth University

2002 Preceptor for Graduate Advance Nursing Student in the Role of CNS, George Mason University.

Publications

Book Chapter:

2008 Arif, M and Grap, MJ. (2008) Introduction to Critical Care Nursing*, 5th ed.* Chapter 5, "Comfort and Sedation." Elsevier, Philadelphia. Editor: Mary Lou Sole.

Journal Publication:

2010 Arif, M.; Fisher, D., Matsuda, Y. (2010) Biobehavioral Measures for Pain in the Noncommunicative Pediatric Patient. *Pain Management Nursing. (In Print)*

2010 Arif-Rahu M, Grap MJ. (2010) Facial expression and pain in the critically ill non-communicative patient: State of science review. *Intensive and Critical Care Nursing*. 26 (6): 343-352.

Educational Professional Presentations:

2010 State of Science on "Facial Expression to Discriminate Between Pain and Absence of Pain in Critically Ill Intubated Adults during Painful Procedures. Poster Presentation at Week of the Nurse. Virginia Commonwealth University Health System, Richmond, Virginia.

2009 State of Science on "Facial Expression to Discriminate Between Pain and Absence of Pain in Critically Ill Intubated Adults during Painful Procedures. Council for the Advancement of Nursing Science, 2009 Special Topics Conference Technology, Genetics and Beyond – Research Methodologies of the Future. Omni Shoreham Hotel, Washington, DC.

2008 Methodology on "Facial Expression Using Facial Action Coding System to Discriminate Between Pain and Absence of Pain in Critically Ill Intubated Adults during Painful Procedures" at the 6th international conference, Measuring Behavior 2008, in Maastricht, Netherlands.

2008 State of Science on "Facial Expression Using Facial Action Coding System to Discriminate Between Pain and Absence of Pain in Critically Ill Intubated Adults during Painful Procedures" at the 22nd annual Southern Nursing Research Society (SNRS) 2008 conference in Birmingham, Alabama.

2006 "Management of ARDs Patient in Critical Care." Virginia Commonwealth University Health System, Richmond, Virginia.

2002 Wound Fair – "Taking the Fear Factor Out of Wound Care." Creation of Wound Care Algorithm and standards. INOVA Mount Vernon Hospital, Alexandria, Virginia.

1998 "Breaking Barriers to Achieving Treatment Goals in the Home." Co-presented with Mary Narayan, at the Congestive Heart Failure Symposium at INOVA Fairfax Hospital, Physician Conference Center, Fairfax, Virginia.

1995 Breast Cancer Awareness: Do you know your risks? Included BSE, George Mason University, Fairfax, Virginia.

Research

2010 "Facial Expression Discriminates Between Pain and absence of Pain." Virginia Commonwealth University, School of Nursing. Biobehavioral Research, Doctoral Program.

2006 "Evaluation of Pain Scale." Virginia Commonwealth University Health System, Richmond, Virginia.

1998 "Does Length of shift impact Nurses' ability to function?" A replicated study to compare difference in levels of fatigue and critical thinking abilities of staff nurses working 8- shifts versus 12-hour shifts. Co-investigators D. Ferris and *I*. Huebner. School of Nursing, George Mason University, Fairfax, Virginia.

Honors and Awards

2010	Martha M. Borlick Research Award: Initiated in 1980, the Dr. Martha B. Borlick Research Award is presented to a graduate student in nursing who demonstrates excellence in nursing research as evidenced in the research culminating products. Presented at Virginia Commonwealth University, School of Nursing, graduation recognition ceremony.
2007 - 2010	NIH Research Grant: "Facial Expressions during pain." National Institute of Nursing Research: NIH F31 NR010433
2007	"Leader of the Year" Nominee for the Greater Richmond Chapter of AACN.
2006	"Vision Awards: Workforce Development" 2006 Week of Nurse, VCU Health System.
2003	"Celebrating INOVA Nurses" Recognized at the WUSA/Channel 9 as Outstanding Nurse.
1999	Sigma Theta Tau International, Nursing Honor Society, George Mason University.
1998	Scholarship: INOVA Health System Foundation.
1998	"President of the Year" Award for Pakistan Student Association at George Mason University.
1998	"Club of the Year" Award, for Pakistan Student Association at George Mason University
1997	Scholarship: INOVA Health System Foundation.
1995	Mayor's Service Award for Community Service Project, Fairfax Nursing Center.
1995	All American Scholars Award, United States Achievement Academy criteria based on academic, citizenship, leadership, attitude, and dependability.

Organization

Pakistan Student Association, President

Alpha Phi Omega, Vice President of Pledge Class, Service Fraternity

Muslim Association of Virginia

Professional Affiliations

American Association of Critical Care Nurses

Greater Richmond Chapter of AACN

Greater Washington Chapter of AACN

Capital Area Affiliate of National Staff Development

Sigma Theta Tau International

Additional Skills

Microsoft Word: Access, Excel, PowerPoint, Corel Win 98, Web Designer, Lotus Notes, JMP & SPSS Statistical Analysis Database.

Reference

Available upon request