Thank God, because you have survived!

(this may be a little bit too simple)

Neurological and neuropsychological sequlae in long term lightning survivors

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As manifold the mechanism of a lightning strike are, as heterogeneous are the symptoms. Usually the patients are only seen by surgeons or intensive care doctors initially at the emergency department, they take care about the burn, broken bones, cardiac arrest, tympanic membrane perforation etc. .

If the patient surprisingly for the doc survives he/she will sometimes tell him:

Thank God, because you have survived!

Thank God, because you have survived!

And if the patient unexpectedly later starts to lament about sensory disturbance, neuropsychological deficits, visual hallucinations, visual field defects, fatigue syndrome, post traumatic stress symptoms like anxiety - mostly his family, boss, colleagues, friends will not understand him.

It seems that he or she is unthankful!

Thank God, because you have survived!

And if the patient unexpectedly starts to lament that he is no longer able to do his job as he did before the lightning experience (if he does not have visible injuries which can be followed by his vincinity like burns, broken bones etc.)….

It seems again that he/she is really unthankful and work-shy!

But you can only see, what you know or heard about.

- I will tell about neurological and neuropsychological after effects in longterm survivors of lightning strikes.

study population:

26 persons

Female:	8
Male:	18

(it is dangerous to be a man and outside!)

Location of the accident:

Germany	12
Austria/ South Tyrolia	10
Slowakia	1
Greece	1
Equador	1

Four patients after lightning strike injuries (out of our group of about 26) were examined in the first four weeks and one year after the lighthing strike.

As manifold the mechanism of a lightning strike are, as heterogeneous are the symptoms.

Medical history

- 24y, female/ student
- lightning strike injury at 2800 m altitude at 03.09.04 (SouthTyrolia)
- flash injury at the occiput, unconsciousness, cortical blindness, anterograde amnesia
- intubation and transport by helicopter

Initial diagnostic and therapy

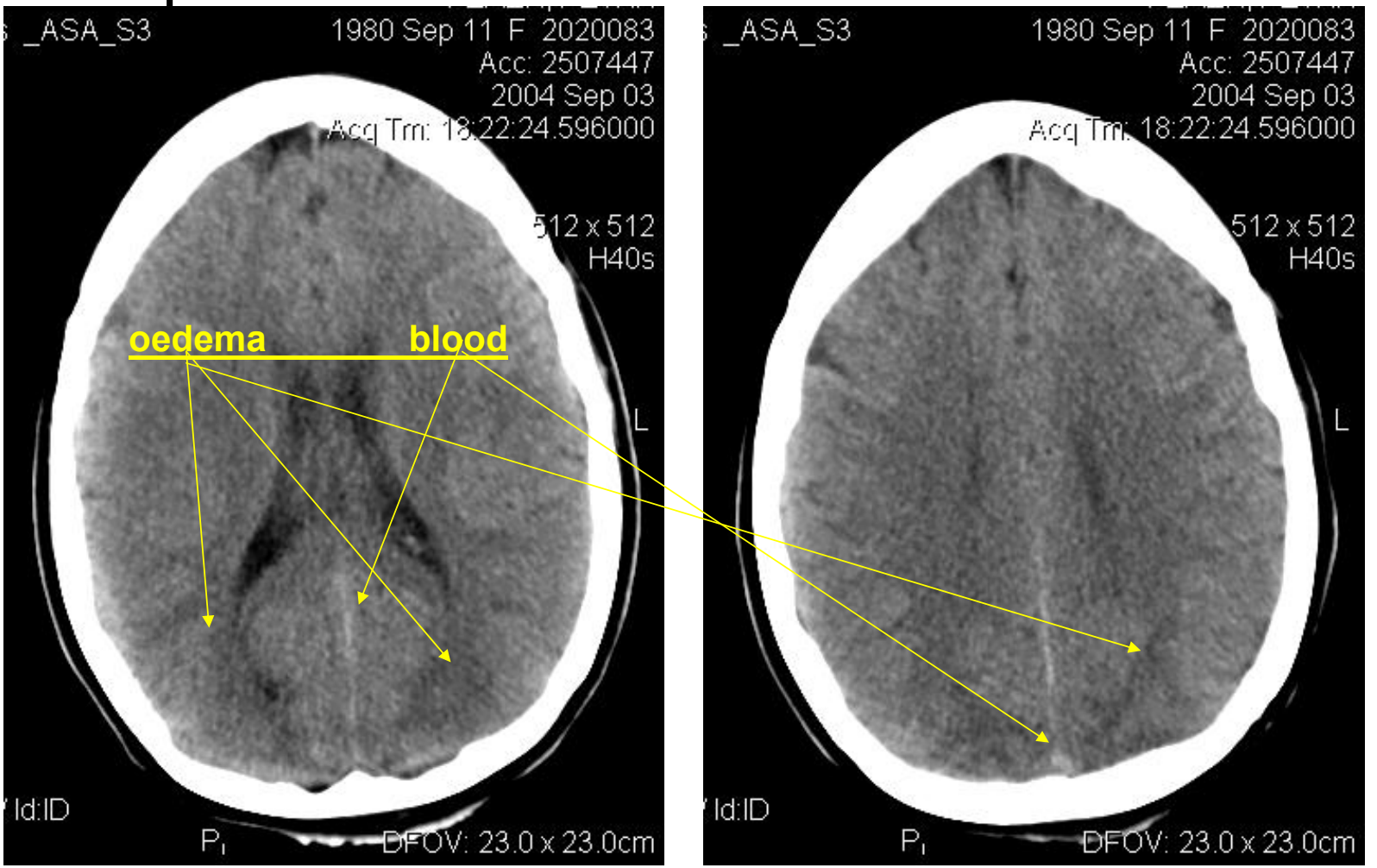
- CCT: bilateral oedema and discrete SAH at occipital lobe
- psychomotoric agitation, disturbance of consciousness
- analgoseditation and ventilation for 3d
- surgical therapy of the burn
- CCT control: oedema declining

general findings

- cutaneous entrance/exit of the flash

combustio of the lung and liver and wet pleurisy

initial CCT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Acc: 2507447
2004 Sep 03
Acq Tm: 18:22:24.596000
512 x 512
H40s
L
Id:ID
P
DFOV: 23.0 x 23.0cm

neurolog. examination. 13.09.04

- bifrontal headache
- biocular paracentral blur, phosphene
- inadaequat euphoric mood,

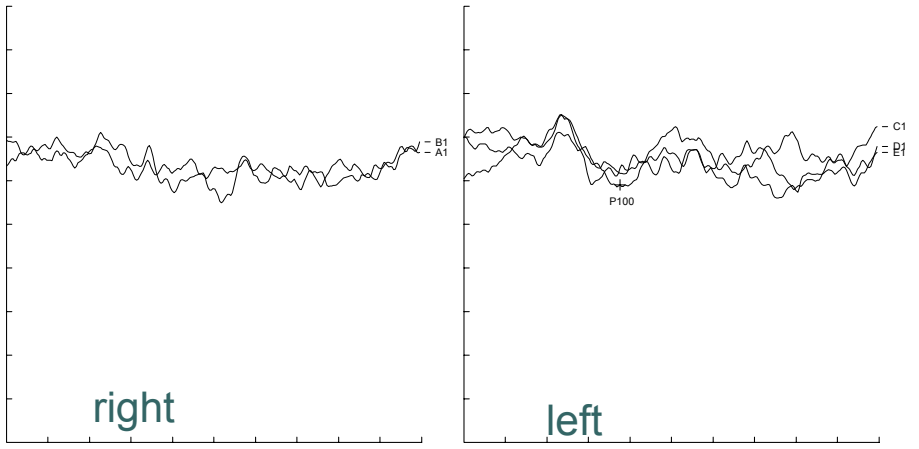
diagnostic procedures

- EEG:
  slight diffuse disturbance of brain function, no focus or typical epileptic potentials, bigeminus
- VEP:
  missing potential right.,reduced amplitude left eye
- cMRT:
  discreet SAH right occipitoparietal und left occipital

VEP visual evoked potenial

13.09.04

V 0.5/1.0



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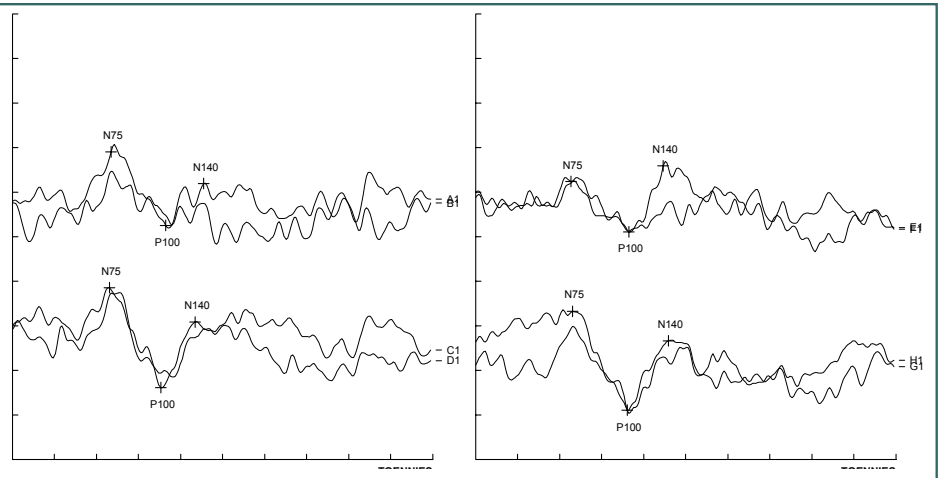
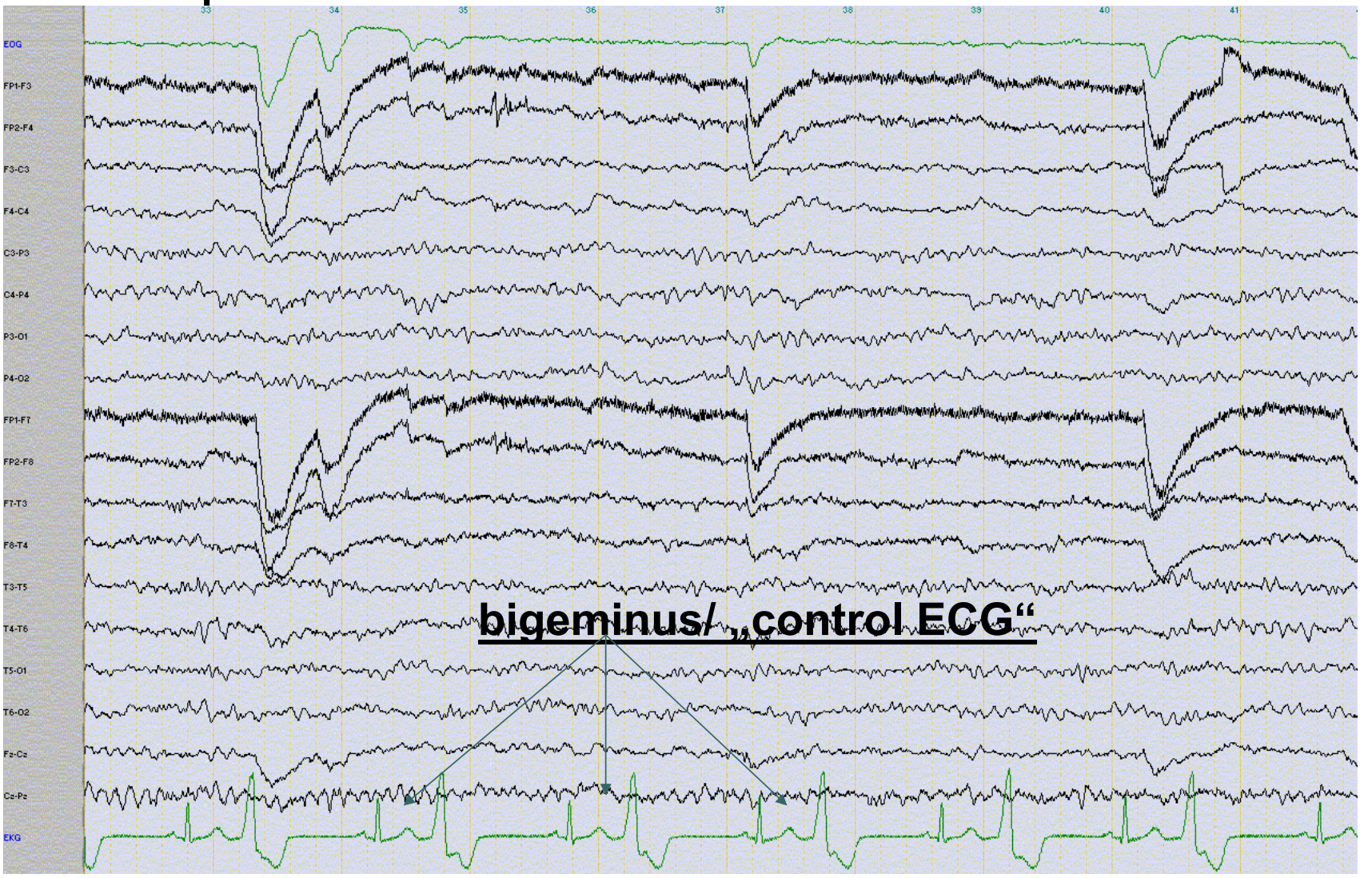


EEG 14.09.04


33
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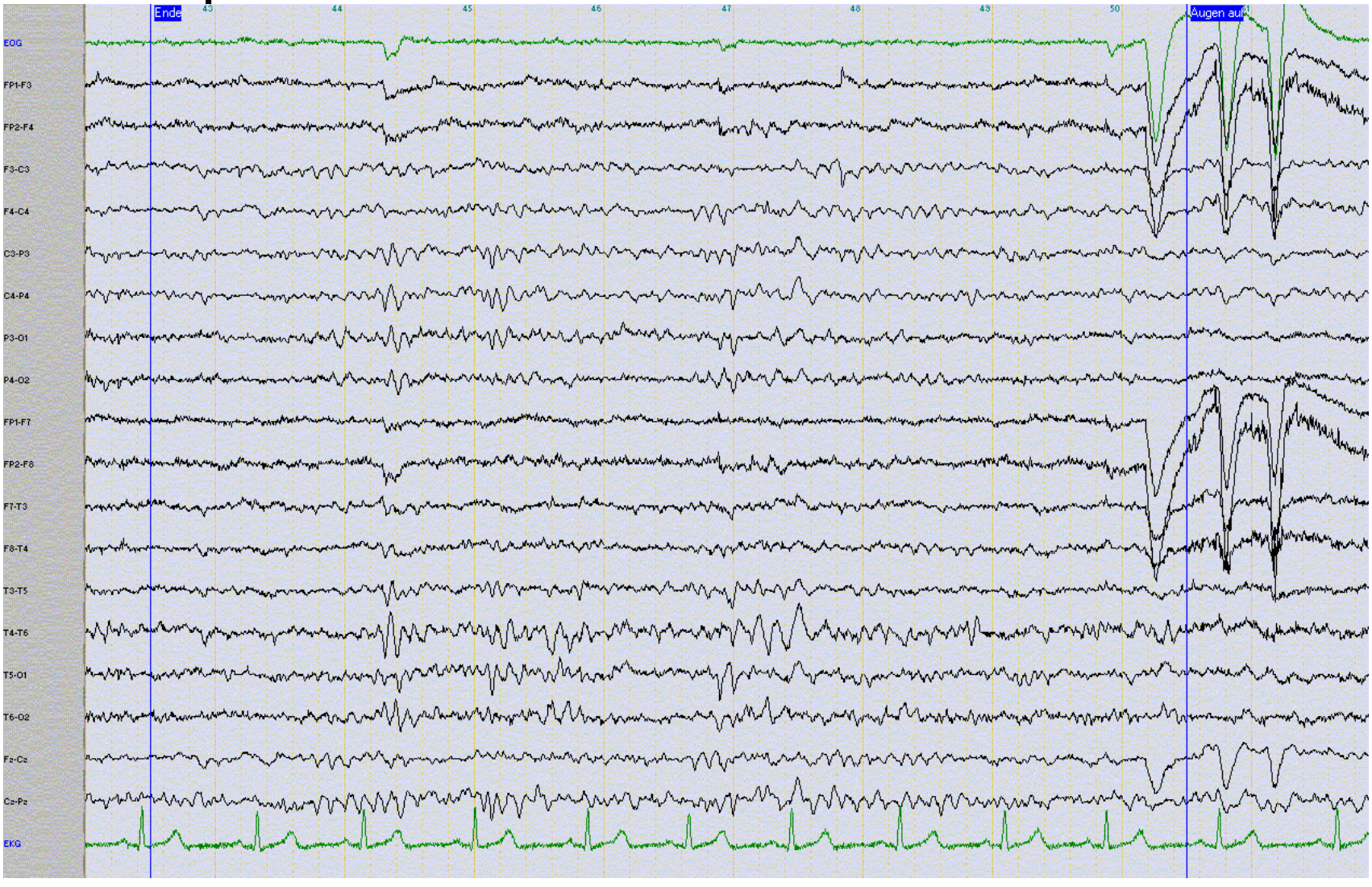
EOG
FP1-F3
FP2-F4
F3-C3
F4-C4
C3-P3
C4-P4
P3-O1
P4-O2
FP1-F7
FP2-F8
F7-T3
F8-T4
T3-T5
T4-T6
T5-O1
T6-O2
Fz-Cz
Cz-Pz
EKG
bigeminus/ „control ECG“

EEG 23.09.04


Ende
43
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Augen auf
EOG
FP1-F3
FP2-F4
F3-C3
F4-C4
C3-P3
C4-P4
P3-O1
P4-O2
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FP2-F8
F7-T3
F8-T4
T3-T5
T4-T6
T5-O1
T6-O2
Fz-Cz
Cz-Pz
EKG

EEG 23.09.04


Ende
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T3-T5
T4-T6
T5-O1
T6-O2
Fz-Cz
Cz-Pz
EKG

further symptoms

- bilat. rupture of tympanic membrane → tympanoplastic

- perimetry: paracentral scotoma downwards
  no cataract or retino-/maculopathy,

<u>neuropsychological testing</u>

action capacity << verbal capacity

<u>reduced</u> verbal competence , disturbance of attentiveness,
disturbed nonverbal working memory and visual detection

∑ **deminished temporal lobe function of the right side**

course of ailment 01/05

- resumption of academic studies, reduced learning capacity
- sleep disturbance, nightmares, „flashbacks“
- halluzinations, delusional ideas after extubation for some days
- depressive mood, reduced impulse, suicidal tendency

Today:

- The patient is now nearly free of longterm sequelae, after intensiv psychological and pharmacological therapy.

Another case:
Medical report

Patient US
initial paralysis of lower limbs
EEG: generalized pathologic activity.
MRI: two edemas right and left frontal,
no hemorrhagia
attention deficit

One year later
Signs for spinal lesions
EEG: temporal asymmetries, pathologic activity right parietal/occipital
MRI: two lesions right, left frontal, and intramedullar lesion
Continuos attention deficit

Medical reports

Patient ID
Allodynia of both feet, no lumbal responses in neurophysiology
Intact attention and memory

One year later
thermhypesthesia and hyperpathia of both feet, no lumbal responses in neurophysiology

Medical reports

Patient IW
Thermhypesthesia of lower limbs, pallhypesthesia, fatigue,
neurophysiology: prechiasmatic damage on the left, hints for axonal or demyelinising damage, autonomic damage in arms and left leg
EEG: vigilance impairment
MRI: two lesions left parietal
Attention and memory deficit

One year later
EEG: no pathology
QST: damage in nonmyelinized fibres
recurring depressive episodes
Attention and memory deficit

Possible neurological symptoms in longterm survivors of lightning strike

- Intracranial hemorrhage (SAH, mass bleeding,SDH/EDH), headache, cortical blindness, retino-/ maculopathy, epileptic seizure, nerve injury, paresis/ plegia, stroke,autonomic failure, polyneuropathy, allodynia, disturbance of thermaesthesia, neuropsychological deficits, suicide, sleep disturbance, nightmares, PTSD, paraplegia etc, etc, etc.....!

Conclusion:

Neurologic sequelae are very common after lightning strike injuries. The lacking of visible injuries often masks severe neurologic disorders, so most of the central and peripheral nerve injuries are profoundly underestimated.

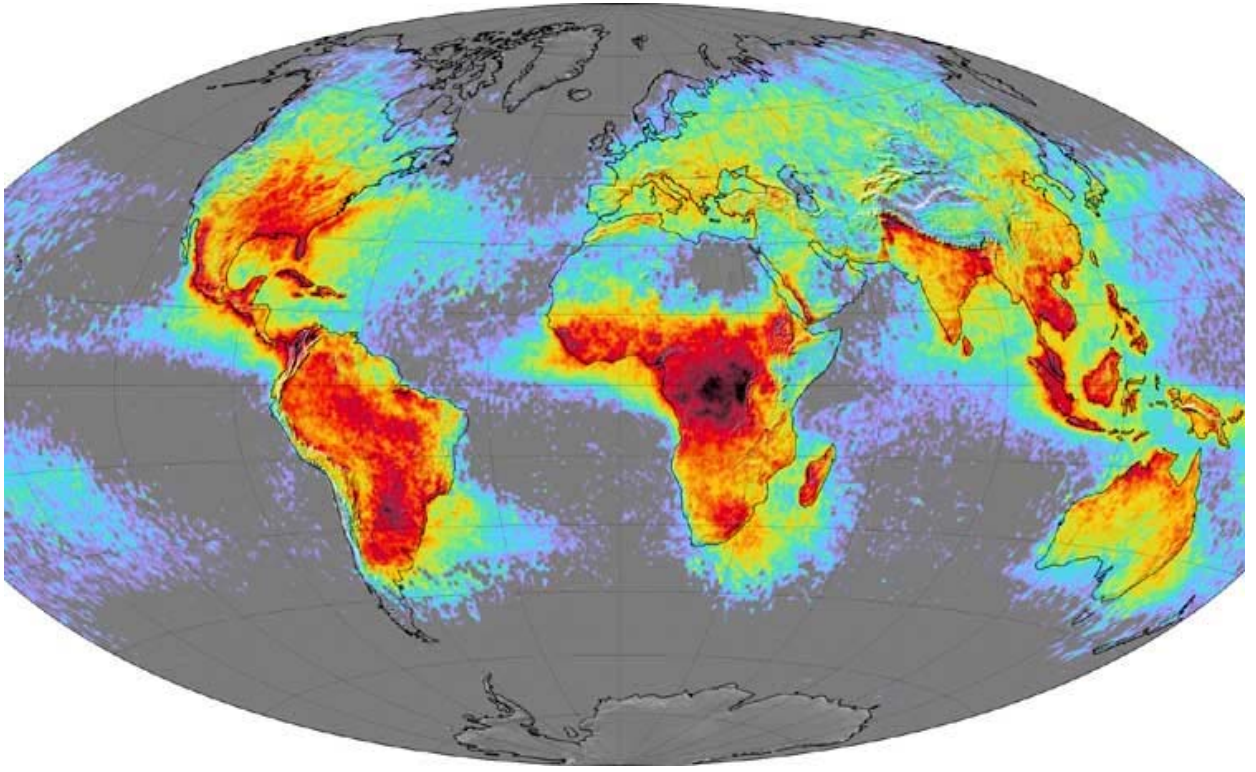
The heterogeneity of the symptoms and of the prognosis prove the need for longitudinal neurologic control . Some patients never show significant improvement, other recover partially or in rare cases (depending of the severity of the initial event) but most of the patients never become free of symptoms.

Bier M, Chen W, Bodnar E, Lee RC. Biophysical injury mechanisms associated with lightning injury. NeuroRehabilitation. 2005;20(1):53-62.

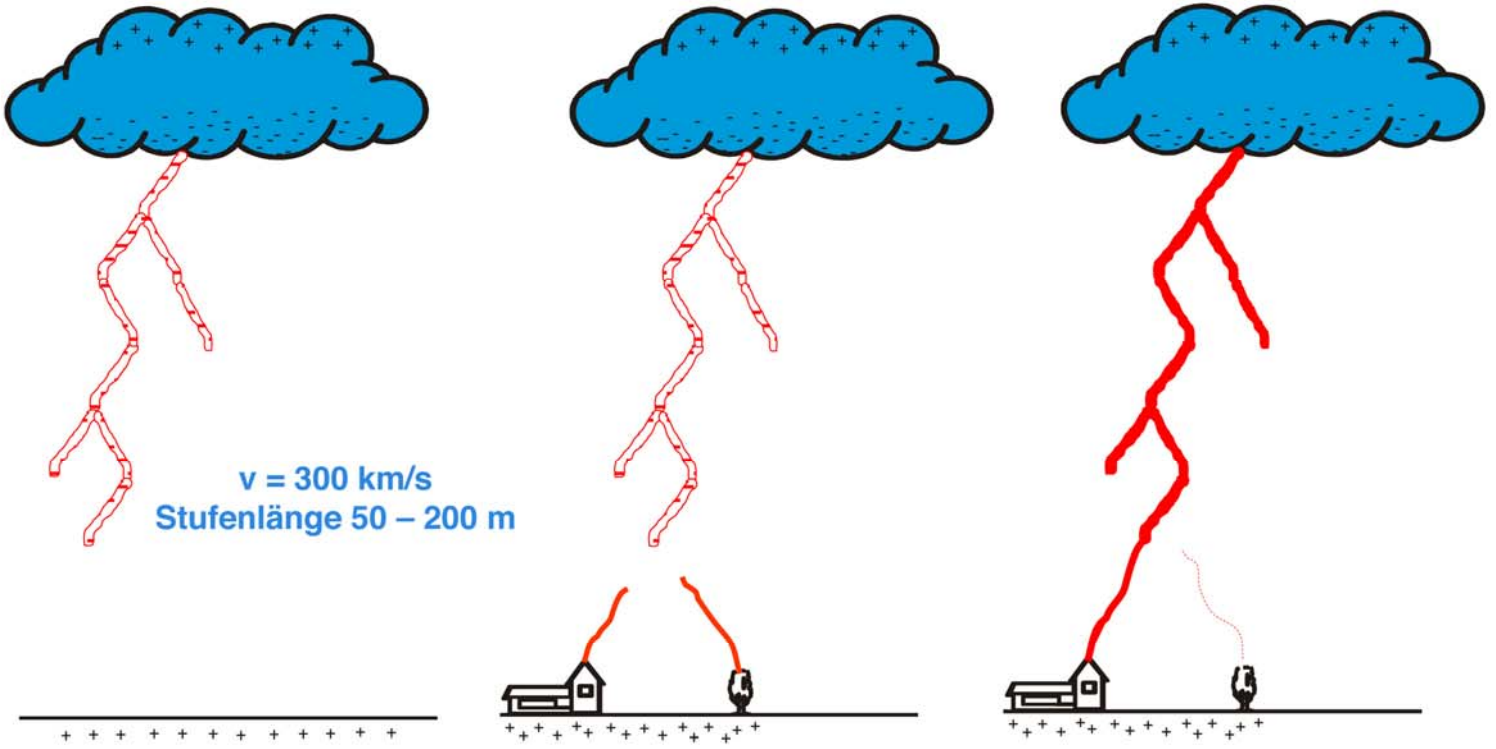
Kleiter I, Luerding R, Diendorfer G, Rek H, Bogdahn U, Schalke B. A lightning strike to the head causing a visual cortex defect with simple and complex visual hallucinations. J Neurol Neurosurg Psychiatry. 2007 Apr;78(4):423-6.

- In der Erdatmosphäre toben täglich mehr als 45.000 Gewitter. Allein in Deutschland gehen pro Jahr rund zwei Millionen Blitze nieder. Starke Blitze sind fünfmal heißer als die Oberfläche der Sonne: Immer wieder kommt es zu Todesfällen - die Regeln für richtiges Verhaltens sollte man daher kennen, bevor es blitzt.

NASA Weltblitzkarte



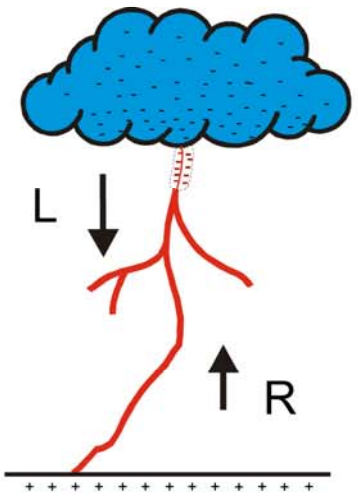
3 PHASEN DER BLITZENTLADUNG



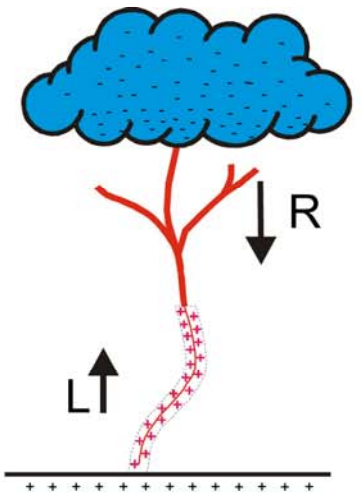
Die vier Blitztypen

Negativer

Abwärtsblitz

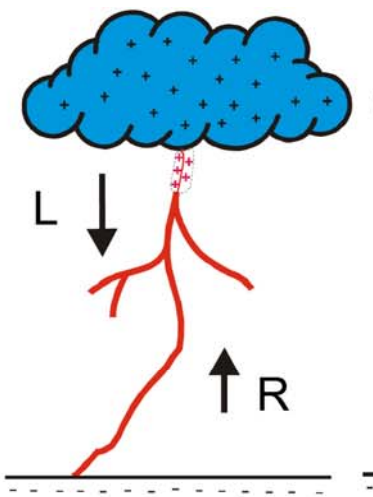


Aufwärtsblitz

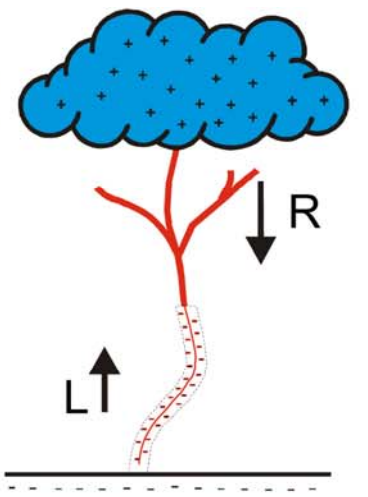


Positiver

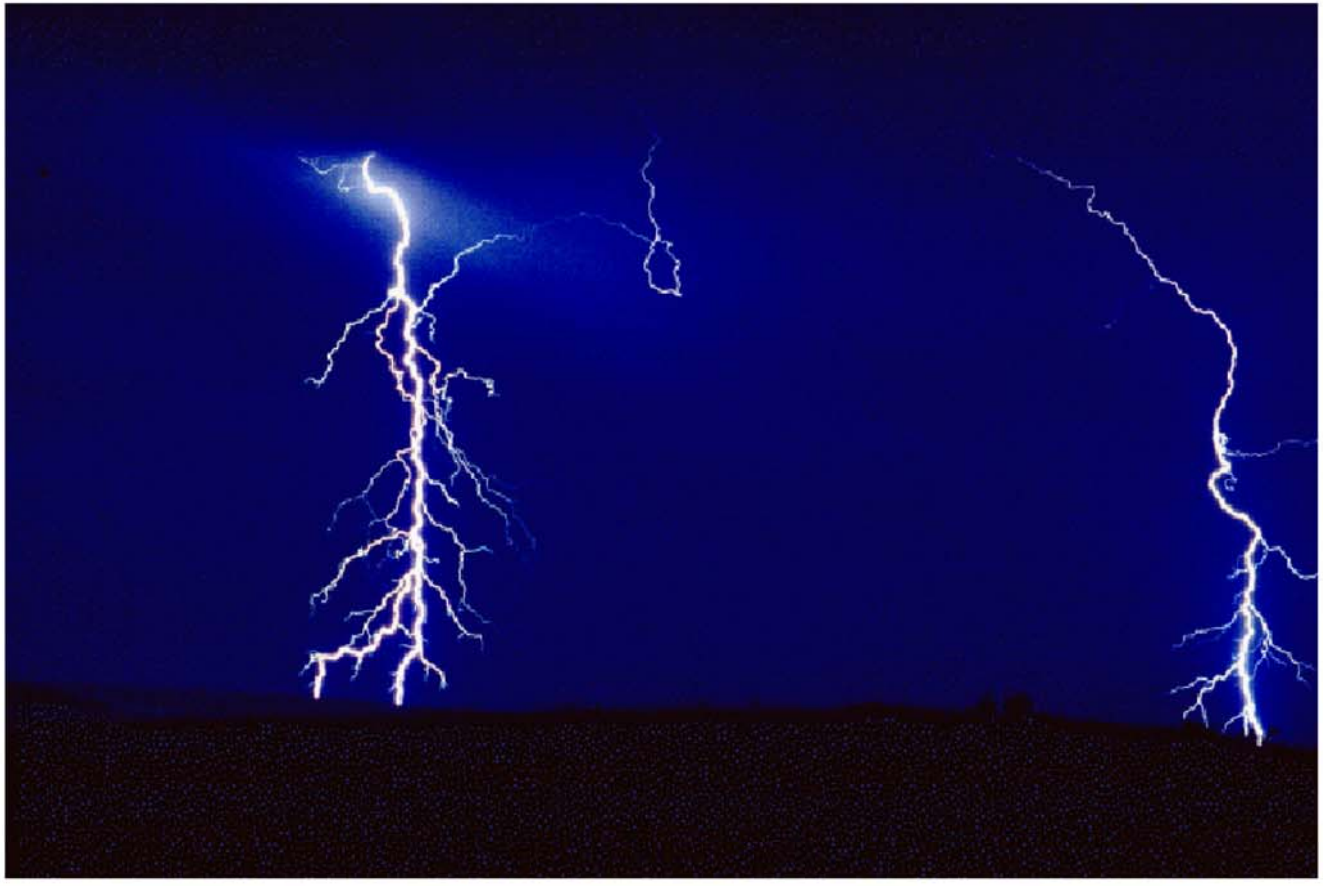
Abwärtsblitz



Aufwärtsblitz



Abwärtsblitz



Aufwärtsblitz

Mechanismen der Energieübertragung I

Abb. 1 ▲ **Direkter Treffer („direct strike") mit Stromfluss durch den Körper**

Abb. 2 ▲ **Kontakteffekt („contact voltage") mit Blitzschlag in ein Objekt, das vom Opfer berührt wird (z. B. Golfschläger)**

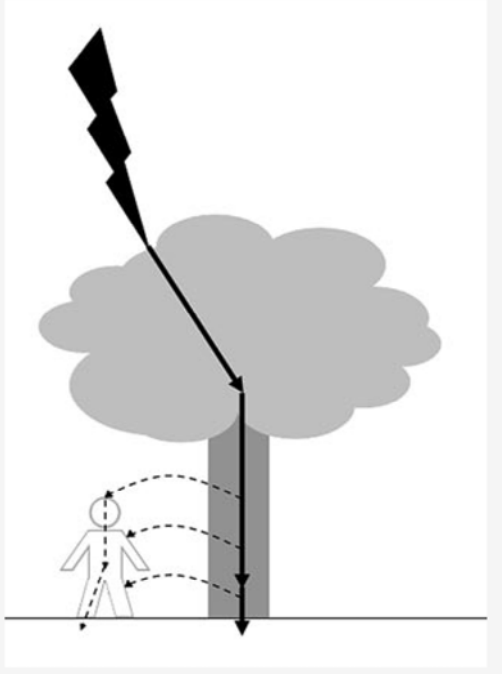


Abb. 3 ▲ **Überschlagseffekt („side splash") mit „Durchschlagen" des Luftwiderstands bei Blitzschlag in ein nahe gelegenes Objekt (z. B. Baum)**

Zack, Rechtsmedizin 2004

Abb 2 a:
Blitzeintritt:
akute Folgen:
traumatische
SAB, vorüber-
gehende Rinden-
blindheit und bds.
Trommelfellver-
letzung.

2b. Brandnarbe
durch Blitz

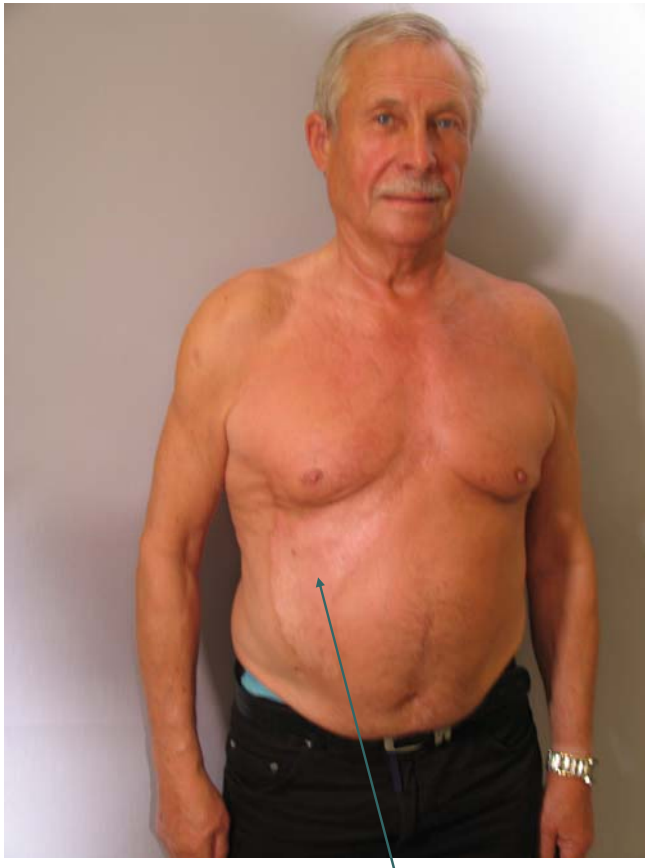


Abb.1:a+b: Zerfetzte Kleidung nach Blitzschlag und Brandnarbe

Mechanismen der Energieübertragung II

Abb. 4 ▲ **Blitzschritteffekt („ground strike") mit abgenommener Schrittspannung bei Blitzeinschlag in den Boden nahe des Menschen**

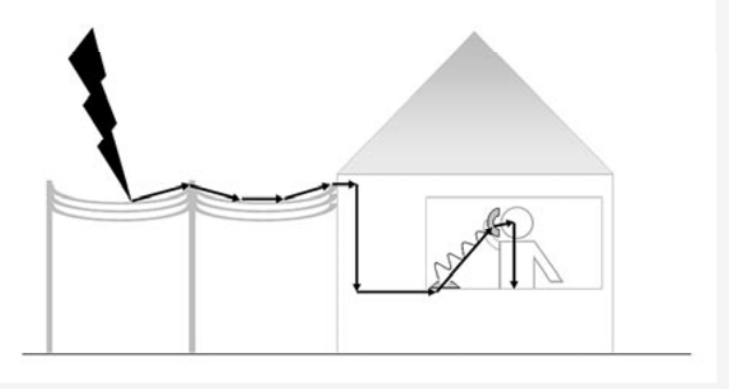


Abb. 5 ▲ **Telefon-/leitervermittelter Unfall mit Blitzschlag in einen Leiter und Energiefortleitung bis zum Opfer**

Zack, Rechtsmedizin 2004

Abb.3a: Verbrennungsnarben nach Blitzschlag im Einschlag-Bereich (dort auch Narbe durch verdampfte Metallhalskette)

3b. Verbrennungen im Ableitebereich an den Beinen unter Aussparung der Füße (Isolierug durch Sportschuhe)

Blitzschlagverletzung I

- Epidemiologie: USA Todesfälle 75-150/a
- Risikogruppe: jung, männlich (m:w=4.5:1), Outdoor-Sportler
- Letalität: ca. 30%
  Herz-/Kreislauf- oder Atemstillstand durch elektrische Depolarisation (Asystolie, Kammerflimmern), Hirnstammläsion

Blitzeintritt am Kopf letal oder schwere Residuen

Blitzschlagverletzung II

Wie entsteht eine Blitz?

Spannungsunterschied in Gewitterwolke (oben positiv, unten negativ), Spannungsausgleich zw. Wolke und Erdoberfläche, Blitzkanal

Schädigungsmechanismen:

1. Direkter Blitzschlag (Ein-/Austrittspforte)
   bis 100.000.000 V, bis 100.000 A, <200 ms, „pathway“ (Nervengewebe, Blutgefäße)
2. „side flash“
3. Bodenspannung („step voltage“)
4. Fangentladung („up-stream“)
5. magnetische Wirkung, Strominduktion (Hypothese)
6. Druckwellen durch Luftkompression
   Trommelfell-/Gefäß-/Organruptur, pulmonale/intracranielle Blutungen, Frakturen, SHT

Blitzschlagverletzung III

Klassifikation neurologischer Komplikationen (Cherington):

1. Akut und transient
   Bewußtseinsverlust (75%), Amnesie, KS, Keraunoparalyse (*keraunos*=Donner; 80%), Lichtenberg-Figur
2. Akut und prolongiert bzw. permanent
   post-hypoxische Encephalopathie, SAB, ICB (Stammganglien, Hirnstamm), cerebrale Ischämien (selten), cerebelläre Symptome/Atrophie (selten), sympt. Epilepsie (selten)
3. Verzögert (und meist progressiv)
   neuropsychologische/psychiatrische Störungen, vegetative Störungen, u. U. Motorneuronerkrankung, Bewegungsstörung, etc.
4. Sekundär nach Sturz, Knalltrauma, etc.

Blitzschlagverletzung IV

Neuropsychologische Defizite („post-lightning syndrome“):

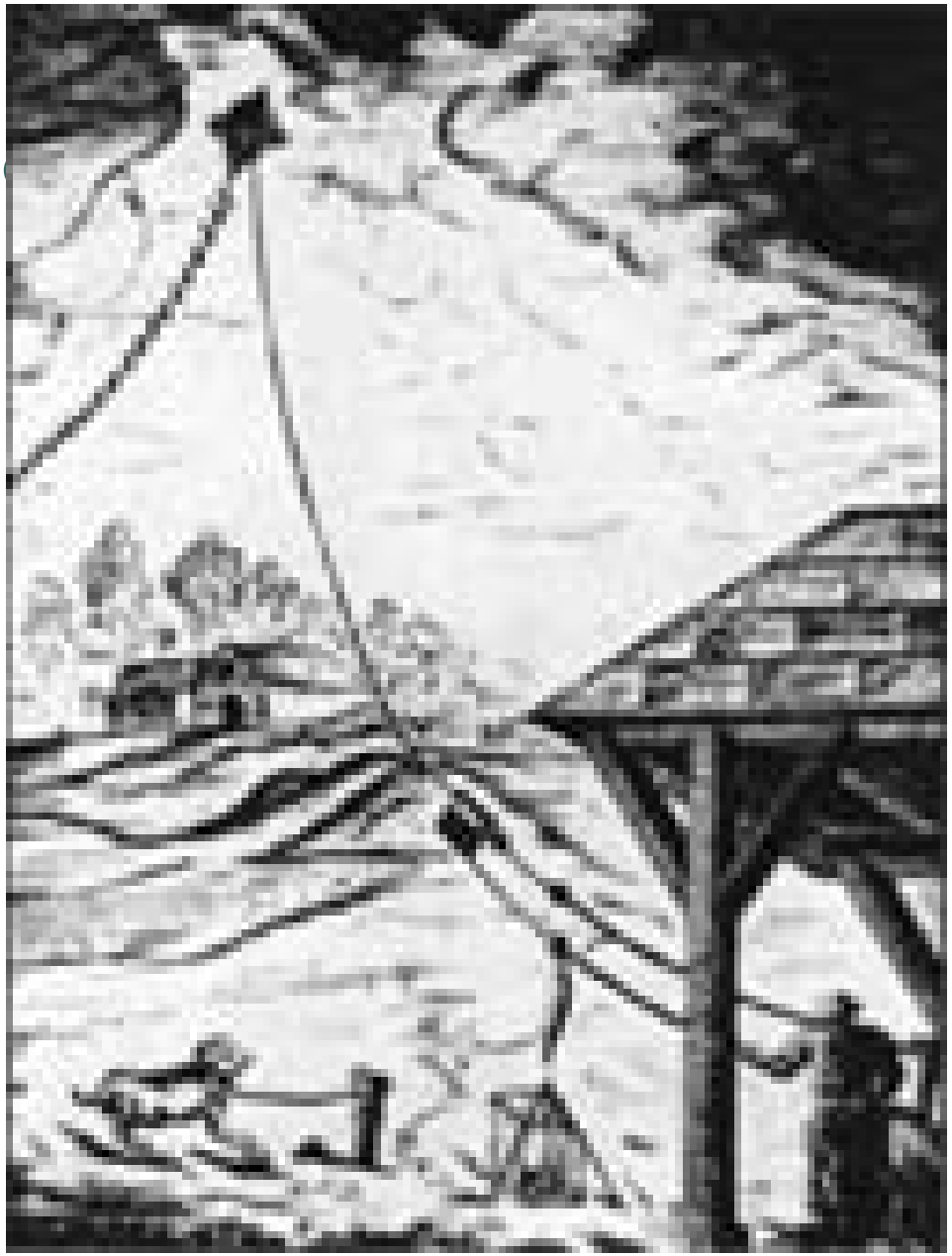
entstehen Tage bis Monate nach Blitzschlag

- Kognition (Mnestik, Aufmerksamkeit, Konzentration)
- Schlafstörung, chron. Fatigue
- Affektive Störung (Depression), Angststörung
- Post-traumatische Belastungsstörung

FRANKLIN'S EXPERIMENT. JUNE 1752.

Demonstrating the Identity of Lightning and Electricity; from which he invented the Lightning Rod.


Vereidigung von B.Obama



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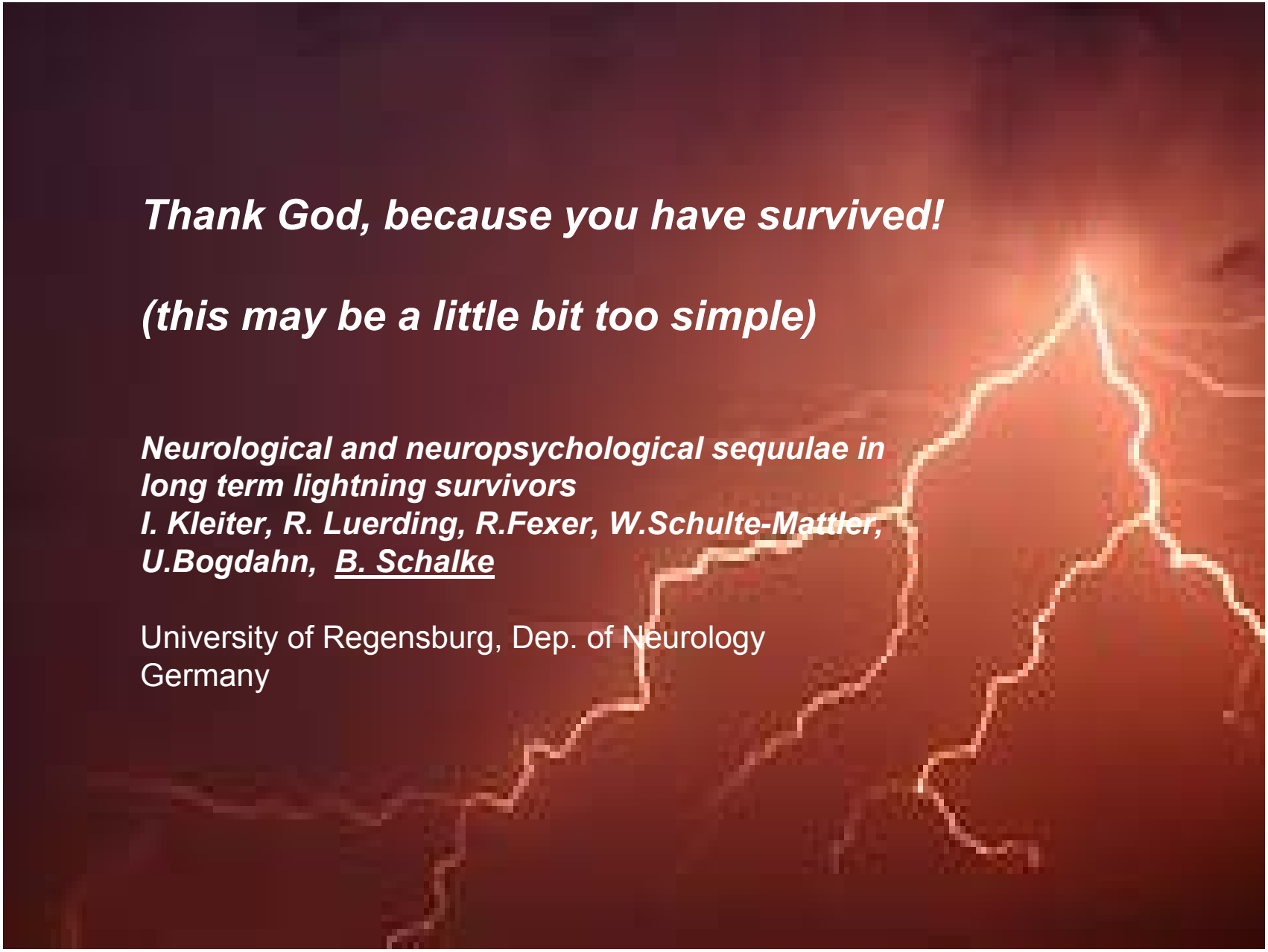
- Duff K, McCaffrey RJ. Electrical injury and lightning injury: a review of their mechanisms and neuropsychological, psychiatric, and neurological sequelae. *Neuropsychol Rev* 2001;**11**(2)**:**101-16.
- van Zomeren AH, ten Duis HJ, Minderhoud JM, Sipma M. Lightning stroke and neuropsychological impairment: cases and questions. *J Neurol Neurosurg Psychiatry* 1998;**64**(6)**:**763-9.
- Yehuda R. Post-traumatic stress disorder. *N Engl J Med* 2002;**346**(2)**:**108-14.



Thank God, because you have survived!

(this may be a little bit too simple)

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Four patients after lightning strike injuries (out of our group of about 25) were examined in the first four weeks and one year after the lighthing strike.

One patient PF with a strike to the head showed skin burns, a focal cerebral lesion int CT, a focal pathology in EEG a corresponding impairment in neuropsychologic assessment.

Two patients US and IW, without skin burns, had cerebral lesions in MRI, neuropsychologic impairment, and peripheric neurologic symptoms.

Patient ID lost19% of his skin from burns, showed no central-neurologic or neuropsychologic, but peripheric neurologic symptoms.

As manifold the mechanism of a lightning strike are, as heterogeneous are the symptoms.

Medical reports (improvements in green)

Patient PF
Neurophysiology: no response from the right eye
EEG: focal disorder right temporal.
CT/MRT: subarachnoid hemorrhage right and left occipital
Attention and memory impairment
Posttraumatic stress disorder

One year later
MRT: resorption of the bioccipital hemorrhage, no lesions
Neurophysiology: visual stream defect
EEG: focal disorder right temporal.
Memory impairment

Post-traumatische Belastungsstörung

- Verzögerte oder protrahiert auftretende Reaktion auf ein außergewöhnlich belastendes Ereignis
- Wiederholtes Nacherleben des Traumas („Flashback“)
- Vermeidungshaltung
- Unfähigkeit sich an wichtige Aspekte der Belastung zu erinnern
- Häufig assoziiert mit Angststörung, Depression

- Therapie: SSRI, Verhaltenstherapie, Traumatherapie
- Prognose: meist gut (80%)