

Correlation between Pain and Biomedical Signals in the Context of Severely Burnt Individuals - Preliminary Results

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Abstract: The objective measurement of subjective, multi-dimensionally experienced pain is a problem for which there has not been found an adequate solution yet. Although verbal methods (e.g., pain scales and questionnaires) are commonly used to measure clinical pain, they tend to lack objectivity, reliability, or validity when applied to e.g. mentally impaired individuals. Biomedical signals and behavioral parameters may represent a solution. Such coding systems already exist, but they are either very costly or time-consuming, or have not been sufficiently evaluated. In this context, we measured multimodal biomedical signals during the treatment of a patient with severe pain in the Burn Unit of the Clinical Hospital of the Federal University of Uberlândia (Brazil). We found convincing correlation between pain and vital signs related to the cardiac activity (e.g., blood pressure) in one person.

Keywords: multimodal automatic pain recognition, burn victims, analgesics.

Introduction

Pain is a very personal sensation that is difficult to interpret without any communication from the patient. Consequently, a method for an objective measurement of pain would be beneficial, particularly in cases where the patient is not able to describe the experienced pain - for example neonates [1], somnolent patients and patients suffering from dementia [2], [3], [4]. Under certain circumstances, there is little correlation between subjectively experienced pain and tissue lesions or other pathological changes; the pain may even be completely unrelated. Therefore, the somatic pathology does not allow any conclusions to be drawn about subjectively experienced pain [5]. Children, older individuals and patients suffering from dementia have different pain thresholds as well as a varying tolerance for pain relative to healthy adults [6], [7]. A central problem is the fact that there is currently no simple method that can

be used to measure pain directly. The examining physician must rely on the patient's qualitative description of the intensity, location and nature of the pain. It is possible to quantify pain with the help of the visual analog scale (VAS) or the numeric rating scale (NRS). However, these methods only work when the patient is sufficiently alert and cooperative, which is not always the case in the medical field (e.g., post-surgery phases). Overall, these methods are either considered inadequate or still in development [6]. If conditions do not allow for a sufficiently valid pain measurement, this may lead to cardiac stress in at-risk patients, underperfusion of the operating field, or to the chronification of pain. For example, 30 - 70% of patients report moderate to severe pain after surgery [8].

To the best of our knowledge, the study of Treister *et al.* [9] was the first that took a multi-parameter biomedical approach. Tonic heat was applied to elicit pain for a minute, with intensities of no pain, low, medium and high pain. The pain intensities were calibrated individually. The biomedical measurements used were: heart rate, heart rate variability-high frequency, skin conductance, number of skin conductance fluctuations, photoplethysmography and a linear combination parameter. All features differed significantly in 'no pain' to the other thresholds (low, medium and high pain), but none of the parameters differed significantly in all three thresholds. In addition, a clinical study by the same working group [10], provided similar results to those obtained with a linear regression and a non-linear Random Forest regression based on the same six features by Treister *et al.* [9] (see also Walter *et al.* [11]).

Walter *et al.* [11] embedded into an experimental design four levels of painful heat stimuli (independent variables) by a Medoc Pathway Chaps were elicited on 85 participants under controlled conditions.

The dependent variables were biomedical and video signals. In total, 135 features - amplitude, frequency,

stationarity, entropy, linearity, variability and similarity – derived from biomedical such as skin conductance level (SCL), electromyography (EMG) and electroencephalogram (EEG) were used to measure the responses. For video recording, the setup allowed the participant of the study to move his head freely, while ensuring that his face is fully visible even in case of large out of plane rotations. It was employed three AVT Pike F145C cameras, one directly in front of the study participant and two at the side. The latter captured a frontal face in case the participant turned his head 45° to the left or right, respectively. The Pike cameras were triggered synchronously at a frame rate of 25 Hz and recorded at a resolution of 1388 x 1038 colored pixels.

At the beginning of the experiment, the pain (T_1) and tolerance thresholds (T_4) for each participant were identified. From these values, a specific average was calculated for T_1 and T_4 for each individual. Two other intermediate individual pain thresholds (T_2 and T_3) were determined mathematically. The participants were randomly stimulated, for about 25 minutes, by means of four individual specific thresholds of pain. The baseline (B) was 32 °C. Each pain level (T_1 vs. T_2 vs. T_3 vs. T_4) was applied 20 times (4s), resulting in a total of 80 stimulations.

The thresholds T_1 , T_2 , T_3 , T_4 , including the effects of age and gender effects, are consistent with the results reported in the existing literature. The biopotential features *scl_stationarity_sdz_mean*, *ecg_slopeRRz_mean*, *emg_trapezius_variance_inrangez_mean* and video signal features *inter_decile_range_of_brow_to_mouth_distance* and *standard_deviation_of_nasal_wrinkling* were chosen as the most relevant. It was shown that the automatic recognition rates of the data fusion are significantly superior compared with separate biomedical or video signal analyses.

A current drawback in the area of automatic pain recognition is the lack of practical studies taking into account the measurement of pain in a clinical scenario. In this context, this research presents preliminary results of the correlation analysis between pain sensation and vital signs for severely burnt individuals.

The overall aim of the long-term study is the advancement of pain diagnosis and monitoring in clinical settings.

Materials and methods

Study design – This paper is a case study of a single severely burnt inpatient (see Fig. 1a) from the Burn Unit of the Clinical Hospital of the Federal University of Uberlandia (Brazil). To track changes in vital parameters related to pain sensation, we monitored the

patient continuously, under four different conditions: a) during wound care (P_1); b) during physiotherapy (P_2); c) at rest, 2.5 hours after pain relief medication intake (R). As painkiller, doctors prescribed the Morphine Sulphate, and the rest intervals were set to collect data in the presence and in the absence of analgesic effect, which lasts only 4 to 5 hours when administered intravenously. The patient was assessed in different days for 3 weeks.

Participant – A 33 year-old male farmhand who suffered an electrical burn injury took part in the study.

Variables – The following parameters were collected at 0.017 Hz (1 sample per minute): a) Pulse; b) Oximetry (SpO_2); c) Temperature (T); d) Heart Rate (HR), and; e) Respiratory Rate (RR). Blood pressure parameters were collected at 0.008Hz (1 sample every 2 minutes): a) Systolic Blood Pressure (SBP); b) Mean Arterial Pressure (MAP); and c) Diastolic blood Pressure (DBP). Clinical staff also assessed and annotated the Subjective Pain Sensation (PS) every two minutes by means of the Verbal Numeric Scale (VNS).

Data Acquisition – We used a commercial version of a Multi Parameter Monitor (DX 2020 – DIXTAL BIOMÉDICA, Brazil) for data collection and storage. The data were later transferred to the computer for offline processing.

Blood pressure sphygmomanometer was positioned at the patient's arm opposite to venous accesses to prevent any circulatory complications. Temperature sensor was placed in the axilla of the same arm. Pulse and oximetry were measured by positioning the sensor in the distal phalanges of the 2nd or 3rd fingers of the opposite hand to prevent inaccurate measures. Heart Rate and Respiratory Rate are inferred automatically from electrocardiography by the Multi Parameter Monitor.

Data Analysis and Statistics – All biopotentials were normalized separately for each individual signal feature. Generalized Linear Models (GLMs) were used to test the quantitative pain intensity with respect to all of the features. This model is based on the Wald χ^2 test [12] and the related *post hoc* test. For this purpose, a Wald χ^2 test for P_1 , P_2 , and R (see Table 1) and three subsequent *post hoc* tests for P_1 vs. P_2 , P_1 vs. R , P_2 vs. R , were carried out. We calculated the Spearman correlation coefficient between the verbal numeric scale and all biomedical signals.

Table 1: Mean, p-Levels and Correlations found for the comparative scenario: Wound Treatment (P1) vs. Physiotherapy (P2) vs. Analgesic (R).

	Mean of the biomedical signals								
	SBP	MAP	DBP	Pulse	SpO ₂	HR	T	RR	VNS
Wound Treatment	134.17	105.26	90.97	104.02	94.37	103.57	32.64	13.64	4.54
Physiotherapy	131.49	99.28	82.94	126.04	94.15	125.39	35.00	16.60	4.11
Analgesic	129.09	97.98	83.58	105.23	94.14	105.91	35.50	18.89	2.95
Test:	p-level								
Chi2 Wald Test	.000	.000	.000	.000	.309	.000	.002	.000	.048
Post Hoc Test 1-2	.010	.000	.000	.000	.276	.000	.037	.000	.000
Post Hoc Test 1-3	.000	.738	.000	.067	.177	.009	.001	.000	.000
Post Hoc Test 2-3	.034	.176	.499	.000	.981	.000	.663	.001	.000
	Correlation r-level								
Correlation between-VNS and Biomedical Signals for the protocol Analgesic	.412**	.507**	.513**	-.423**	.165*	-.502**	.511**	-.096	1

SBP: Systolic Blood Pressure, MAP: Mean Arterial Pressure, DBP: Diastolic Blood Pressure, SpO₂: Oximetry, HR: Heart Rate, RR: Respiration Rate, VNS: Verbal Numeric Scale, $p \leq .05^*$, $p \leq .01^{**}$

Results

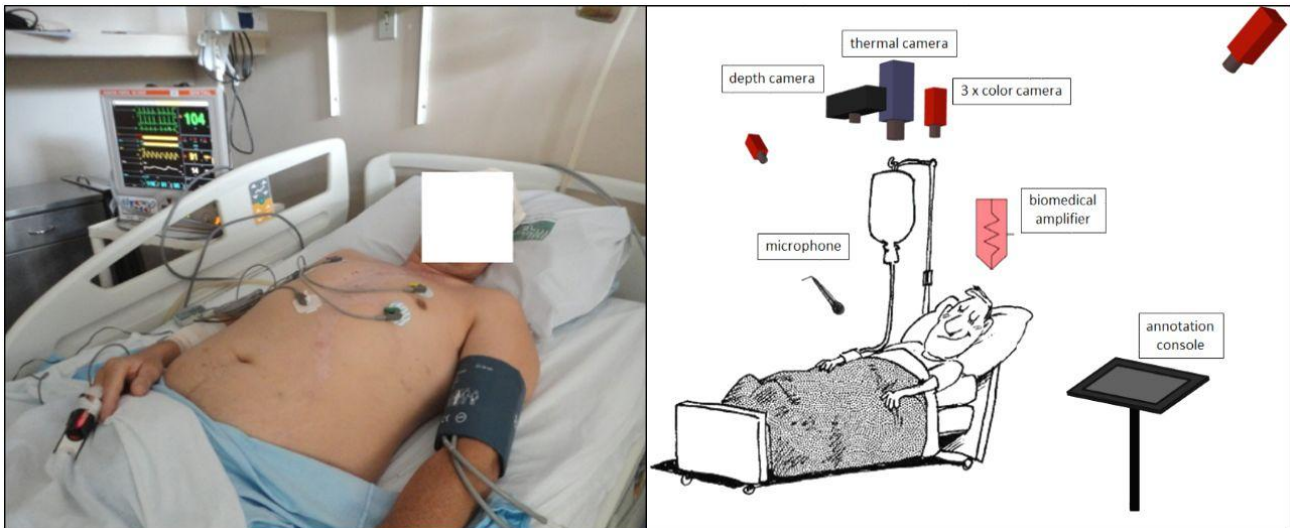


Fig. 1a: Clinical setting, 1b: Our vision: multimodal automatic pain recognition system.

We found for the comparison of wound treatment (P1) vs. physiotherapy (P2) vs. analgesic (R) significant results regarding the pain quantification of the cardio related variables SBP, MAP, DBP and RR. Furthermore, for the analgesic treatment we found also high significant correlation between SBP*VNS, MAP*VNS, DBP*VNS, Pulse*VNS, HR*VNS and T*VNS.

Discussion and Conclusion

This is the first study to our knowledge in which biomedical signals were tested to quantify clinical severe burn. Most convincing are the cardio dependent signals.

The most crucial clue has been found for the planned long-term data recording for the distinction of treatment vs. physiotherapy vs. analgesic.

We plan a study with multimodal automatic pain recognition (Fig. 1b) via biomedical, video and paralinguistic signal. Our challenge is to recognize the pain intensity, characteristic and localization in a clinical environment.

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