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# **Hypothermic Neural Protection Against Cardiac Arrest: Neural Electrical Dynamics**

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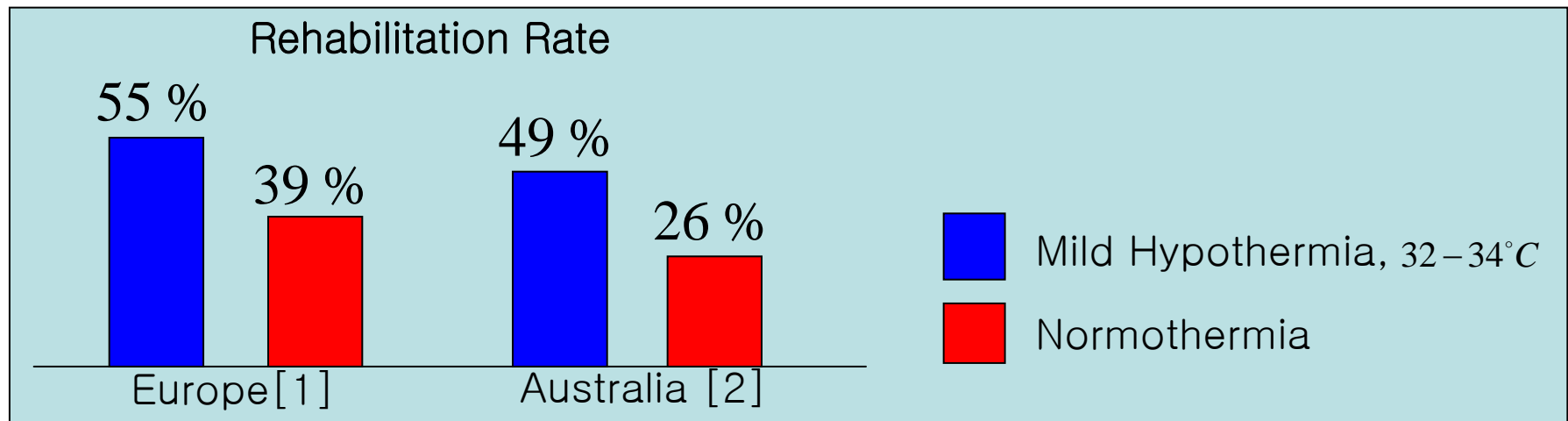
## Cardiac Arrest

### Neurological Consequences of CA

Even survivors of CA suffer from neurological complications.

In 2000, the AHA statement captures the needs of research incorporating the brain in any cardiopulmonary resuscitation.

### Hypothermia as a Neuroprotective Strategy



[1] Group, H.a.C.A.S., “Mild therapeutic hypothermia to improve the neurologic outcome after cardiac arrest,” N Engl J Med, vol. 346(8), pp. 549–56, 2002.

[2] Bernard, S.A., et al., “Treatment of comatose survivors of out-of-hospital cardiac arrest with induced hypothermia,” N Engl J Med, vol. 346(8), pp. 557–63, 2002.

## Goals

Effects of hypothermia leading to recovery on the injured brain after CA

## Hypothesis

The brain's response to hypothermic treatment after CA can be directly reflected in the neural electrical responses

## Aims

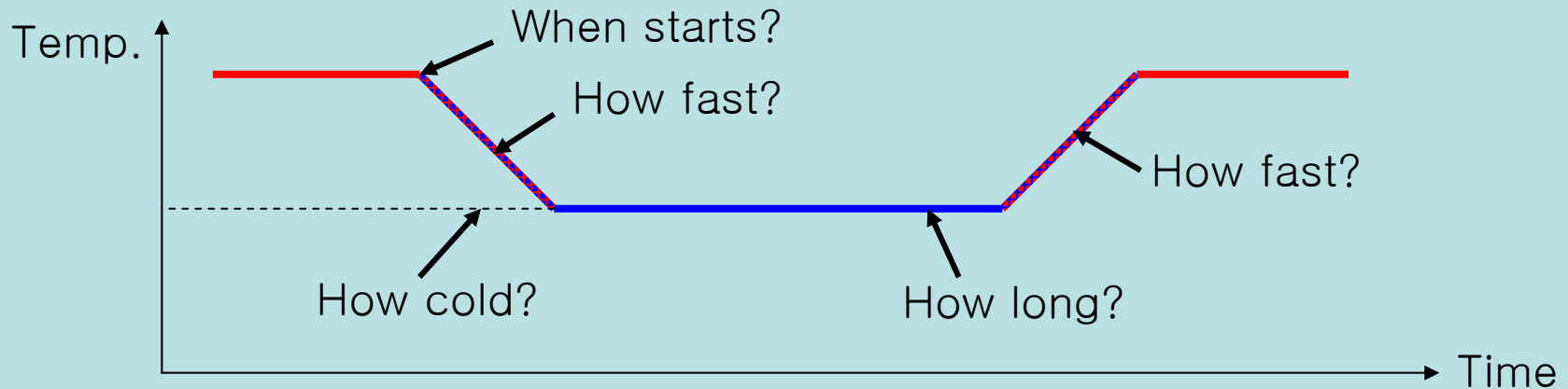
To develop novel quantitative methods for studying the neural firing patterns to graded levels of ischemic brain injury

To evaluate the relation between the subcortical and cortical rhythms in the time course of brain injury and its recovery

To demonstrate neural electrical changes to hypothermic/normothermic treatment in rodents resuscitated from cardiac arrest

## Quantitative Assessment of Hypothermic Neuroprotection

Parameters of hypothermia are still under evaluation:  
temperature, duration of hypothermia, rate of cooling and rewarming



We need real-time neurological monitoring  
during the hypothermia therapy

**WHY?**

The effect of temperature modulation to brain  
is needed to assess during therapy.

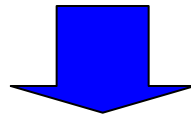
## EEG-Based Direct Assessment of Hypothermic Neuroprotection

The effects of changes in brain temperature on EEG have been exploited since 1930s. (H. Hogland [1936])

Ischemic brain injury from oxygen deprivation affects synaptic Transmission, axonal conduction, and cellular action potential firing. (G. Holmes [1982] and Somjen, G. [1993])

The features of EEG power spectrum during recovery are indicative Of the course and extent of recovery. (K. Watanabe [1980])

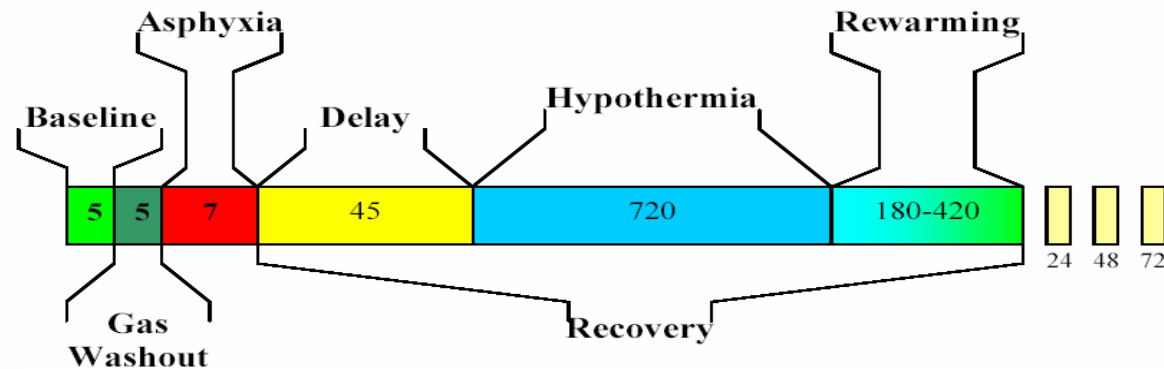
The relation between hypothermia and EEG has been reported. (H. Fritz [1999] and R. Burger [2003])



The information content of the EEG is expected to includes a more direct assessment of the neuroprotective effect of hypothermia.

# Quantitative Assessment of Hypothermic Neuroprotection

## Cardiac Arrest Model (Rat)

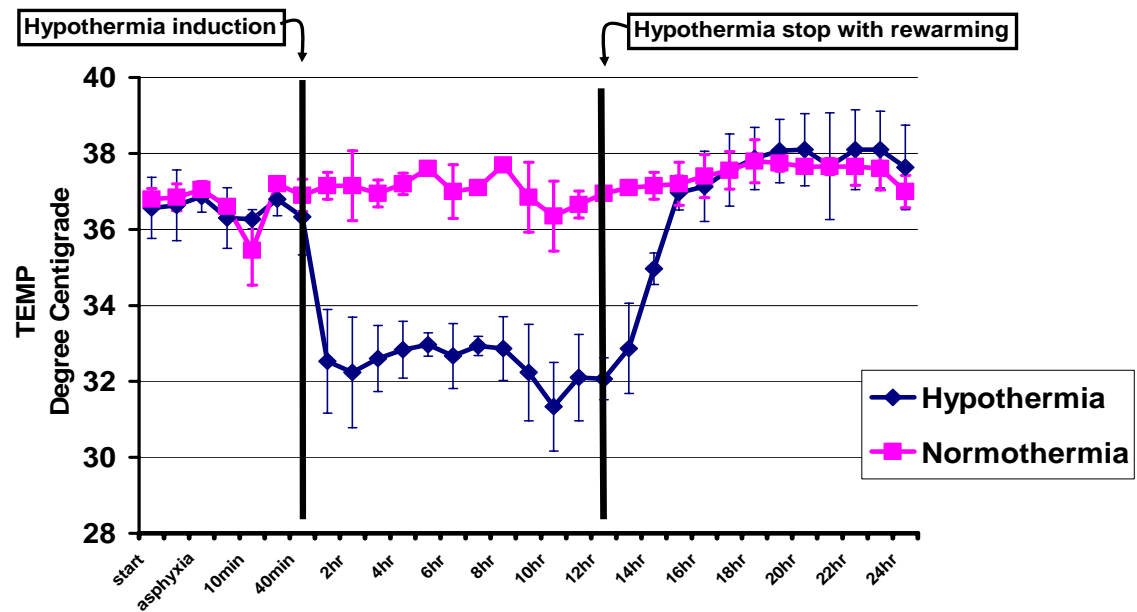


## Temperature

### Hypothermia and Normothermia Groups after 7 min CA

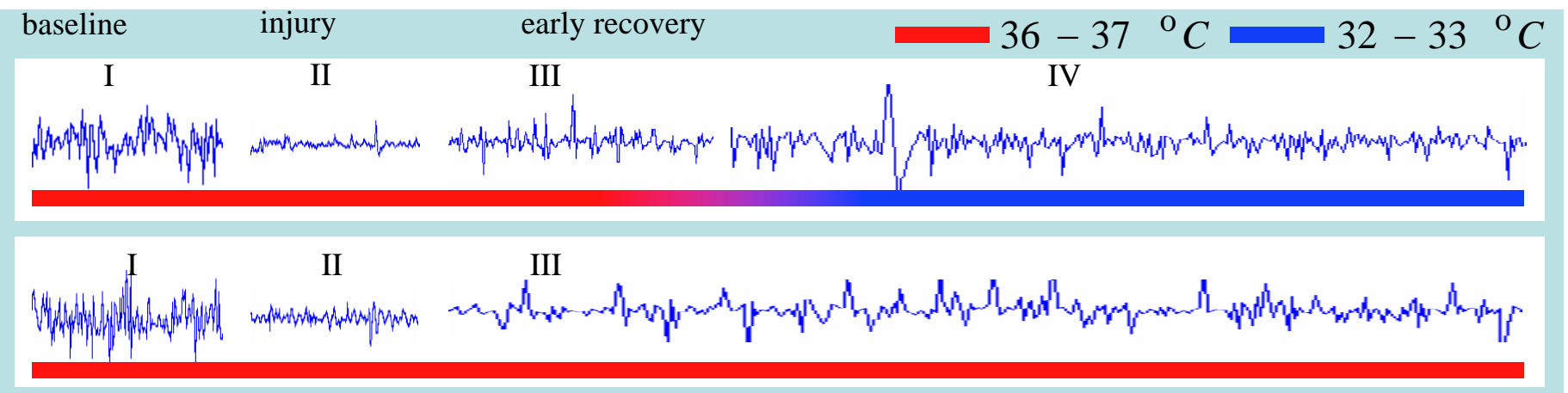
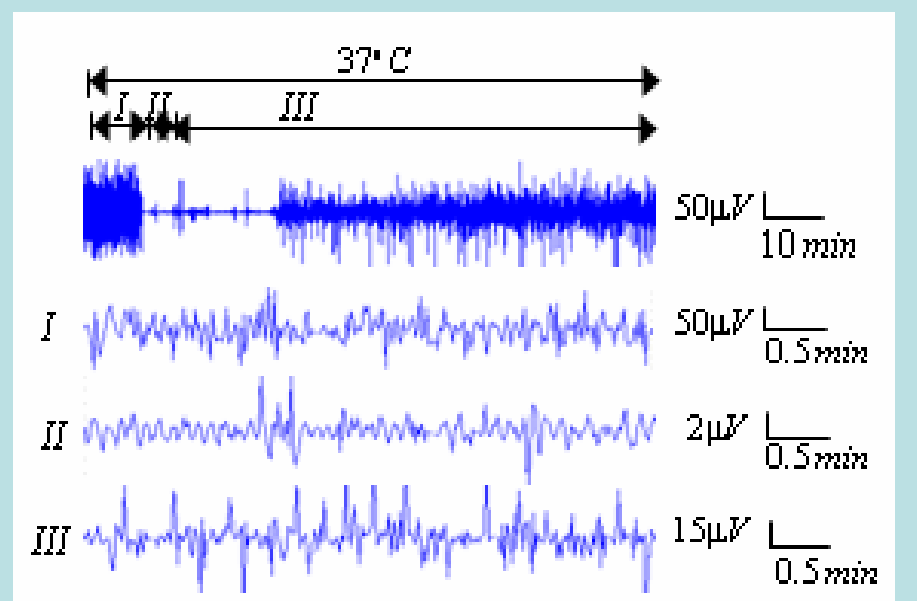
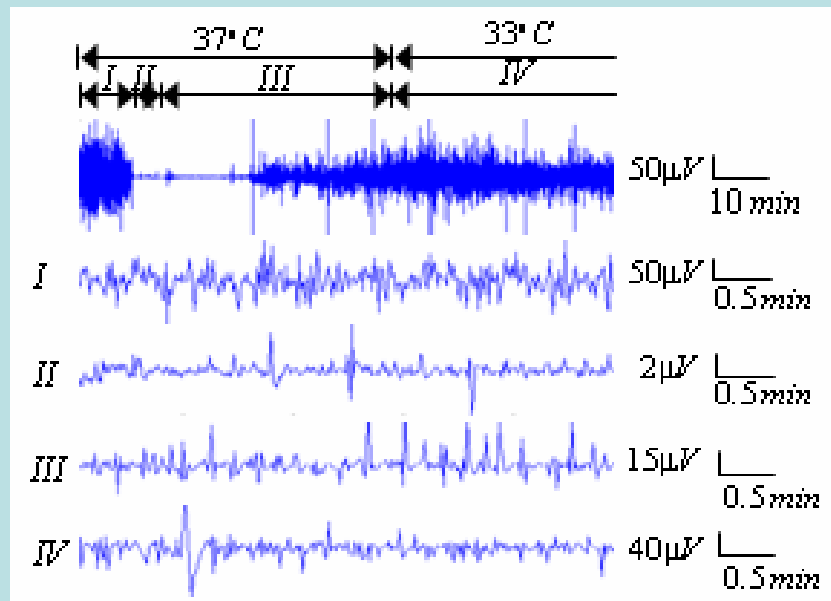
Group I  
(normothermia)

Group II  
(hypothermia)



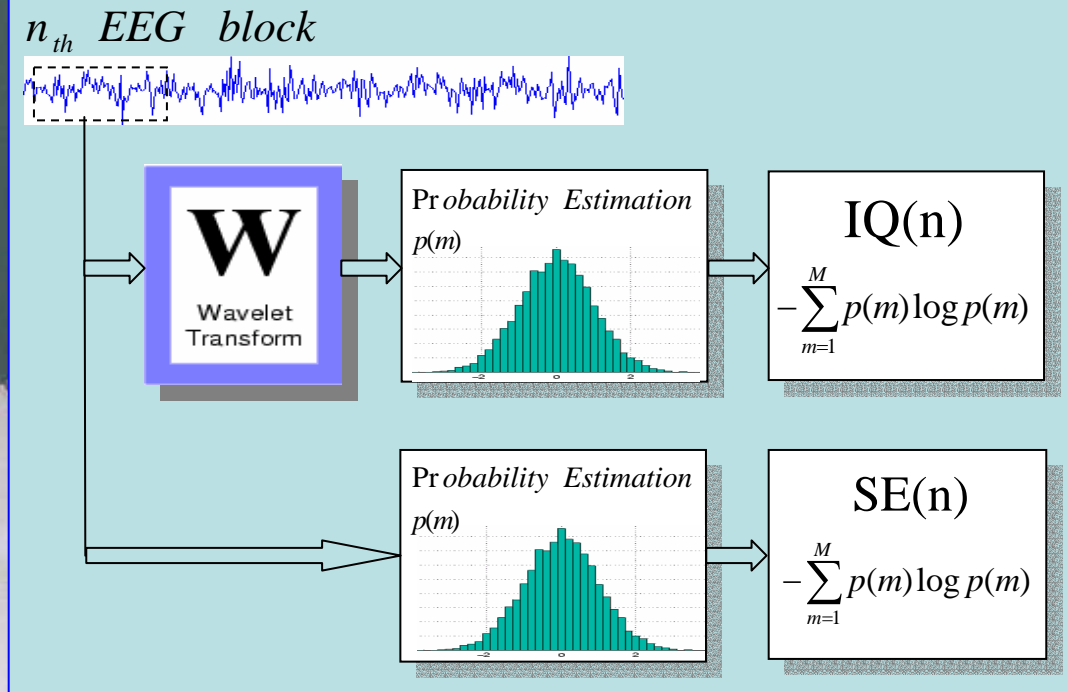
# Quantitative Assessment of Hypothermic Neuroprotection

## Recorded Raw EEG



# Quantitative Assessment of Hypothermic Neuroprotection

## Quantitative Measure of EEG



$$W(n; w; \Delta) = \{s(i), i = 1 + n\Delta, \dots, w + n\Delta\} \quad W(n; w; \Delta) = \bigcup_{m=1}^M I_m$$

$$SE(n) = -\sum_{m=1}^M p_n(m) \log_2 p_n(m)$$

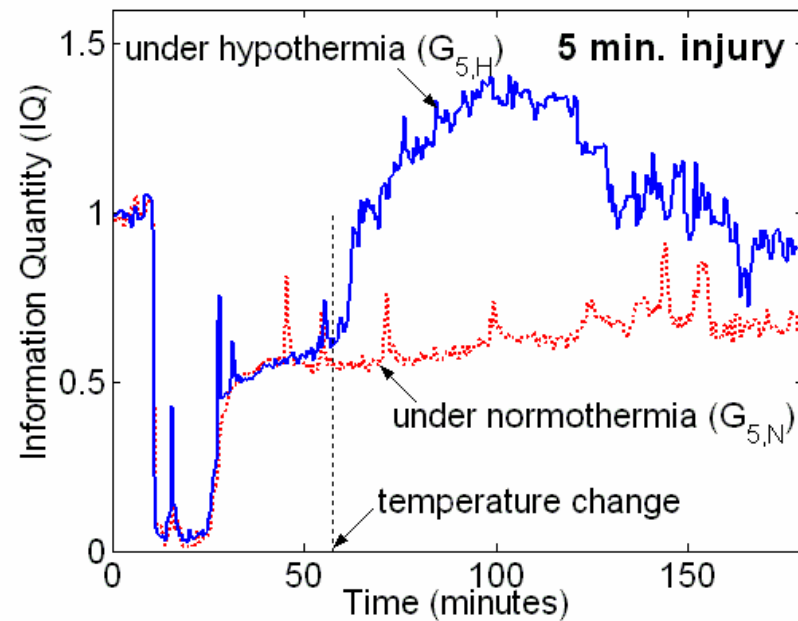
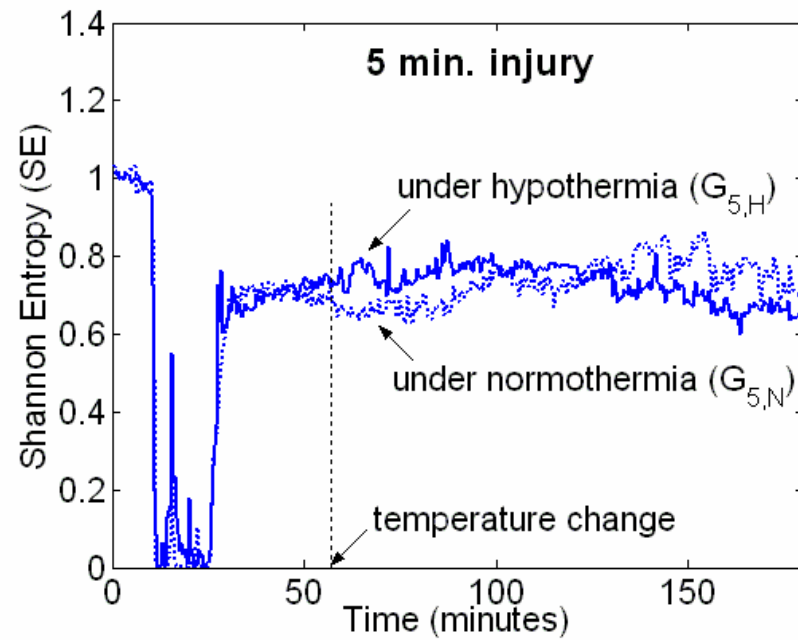
$$WC(r; n; w; \Delta) = DWI[W(n; w; \Delta)] \quad WC(r; n; w; \Delta) = \bigcup_{m=1}^M I_m^{wc}$$

$$IQ(n) = -\sum_{m=1}^M p_n^{wc}(m) \log_2 p_n^{wc}(m)$$



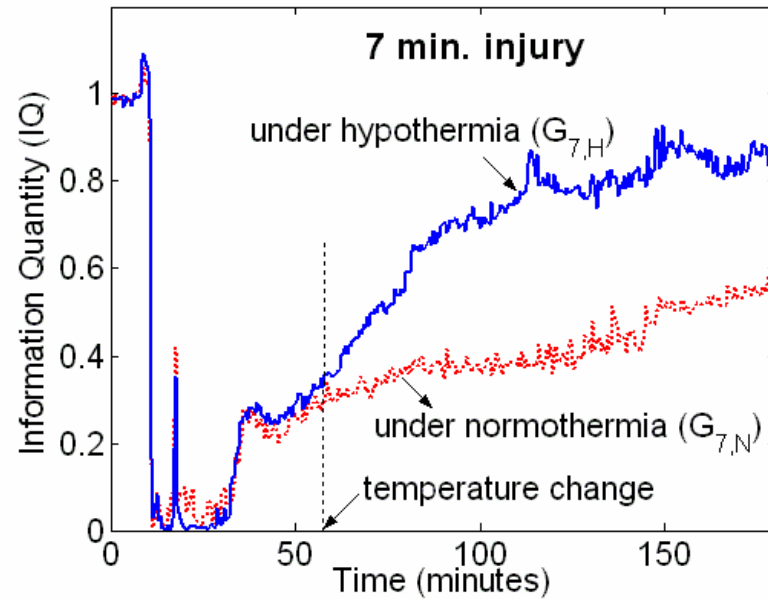
## Animal Results

### QEEG and effect of hypothermia after CA (5 min injury)

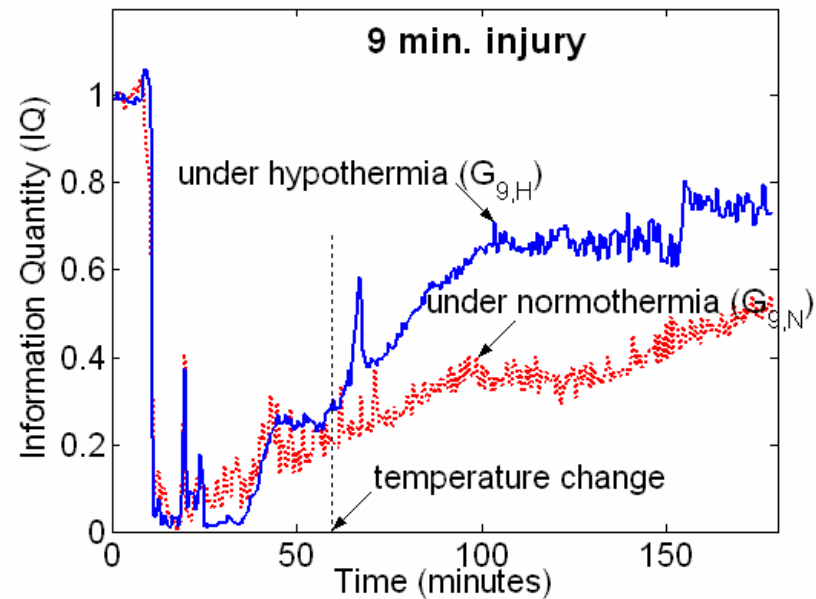


## Animal Results

QEEG and effect of hypothermia after CA (7 min injury)

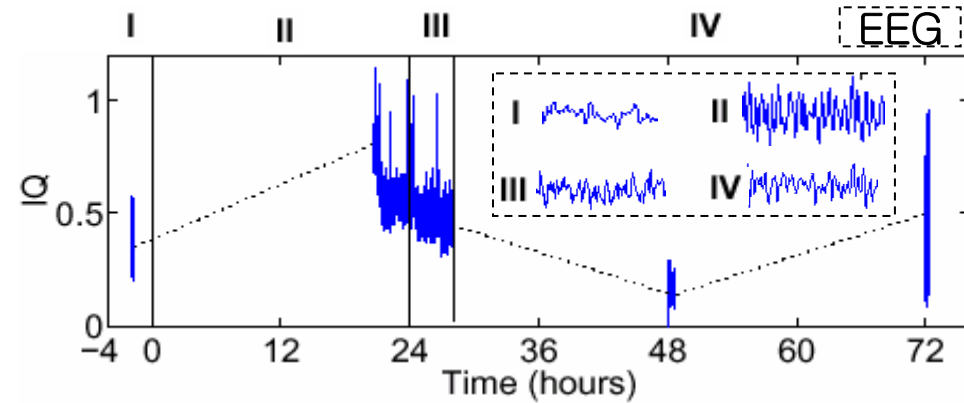


QEEG and effect of hypothermia after CA (9 min injury)



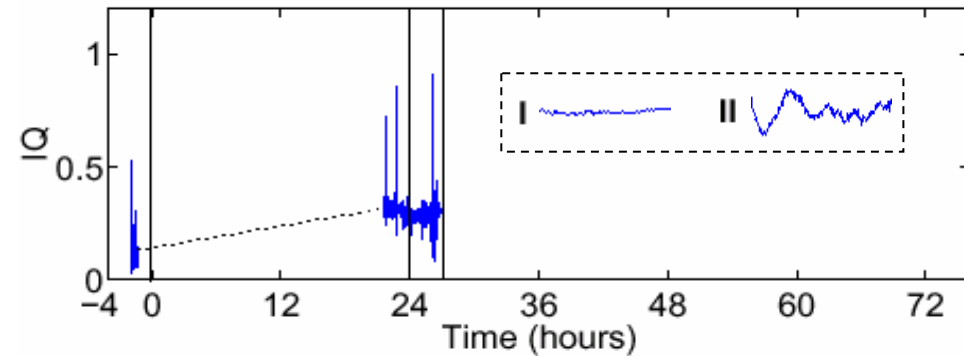
## Clinical Results

(a) EEG from a patient with a good outcome (CPC=1)



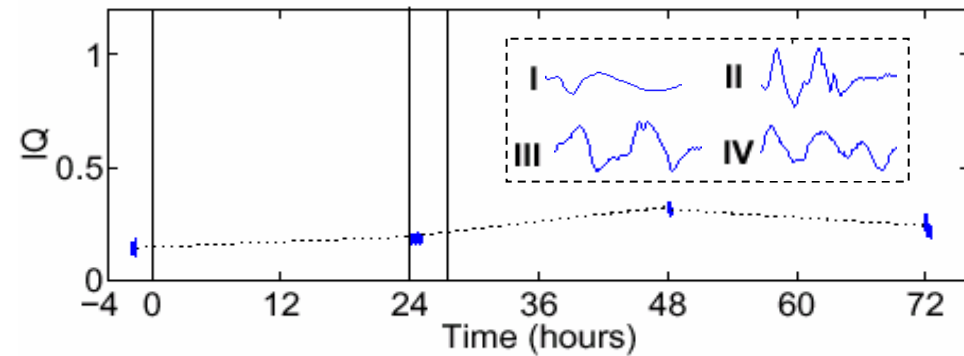
(a)

(b) EEG from a patient with a bad outcome (dead)



(b)

(c) EEG from a patient with a bad outcome (CPC=5)



(c)

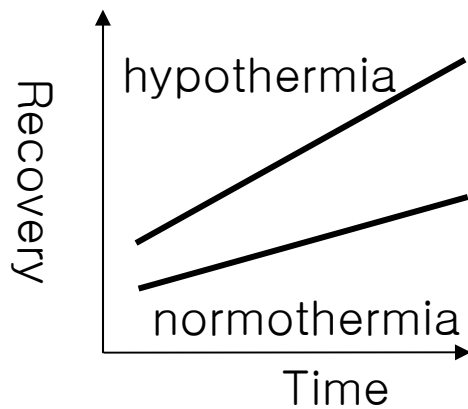
CPC: Glasgow Pittsburg Cerebral Performance Categories

## Future Research

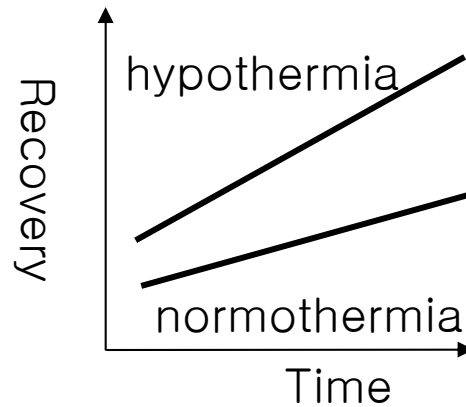
	CA	Temperature		Recording	
		Normothermia	Hypothermia	Cortex	Thalamus
1	√	√		√	
2	√		√	√	
3	√	√		√	√
4	√		√	√	√

## Expected Results

Cortical response



Thalamic response



Thalamo-cortical  
and cortico-thalamic  
relation

