ORIGINAL ARTICLE

Anterior Uveitis Caused by Electrical Discharge in Whole Body Injuries (Fifteen-Year Study)

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SUMMARY

Aim: To inform about clinical analysis of early ophthalmologic complication (uveitis) in patients sustained electric discharge injury.
Study group: The authors refer about fifteen years follow-up of pediatric patients at the Department of Burns Medicine, 3rd Medical Faculty, Charles University in Prague, Czech Republic, E.U., with electric discharge injury, in which the anterior uveitis was detected. Out of 43 patients after electric discharge injury, the always-unilateral iritis (iridocyclitis) was diagnosed in four (9 %) patients according to thoroughgoing follow-up after first accidental diagnosis in the year 1998. Out of four boys aged 12 – 15 years, the first two were injured during the "play" - due to the contact with electrical trolley wire while running on railroad wagons' roofs, and the two others were stuck by lighting under a tree by secondary electrical discharge. More serious skin burns were noticed in high-voltage current injury – 69 % or 55 % of body surface respectively, with the necessity of skin transplantation. The same was necessary in one boy injured by lighting with burns of 25 % of body surface, while the last one had on the skin the lighting signs only. In most of the patients, the resuscitation care due to unconsciousness and posttraumatic shock was necessary. The anterior uveitis was diagnosed subsequently, after initial preliminary diagnoses as conjunctivitis, episcleritis, or ophthalmia electrica. The iritis without visual function decrease was discovered in few days after the injury in three patients.
Treatment and results: The inflammation was in these cases treated with short-term application of mydriatic and corticosteroid eye drops. Once only, the uveitis appeared after two months during the patient's hospitalization and then the signs of iridocyclitis in the anterior chamber worsened and caused visual acuity decrease to hand movement in front of the eye. The condition was successfully treated by means of parabulbar betamethasone injection and long-term application of mydriatic and corticosteroid drops. Conclusion: Uveitis in electrical discharge injury of different origin is a rare early complication, which may be determined solely by regular ophthalmologic follow-up examinations of the patients.

Key words: high–voltage electrical current injury, lighting injury, anterior uveitis.

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INTRODUCTION AND EPIDEMIOLOGICAL DATA

Humanity has been confronted with the existence of electrical discharge and its consequences since the beginnings of its existence in the form of lightning strikes which killed, but were also the first source of fire. Thunder and lightning have been surrounded by myths since time immemorial. It was the god Zeus, the most important and majestic of all the Greek gods [26], for whom the Cyclopes wrought thunder and lightning for the battle with the Titans, and these became symbols of his power. The first lightning rod was constructed in 1750 by the American scientist and diplomat Benjamin Franklin, and its principle of a receiving device, with conductors which enable the earthing of electrical energy through their embedding in the ground, is applied to this day.
At present lightning strikes one hundred times every second, which means 8 million lightning strikes per day. The voltage between the clouds and the earth or another object which lightning strikes is approximately 2 million V/m, with direct current of 30 000 – 50 0000 A. The time of its effect is extremely short – 10-100 ms. The temperature reaches 30 000 K (Kelvin) [19]. The result is approximately 50 000 fires of agricultural facilities or injuries to humans [19]. Direct strike by lightning is practically always fatal. More frequent are secondary contacts, nevertheless every tenth injury from lightning strike results in death [18]. The number of deaths in individual developed countries differs markedly. The highest numbers have been recorded in the USA, at an average of 106 deaths per year over the course of the 1960s to the 1980s [19].
The industrial revolution in the 19th century brought about the development and application of electrical sources, which became a force of progress, but also began to injure and kill. The first death, caused by a discharge of a 250-volt alternating current generator was described in France in 1879 [10]. Human ingenuity could not be stopped, however, and as early as in 1890 the electric chair was first used in the USA for applying the death penalty [12]. In general it applies that alternating current is three times more dangerous than direct current. Injuries from electrical discharge constitute approximately 3-4 % of burn injuries admitted to burns centres. Men are several times more likely to be afflicted by this type of injury than women, even in childhood age. Mortality from electrical

current is stated only between 2-3 %, which is conditional upon the higher frequency of low-voltage injuries than high-voltage ones [13].

Ocular complications as a result of electrical injuries are highly variable: chemosis of the conjunctivae, perforation of the cornea, iritis, cataract, damage to RPE, macular oedema to macular hole, vitreous haemorrhage, retinal detachment and optic neuritis [16]. In the professional ophthalmological literature, primarily studies concerning complicated cataracts have been appearing for several years. Historically a cataract following lightning strike was described by St. Yves as far back as in the 18th century, whilst the first description of damage to the lens by high-voltage current is by Brix, from 1900 [6]. In the professional literature of former Czechoslovakia in the 1950s, the terms “Cataracta electrica” [17] and “Lightning cataract” [7] appear. Affliction of the lens is connected to the fact that this concerns a stochastic organ, for damage of it a current of over 1000 V suffices, above all in contact with the head, which causes a change of macromolecules and vacuolisation [13]. According to PUBMED, iritis or iridicyclitis is described rarely as anterior uveitis in rare cases as individual reports in the world literature, including also previously classified reports by Czech authors [11, 23]. The aim of our report was to compare the findings of a number of paediatric patients on the basis of long-term observation, to evaluate the development of the disorders and in a discussion to present theoretical bases for the incidence of uveitis on the basis of an analysis of the whole body injury from electrical discharge.

Our population

In the period from 1998 to 2012 (total of 15 years) a total of 46 children up to the age of 15 years were hospitalised with injuries from electrical discharge at the burns unit of the University Hospital Královské Vinohrady in Prague. Of these three died from their injuries, and as a result were not included in the population. Of the remaining 43 patients, anterior uveitis manifested in 4 (9%). The patients were four boys of secondary school age. In two of them (aged 12 and 15 years) the cause was the dangerous game “running on the roofs of carriages” beneath electric rail traction conductors with high-voltage current. They were subsequently struck by a direct current of 1.5 or 3.0 kV, which was transformed into an alternating current of 25 kV / 50 Hz. The other two patients (aged 12 and 14 years) were struck by secondary contact with lightning which struck a tree, under which they were sheltering from the storm. The patterns of the findings of electrical discharge entry points were characteristic in the individual injuries (Fig. 1, Fig. 2). The exit point of the lightning discharge was always the metatarsus. Overall the more serious burns were caused to the two patients injured by electrical current from the electric rail traction, in which the more serious affliction of the overall condition and the subsequent course of therapy also corresponded to the scope of the injury to the skin (Fig. 3). The injury to the patients from indirect contact

Fig. 1. Strike of electrical discharge on head of patient no. 2

Fig. 2a. Lightning strike entry point on a shoulder, with burning of torso

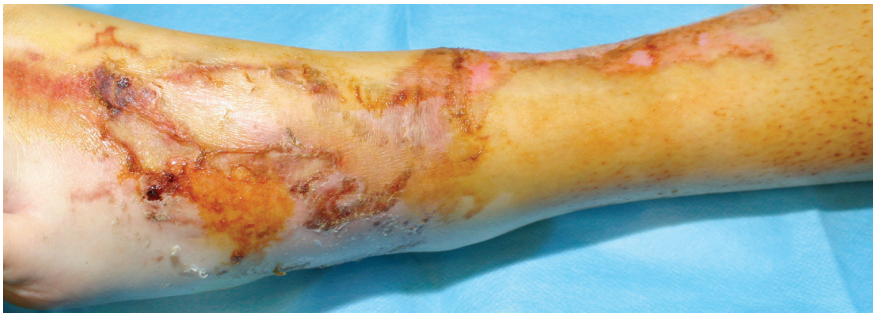

Fig. 2b. Exit point of discharge on metatarsus of patient no. 3

with lightning was less serious. The cardiological and neurological finding in all four patients was without pathological fluctuations during the course of hospitalisation following initial resuscitation in all four patients.
The ocular symptomatology is subsequently analysed in the individual case reports classified according to the seriousness of the overall injury by electrical discharge.

Patient no. 1: The initial finding of irritation of the anterior segment of only the right eye on the fifth day after admittance upon an examination performed with the patient on a bed was considered to be conjunctivitis, and it was not until an examination on slit lamp with regard to anisocoria in the following days that anterior iritis was demonstrated – slight ciliary injection was present (Fig. 4), as well as traces on the endothelium and flare in the anterior chamber, the pupil was slightly wider in comparison with the left eye, but without synechiae, loose, reaction to light exposure symmetrical. The lenses were bilaterally clear and there was also a bilateral physiological finding on the fundus, only the macula in the right eye was without foveolar reflex, visus of the right eye and visus of the left eye 0.5 nat. After application of local therapy: Homatropine 4% 1x and Dexamethasone gtt. 5x daily, alleviation occurred after one week and the therapy could be discontinued. At the check-up following discharge four months after the injury the bulbs were placid, normotonic, without symptoms of inflammation, posterior "Y" joints were evident in the lenses, in the right eye slight dissociation of the posterior subcapsular layer. Fundus physiological, maculae with reflexes, but with regard to the previous finding a contrast sensitivity examination was performed (CSV 1000) with a result of symmetrical normal scope in all four cycles to the grade: visus of the right eye = visus of the right eye 0.66 with -0.5/90 binocularly later 1.0. We do not know the further development, the patient did not attend subsequent check-ups.
Patient no. 2: It was not until two months after the injury from electrical discharge that clinically evident post-traumatic ocular disorder was manifested, only in the right eye, which initially when examined with the patient on a bed care had also been considered to be conjunctivitis, treated with Garason gtt. at two hour intervals. There followed progression of the finding, after two days iridocyclitis with hypopyon was

Fig. 3a Healing of torso by auto-transplants

diagnosed, mydriatics were applied in therapy. Despite the application of Atropine 0.5% three times per day and Dexamethasone gtt. with frequency of application at one hour intervals, the condition progressed. Vision in the right eye deteriorated to slight projection, the anterior chamber was filled with fibrin conglomerate, due to which it was no longer possible to differentiate. With regard to the overall condition of the paediatric patient, severe pain and photophobia, it was not possible to perform photo documentation. Subsequent parabulbar application of 1 ml Diprophos

Fig. 3b. Healing of torso by auto-transplants on patient no. 3

conditioned the progressive attenuation of the inflammation whilst maintaining local therapy. The ocular finding upon discharge of the patient after two weeks demonstrated pacification of the inflammation process. The bulb was placid in the right eye, normotonic, isolated element on the corneal endothelium, anterior chamber and iris placid, pupil in artificial attenuating mydriasis, loose, lens (Fig 5) with dissociation of posterior "Y" joint and vacuoles (this finding is lacking in the left eye), vitreous body slightly opaque, physiological finding on fundus, retina lying, only foveolar area without reflex (in left eye with reflex). Visus of the right eye 0.5 stenop. with +1.5 = +0.5/75, visus of the left eye 0.66 with -0.5 = -0.5/45. It was recommended to continue in the right eye with therapy using Dexamethasone gtt. 2x daily with monitoring at home. The patient did not attend a check-up when called upon.
Patient no. 3: On the day of admission only singeing of the eyelashes was stated, bulbs placid. After ten days upon examination with the patient on a bed using a portable manual slit lamp the bulbs were placid, but in the right eye there was fibrin on the anterior surface of the lens and there were precipitates below on the corneal endothelium in the area above the chamber angle (Fig. 6). In the left eye the bulb was without inflammatory changes, lens clear. The finding on the fundus was bilaterally physiological. Condition in the right eye was treated: for the first three days the patient was administered Homatropine 4% 1x per day and Flarex gtt. 5x daily for ten days. Upon discharge the bulbs were placid and the lenses were clear, visus of the right eye = visus of the left eye 1.0 nat. A check-up in December 2012, six months after the injury, did not demonstrate and inflammatory or subsequent changes on the bulbs as a whole.
Patient no. 4: Within the framework of the consultation examination upon admission, reddening of the right eye was evaluated as ophthalmia electrica and on the following day the condition was re-evaluated (again only upon examination on bed without a slit lamp) as episcleritis, it was recommended to apply Maxitrol ung. 5x daily. It was only upon a detailed examination on a slit lamp several days later that the condition was evaluated as iritis (Fig. 7) – present in the finding were pericorneal injection, traces of cells on the corneal endothelium, flare in the anterior chamber and fibrin network in the pupil. The lens was clear and the finding on the fundus physiological. A complex physiological finding was

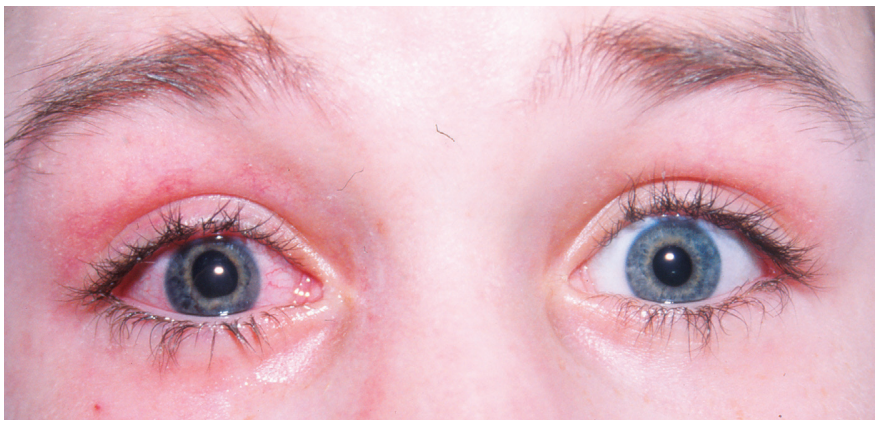

Fig. 4. Irritation of right eye with indication of aniseikonia in patient no. 1

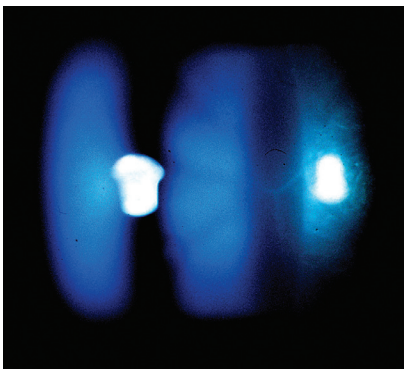

Fig. 5. Dissociation of affliction of lens (posterior "Y" joint and vacuole) in right eye in patient no 2

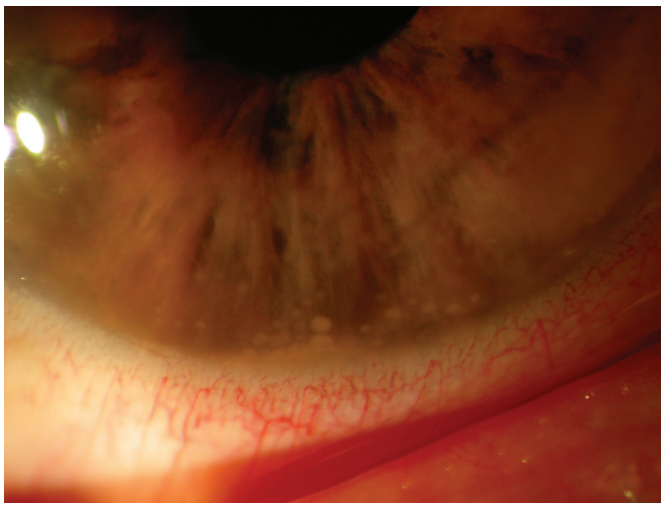

Fig. 6. Precipitates on corneal endothelium in right eye in patient no. 3

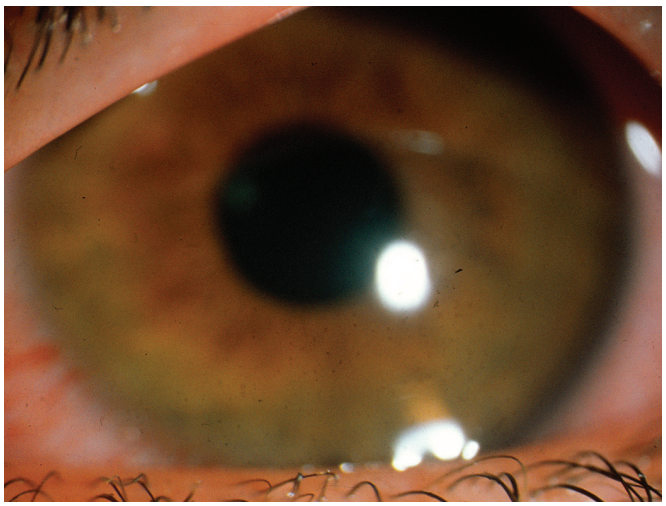

Fig. 7. Iritis in right eye in patient no. 4

stated in the left eye. Visus of the right eye = visus of the left eye 1.0 nat. Subsequent local therapy only in right eye: Homatropine 4% 1x daily and Flucon gtt. 5x daily for a period of one week eliminated the inflammation process. The patient was monitored at irregular intervals at home, at the proposed check-up in December 2012 complicated electrical cataract was determined in the right eye only (Fig. 8): above all honeycomb in posterior cortex, pronounced dissociation of core and radial turbidities or vacuoles in anterior cortex. The patient stated in the history that he had become aware of deterioration of vision only two years ago. Both bulbs were placid and normotonic, without symptoms of inflammation, fundus bilaterally was entirely physiological. Visus of the right eye 0.1 naturally and 0.33 with -2.0/20, whilst visus of the left eye 1.0 with -0.75, which impaired spatial vision. The patient was offered a surgical solution for complicated cataract using an implanted toric lens, since the corneal map showed only unilateral, evidently post-traumatically caused corneal astigmatism.

DISCUSSION

Small children have a predisposition towards injuries from low-voltage current, in which, with regard to their mobility, the source is electrical cables on the floors of their homes. In puberty the number of injuries from high-voltage current increases, with serious injuries or death [3]. In our region injuries at home have appear and will continue to appear, without larger permanent consequences, but high-voltage injuries occurring

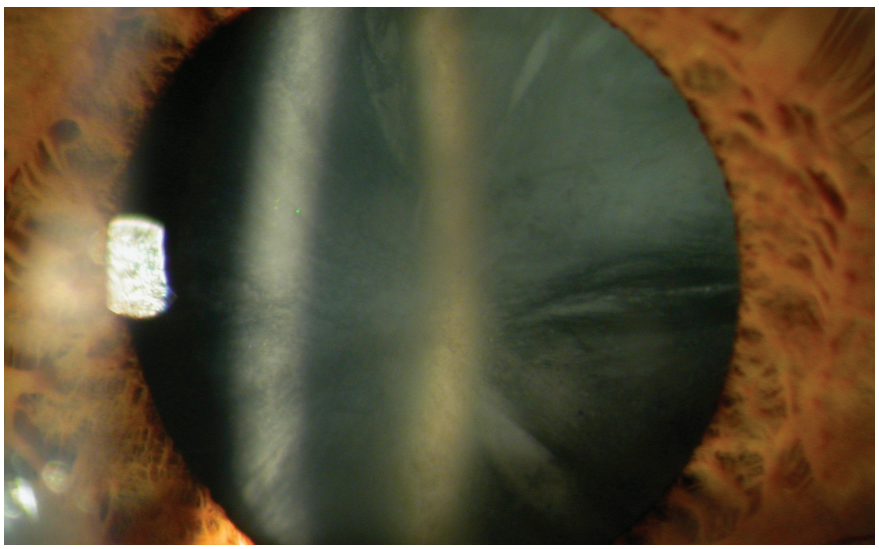

Fig. 8. Complicated cataract in right eye ten years after lightning strike in patient no. 4

Table 1. Relationship of etiological factor to scope of burn and overall injury

	patient no. 1	patient no. 2	patient no. 3	patient no. 4
Age	12 years	15 years	12 years	14 years
Year of injury	2003	1998	2012	2000
Source of electrical injury	Electric rail traction		Lightning	
Entry point of strike of electrical discharge	Neck	Head	Shoulder	Chest
2nd degree burns (%)	59%	10%	20%	Lightning marks
2rd degree burns (%)	10%	45%	5%	
Total burns to the body surface	69%	55%	25%	
Afflicted areas of burn	Torso, left lower limb, face, circularly neck	Head, stomach, chest, both lower limbs	Right shoulder, torso, left lower limb - metatarsus	All on left side = torso, metatarsus, chest
Total affliction, complications	Post-traumatic shock, contusion of lungs, Klebsiella sepsis	Unconsciousness, post-traumatic shock, respiratory arrest	Infiltration of lungs, perforation of eardrum, cephalitis	Unconsciousness, cramps, amnesia, haematoma of eardrum
Plastic surgery therapy	Repeated necrectomy, skin transplant			sine

in unsecured transformer stations on housing estates [24] have been replaced by "games" on the roofs of railway carriages beneath electric rail tractions amongst our patients. The fundamental manifestation of electrical injuries is electrodermal destruction of varying scope, in injuries from high-voltage current this is more extensive than in the case of lightning strike [3]. Injury from lightning is linked to the skin manifestation of lightning mark or Lichtemberg figures (keraunographic marking) [19], which were detected on our patient no. 4. This specific structure is formed by the current spreading in the surface layers of the skin, which causes sporadic discrete extravasates of erythrocytes in the dermis. In the actual pathophysiology of tissue damage electrophoresis is considered, which is regarded as the cause of myonecroses [13]. The most serious complication is cardiopulmonary affliction due to the possibility of arrest of circulation (asystole and fibrillation of chambers) and breathing, which is linked to neurological manifestations [3, 4], which were manifested in all patients on various levels and required resuscitation care, primarily contusion and infiltration of the lungs in two of the patients. Further acute neurological manifestations include coma, expressive dysphasia and amnesia [3, 4], which was observed in one of the patients. A serious condition is acute kidney failure, which is manifested in oligouria, albuminuria and haemoglobinuria [3, 4], thankfully we did not record this in the observed boys thanks to quality intensive care. We also did not observe damage to the musculoskeletal system, which is manifested in tetanic muscle contractions with the possibility of traumatic fractures of the skeleton and actual rupture of the muscles [3, 4]. Voltage above 70 kV is fatal. Due to the character of injury, an important factor is the resistance of the individual tissues. This is high in bones, fat and cartilage. Skin has medium resistance, but dry skin has one hundred times higher resistance than moist skin. The lowest in descending order is in muscle, filling ligaments and finally in blood vessels filled with blood and nerves, which therefore represent the highest risk. Electrical burns are caused by direct contact (electrothermal burns) or secondary contact, which represents arc and flame [3]. An important part of injury by lightning is the impacts of sonic and pressure waves on the human organism, such as rupture of the tympanic membrane [19], which we confirmed in our patients to varying extents.

The most common ocular issue in connection with whole body injury from electrical discharge is damage to the lenses, a subject matter also investigated by other ophthalmologists, which is also confirmed by two of the latest works in the Czech-Slovak periodical by Slovak authors [1, 9]. Ocular affliction of bilateral electrical cataracts without accompanying uveitis preceded serious burns to the limbs, neck and face in two ten year old boys (one entered an unsecured transformer station for a balloon, the second went to take down a toy from high-voltage wiring) and two young electrical installers in injuries from high-voltage current [9]. The development of unilateral cataract with a deterioration of visual acuity six months after lightning strike without previous uveitis was described [1] two years ago. At the same time the Slovak authors referred to the seriousness of injury by lightning. Four hikers were caught in a storm on a mountain, lightning struck within their proximity, two were killed on the spot and two were rendered unconscious [1]. This represented an indirect mechanism of the action of lightning by earth current, in which the energy of the lightning from the struck ground extends through the earth to the injured person, who suffers secondary strike [3, 19]. In the patients we observed this also concerned an indirect mechanism, either lateral lightning representing secondary contact, because this "splashes off" an object close to the injured person, or a contact injury, since lightning first of all strikes an object which the injured person is touching [3, 19]. In the cases of two of the injured boys this was a tree under which they were sheltering from the storm.

The subsequent progression of deterioration of visual acuity to the level of vision of 0.1 in one of the two survivors in the Slovak mountains [1] was conditioned by a cataract with a predominance of posterior subcapsular turbidity, which was in accordance with our finding. However, in our patient the deterioration of vision in the right eye stated in the history did not appear until 10 years after the injury, which is unusual. A study of 113 patients over the course of five years following electrical injury observed the incidence of cataracts. It demonstrated them in 13 eyes, which is 6.2%, over a time frame of 1-27 months following the injury [20]. A transitional change of the finding on the ocular fundus in our two patients was non-specific attenuation of

the foveolar reflex. Retrospectively it is not impossible to exclude the possibility of accompanying incipient macular oedema, which it was not possible to verify precisely due to the overall condition of the patient. Pathological changes on the level of the RPE, on the basis of indistinct hyperfluorescence in the foveolar area upon FAG examination were recorded by the Slovak authors [1], but a further control examination in this single patient using OCT was without a pathological image. The macular areas are highly sensitive to thermal damage, because here there is a high melanin content. Electrical current may damage the RPE by electrolysis. Macular oedema simulates Berlin's oedema soon after injury by lightning, in which during the further course it is possible to describe the lesion as a cyst or macular hole, or solar maculopathy [8, 14].

In the last decade, only individual observations of intraocular inflammations following injury by lightning of a serious character have been recorded [5, 15, 21], but also following injury from electrical current with isolated unilateral form of uveitis [2]. In the case of injuries by lightning this concerned bilateral inflammation of the uveal tissue with further accompanying manifestation, such as simultaneous affliction of the cornea or development of changes of the opacity of the lenses, which could be treated well [5, 15]. In our literature, injuries from electrical discharge are stated in connection with the incidence of uveitis in the content of the basic ophthalmological periodical practically since its beginnings. The first case study is recorded as far back as 1937 following injury by lightning, in which it ensues from the description of pericorneal injection and transitional turbidity in the area of the lens that here also the contribution of intraocular inflammation could not be excluded [25]. Iridocyclitis was stated in direct connection with lightning discharge after 25 days as a late result of the injury [22]. Injury to the eyes from high voltage discharge of 35 kV was initially accompanied with a pattern of electrical ophthalmia, but after ten days variously extensive bilateral iridocyclitis occurred, and after three months also symptoms of electrical cataract followed [12]. Exsudative amotion with iridocyclitis occurred after as long as 2.5 months in one eye following injury by lightning, in which conservative therapy succeeded in restoring the condition in the periphery of the chorioretinal scar, with an improvement of vision from 0.1 to 0.25. Later a cataract developed [23]. In our patients it always concerned a case of unilateral affliction, and with only one exception iritis was transient. Serious unilateral iridocyclitis in one patient did not appear until two months after the injury, but still within the period of hospitalisation. As a result it is a question of whether or not this concerned a late consequence. No predispositions or other circumstances of the overall affliction were found causing a local ocular immunopathological state, and as a result we included the patient in the population also on the basis of previous Czech observations [22, 23]. In the literature we did not find any histological reports dealing with uveitis caused by electrical current, which were conducted on dead patients. Nevertheless, it is possible to present a possible theory of the origin of uveitis as a correlation with known observations relating to a parenchymatous organ well supplied by blood vessels, such as the kidneys. The direct electrothermic effect of high voltage current on the parenchyma and capillary system disturbs the transmission of ions in tubules, and the response is a passage of proteins and cells. The formation of extravasate described in the epidermis may have an effect. A potential factor could also be vacuolisation and reactive miosis described in the nerve tissue, since this presents the least resistance and is the most receptive to electrical current [13].

CONCLUSION

Anterior uveitis is a rare ocular complication within the framework of whole body injuries from electrical discharge, which due to its frequently transient course may escape attention. We were helped in identifying this by regular monitoring of all paediatric injuries from electrical discharge over a period of 15 years at the Burns Unit of the University Hospital Královské Vinohrady in Prague.

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