

Electrodermal activity and suicide risk assessment in patients with affective disorders

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Summary

There are questionnaires and scales, including self-assessment scales, used to evaluate suicide risk. Additionally, suicide risk factors (i.a., prior suicide attempts, willingness to commit suicide, somatic diseases, male gender) are also known. Their application, however, does not provide a sufficient guarantee for properly distinguishing persons with high and low suicide risk. In 1986, Gunnar Edman observed that there is an association between low electrodermal activity and suicidal tendencies, which was confirmed in other studies and meta-analyses. Electrodermal activity (EDA) is commonly considered to be a very good indicator of orienting reflex, which is a response to the information linked with a stimulus and, in a way, a physiological mechanism that helps an organism to survive. This phenomenon is related to habituation, the rate of which is a measure of EDA reactivity. Hyporeactivity consists in very rapid habituation of a stimulus, even after first exposure. According to Lars Håkan Thorell, hyporeactivity may be understood as a specific deficit of attention, which is associated with inability to arouse curiosity with ordinary, everyday events at the physiological level. This results in a greater tendency to attempt suicide shown by persons with mood disorders, and lower fear of hurting oneself. The goal of this paper is to present the history of studies on electrodermal activity, relationship between EDA and suicide tendencies in persons with affective disorders and to discuss EDOR System that identifies persons at particularly high risk of committing suicide.

Key words: electrodermal activity, affective disorders, suicide

1. Suicide risk assessment methods

Suicides account for one of the major causes of deaths in psychiatry. Suicide risk in patients diagnosed with a depressive episode is the largest among all mental disorders. Although women suffer more often from affective disorders, men attempt suicide more frequently. The following symptoms of depressive disorders are associated with suicidal tendencies: high-intensity anxiety, hopelessness, feelings of guilt, nihilistic

delusions, dysphoria, and persistent sleep disturbances. In addition, the following factors significantly increase suicide risk: absence of perceived social support, prior suicide attempts, self-injury, unstable professional situation, occurrence of a traumatic event, somatic illness, and verbalisation of suicidal ideation and tendencies [1].

We can assume that if we could correctly assess the risk of suicide, almost all patients at risk could avoid death. A study of Neuner et al. revealed that merely 3% of patients who attempted suicide were assigned to the high-risk group based on typical suicide risk assessment methods [2]. This fact reflects their very low sensitivity. The National Guideline Clearinghouse recommends the following methods while assessing the suicide risk: clinical history taking, the *Hamilton Rating Scale for Depression* and four scales developed by Beck: *Beck Depression Inventory* (BDI), *Beck Hopelessness Scale* (BHS), *Suicide Intent Scale* (SIS) and *Scale for Suicidal Ideation* (SSI) [3]. These tools applied to assess suicide risk may turn out to be helpful for a clinician, but none of the known scales for suicide risk assessment guarantee its correct estimation. The scales rather assess an attitude towards suicide instead of an actual probability of committing suicide [1]. Furthermore, their downside is that they may taint the answers. Biomarkers of suicide risk provide an alternative for limitations of the suicide risk assessment using questionnaires. Kim and Lee reviewed in detail the studies on biomarkers of suicide risk performed so far. They listed the following factors correlated with such tendencies: low serum cholesterol, low BDNF, serotonin transmission dysfunctions, and non-suppression in the dexamethasone suppression test [4]. The authors concluded that so far no one has found at least one highly sensitive factor and the ones currently being used are correlated and often have an additive effect on one another. Therefore, it is necessary to develop a new objective method for identifying persons at particular risk of committing suicide. The aim of this article is to present theoretical background and current studies on using electrodermal activity as a possible biomarker of suicide risk.

2. Electrodermal activity and orienting reflex

Eccrine sweat glands that perform thermoregulatory functions are able to strongly react to mental stimuli. Numerous authors claim that glands on palms and feet are able to react primarily to mental stimuli, but their thermoregulatory functions start to prevail only in relatively high temperatures that exceed 30°C. Electrodermal activity (EDA) shows changes in electrical conductance of the skin and is considered as an indicator of changes in the sympathetic part of the autonomic nervous system. The ventromedial prefrontal cortex is responsible for its modulation [5]. EDA can be tested using two methods: exosomatic and endosomatic. The exosomatic method consists in measurements of skin resistance or its conductance when the current generated by an external source passes through it. Active resistance, or skin resistance level (SRL), and active conductance, or skin conductance level (SCL), are measured using direct current.

The endosomatic technique, in turn, involves measurements of differences in potentials between two separate skin areas. There is a positive and very high correlation between skin conductance level and number of active sweat glands, but no correlation between this SCL and amount of sweat on the skin has been determined [6]. Two types of EDA can be distinguished, i.e. tonic activity (relatively constant level or slow spontaneous changes in its activity) and phasic activity (responses to various stimuli). In measurements of phasic activity, amplitude, latency, rise and drop time, and habituation are taken into account [7, 8].

Studies conducted so far indicate that electrodermal response is a very good indicator of orienting reflex (OR), understood as a body's response to new stimulus or change of a stimulus. Stimulus intensity as well as its meaning for the recipient play a significant role in triggering this reflex – the greater the informative content of a stimulus, the larger the orienting reflex that should be triggered [9]. The same stimulus appearing over and over again leads to reduction or disappearance of the orienting reflex, i.e. habituation. Habituation takes place when no electrodermal response occurs after three subsequent exposures to the same stimulus. In contrast, a change in the stimulus parameters results in OR recovery, i.e. dishabituation. The orienting reflex itself does not need to be learnt, while habituation is one of its most elementary forms. Reactive EDA, hyporeactive EDA (habituation after three stimuli), EDA at the limit and hyperreactive EDA can be distinguished depending on habituation rate.

EDA may be triggered by stimuli related to any sense. These stimuli do not need to be strong. Skin conductance ranges from low during sleep to very high, e.g. when a person experiences very strong emotions. Numerous studies demonstrated a relationship between reduced SCL and induced pleasant emotions, e.g. satisfaction (described as self-satisfaction, being relaxed and calm) and sense of security. Unpleasant emotions, such as anger, anxiety, fear and disgust are associated with increasing SCL [10]. The relationship between EDA and personality traits is not clear – extraversion and introversion differ from each other rather in phasic stimulation than in tonic one, in particular if sudden protective inhibition must take place in laboratory setting [11].

The following factors have an impact on electrodermal activity: individual differences (age, race, menstrual cycle), movements of studied person during measurement, condition of tested skin and room temperature. Furthermore, constant intake of caffeine and stimulants increases conductance, whereas a single application results in growing amplitude and decreasing habituation [7]. Changes in this respect often substantially modify EDA. Therefore, the test procedure should be standardized and a decision should be made e.g. as far as hand washing or the same room temperature are concerned [12, 13].

3. History of studies on electrodermal activity and orienting reflex

The first observations of the relationship between mental factors and electrodermal activity were made in the second half of the 19th century. They are usually attributed to Marie Gabriel Romain Vigouroux (1831-1911), who examined tension on palms using a galvanometer and noted that it changed under influence of hand movement. In further experiments he incorporated a source of direct current in the circuit consisting of hands and electrodes and measured skin resistance. He found out that changes in skin resistance take place in parallel to various physiological conditions and concluded that EDA may be successfully used as a diagnostic method of mental changes [14].

Charles Féré (1852-1907) is another person who had contributed to broadening of knowledge about EDA. He proved that skin resistance to generated electric current is variable and depends on the emotional state of the person studied and on the stimuli presented to this person. He was interested in involuntary movements during hypnosis or hysteria. Féré is believed to be the discoverer of the galvanic skin response, i.e. transient change of skin resistance caused by external stimulus (e.g. noise) or internal stimulus (thoughts, emotions) [15, 16].

In turn, Ivan Tarchanoff (Russian: Iwan Romanowicz Tarchanow or Georgian: Ivane Tarkhnishvili) (1846-1908) investigated physiological mechanisms responsible for regulating skin conductance. He concluded that skin conductance is dependent upon activity of innervated sweat glands. Tarchanoff was the first to use the endosomatic method to measure EDA as opposed to Vigouroux and Féré, who applied the exosomatic method [17].

In 1906 Otto Veraguth (1870-1944) coined the term “galvanic psychophysical reflex” (2 years later he changed it into “psycho-galvanic reflex”). He defined it as a vegetative response of affective nature that is expressed as changing electrical resistance of the skin [18]. Vigouroux, however, was the first one to study this phenomenon. The term introduced by Veraguth had been used in source literature for a very long time. Currently the term “galvanic skin response” is being used.

The concept of orienting response (OR) stems from observations on classical conditioning made by Ivan Petrovich Pavlov (1849-1936). He noted that a sudden competitive stimulus may lead to no response to the conditional stimulus with concomitant focus of the entire body on this stimulus. Pavlov claimed that the role of the orienting response was to draw attention to all what is new and essential for survival [19].

These observations were continued by Eugene Nikolayevich Sokolov (1920-2008), who described specific elements of this response. He distinguished adaptive response (AR), the goal of which is to make the organism adapted to a stimulus and which is dependent on its strength (sensitivity of the sensory system will increase if stimulus strength is low and *vice versa*) and defensive response (DR), the aim of which is to inhibit a given stimulus if the sensory system is overloaded [9]. DR does not undergo habituation. Furthermore, Sokolov proposed a neuronal model of orienting response, ac-

ording to which OR results from lack of agreement between a stimulus and its neuronal model that was established as a consequence of prior exposure to this stimulus [20].

The study of neuronal OR correlates revealed a particular class of neurons, the so-called “novelty-sensitive neurons”, that responded to the first presentation of stimuli. They were discovered in the 1960s by Herbert H. Jasper (1906-1999). It turned out that they are located in different brain structures. They were studied by Olga Sergejewna Winogradowa (1929-2001). In 1969 Winogradowa established laboratory researching of systemic organisation of neurons. She mainly focused on the role of limbic neurons (located mainly in hippocampus) in processing new significant information. She concluded that the hippocampus plays a decisive role in OR mechanisms for sensory stimuli and acts as a comparator determining whether incoming information will be stored in memory (if they are new) or ignored (if they were already recorded) [21-25].

4. Relationship between electrodermal activity, orienting response and suicide risk

In the ‘70s Richard F. Thompson and Philip M. Groves developed a dual-process theory of habituation which distinguishes between two systems. The first one is responsible for generating a relationship between a stimulus and response to it in the central nervous system, resulting in reduced response, i.e. habituation. The second one is responsible for the overall reactivity of an organism, leading to increased response, i.e. sensitization. Both systems can act separately, but response to a stimulus is an interaction between both of them – strength of response is a result of interaction between habituation and sensitization [26, 27].

In 1986 Gunnar Edman was the first one to observe that there is an association between low electrodermal activity and suicidal tendencies [28]. In the following years, his observation was confirmed in other studies and meta-analyses [29-32]. The study of Thorell conducted in 2013 enrolled 783 hospitalised patients diagnosed with depressive episode [30]. This was a follow-up study (the subjects were contacted from one year to five years later). Out of the 36 recorded suicides, 6 suicides were committed by patients with a reactive electrodermal system, while 30 of them were committed by persons with a hyporeactive electrodermal system. The study of Iacono et al. [32] revealed that patients with a depressive episode and bipolar affective disorder in remission have significantly lower EDA results than the control group (without affective disorders). Also based on other studies it can be concluded that patients with depression exhibit lower EDA than persons without depression [33-36].

According to Thorell’s concept, tests of electrodermal activity can detect neuropsychological dysfunction that was previously unknown and is independent of the depressive state. It is caused by biological factors (e.g. stress with high levels of corticosteroids, genetic predisposition) and specific psychological factors (e.g. learned helplessness, trauma in childhood) [29, 30]. Neurons associated with it are located

in the CA3 region of the hippocampus. This dysfunction is reflected by a reduced concentration of BDNF. It results in decreased ability to detect new things. Persons with lowered activity of the electrodermal system habituate stimuli very rapidly. The first response to a stimulus in such persons is the same as in persons with normal electrodermal activity, but afterwards OR disappears very quickly (even after third exposure to a stimulus and at a maximum after tenth one); in persons with a reactive electrodermal system this happens even after the thirtieth one (after eleventh one on average). In practice, this means that persons with lowered activity of the electrodermal system very rapidly stop responding to repeated external stimuli (decreased natural orienting response), which is why they lose curiosity about and interest in neutral everyday events and have troubles remembering them. They think in an inflexible and dichotomous manner, and have an overly generalized autobiographical memory. This in turn may increase likelihood of a tendency to perceive life as colourless and invaluable, experience anhedonia and, as a consequence, to greater risk of suicidal ideation and willingness to commit suicide. Thorell also points out that hyporeactivity of the electrodermal system may result in less fear of pain, which may also make a given person eagerer to attempt suicide. Increased hyporeactivity was also noted among persons who inflict self-harm, being one of the predisposing factors for committing suicide. It is also reflected by selection of suicide method. Most frequently this method is violent; it involves hanging, jumping from height, gunshot suicide, jumping under a train or car, or using a sharp/blunt tool [37, 38].

Sarchapione et al. systematically reviewed 77 studies on EDA in terms of its usefulness as a biomarker for depression and suicidal behaviour. As a result of the analyses, the authors concluded that EDA is a reliable sign of depression and an important marker of suicide risk. In addition, the authors are of the opinion that there is preliminary evidence that monitoring of EDA may help differentiate the phases of affective disorders. Patients with slowness of movement, psychotic depression and endogenous depression have lower EDA levels than patients with anxiety, or depression of exogenous origin [29]. Numerous studies reveal that EDA is effective in identifying patients who will commit suicide in the future, but it is not entirely certain if it is possible to distinguish between patients with suicidal thoughts and tendency to realize them from patients without these tendencies based on EDA measurements [30, 39]. Studies performed so far show i.a. that EDA is independent of the severity of depressive episode, duration of depression, medication, sex and age [30]. EDA is also stable during subsequent depressive episodes [29, 30].

The most recent Thorell's study revealed that suicide risk in persons with lowered electrodermal activity is as much as 25 times higher than in persons with normal electrodermal activity. Ten out of 136 patients with affective disorders committed suicide; all of them were hyporeactive in tests of orienting response. Thus, hyporeactivity may be considered as a biomarker of high suicide risk [40].

5. EDOR Test – a new tool to estimate suicide risk

The EDOR Test measures orienting response. It had been developed and modified for many years by Thorell in the course of his studies carried out at the University of Linköping. In 2014, on its basis, Emotra [company] created a standardised EDOR System which is a diagnostic method for examining patients with depression and measuring their electrical reactivity. In order to ultimately assess efficacy of this tool to identify persons at particular risk of suicidal behaviour, Emotra commenced European multicentre clinical studies on the relationship of EDA with suicidal tendencies in patients suffering from affective disorders. Two Polish centres also participate in the study. So far 1573 persons have been examined.

The EDOR System consists of software installed on a computer with Bluetooth (EDOR Test), devices used to measure orienting response (EDOR Box) with sound-proof headphones and cloud (Emotra Cloud). The EDOR Test examines habituation rate related to repeated and neutral auditory stimuli. EDOR is an acronym that was coined by combining expressions “ElectroDermal” (ED) and “Orienting Response” (OR). It is used to identify an extremely hyperactive and an extremely hyporeactive EDA system. EDA responses measured in the test are involuntary and cannot be intentionally triggered, so it is impossible to falsify the test result, which is an additional advantage of this method. The figure below shows the EDOR Box.

There are two electrodes on the device that measure skin conductance. Additionally, sensors used to measure blood volume and pulse have been placed on the smaller electrode. The measurement procedure starts with running the EDOR Test program



Figure 1. EDOR Box

installed on a PC, and an interview about possible interfering variables, which include: last alcohol consumption and its amount, medications, smoking, use of stimulants, hearing problems, level of perceived stress, drowsiness level, etc. Afterwards the examined person is given soundproof headphones. The second and third finger of preferably non-dominant hand are placed on the device, and the EDOR Box that is connected with PC via Bluetooth is turned on. The measuring room does not have to be soundproof and electronically isolated – it is important to turn mobile off, take care that no one enters the room during the test and that the wall in front of the examined person is empty so that nothing would attract his or her attention. As previously mentioned, sweating level of examined person does not affect test results. The PC has to be connected to the internet, otherwise the EDOR Test will not start. Instructions given by the clinician must be as general as possible, while the person examined should not move, make contact with the clinician, or close eyes for a longer time during the test. Auditory stimuli are presented 5 minutes after the test commences. At that time, sinusoidal tones with frequency of 1 kHz and intensity of 85 or 90 dB above general audible threshold are played for 1 second at intervals from 15 to 80 seconds. The entire test lasts for approx. 25 minutes, 10 minutes of which are spent on interviewing the patient and 15 minutes of which are taken by the test itself. After the test, data are transferred to the computer, sent to the Emotra cloud, analysed by experts in psychophysiology, and sent back. EDA test results are divided into 4 categories:

- hyporeactive (OR does not take place or habituation is very rapid at a maximum after third exposure to auditory stimulus);
- at the limit of hyporeactivity;
- reactive;
- hyperreactive (habituation of auditory stimuli does not take place).

Results should be provided as fast as possible to a person with a hyporeactive electrodermal system. In connection to powerful arguments supporting the relationship between EDA and suicidal tendencies, such person should be given particular care, starting from a detailed discussion about the results and finishing with in-depth psychoeducation.

6. Conclusions

Electrodermal activity appears to be a reliable marker of suicidal behaviour among patients suffering from affective disorders. The testing method described above is fast and simple to perform, and the obtained results are objective, which undoubtedly is an advantage. Nevertheless, further studies are required to validate EDA as an objective method for identifying persons at particular risk of committing suicide.

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