

Magnetic inductive phase shift: a new method to differentiate hemorrhagic stroke from ischemic stroke on rabbit

Qingguang Yan, Gui Jin, Ke Ma, Mingxin Qin, Wei Zhuang, and Jian Sun

Abstract—Background: The major therapy for ischemic stroke is thrombolytic treatment, but severe consequences occur when this method is used to treat hemorrhagic stroke. Currently, computed tomography and magnetic resonance imaging are used to differentiate between two types of stroke, but these two methods are ineffective for pre-hospital care.

Methods: We developed a new brain diagnostic device for rabbits based on electromagnetic induction to non-invasively differentiate two types of stroke. The device includes two coils and a phase difference measurement system that detects the magnetic inductive phase shift (MIPS) value to reflect the tissue's condition. The hemorrhage model was established through the injection of autologous blood into the internal capsule of a rabbit's brain. Ischemia was induced in the brain of a rabbit by bilateral carotid artery occlusion. Two types of animal models were measured with our device.

Results: The MIPS value gradually decreased with increasing injected blood and increased with ischemia time. The MIPS changes induced by the two types of strokes were exact opposites, and the absolute values of MIPS variation in the hemorrhagic and the ischemic groups were significantly larger than those of the normal control group ($P > 0.05$).

Conclusions: The tested technique can differentiate ischemic stroke from hemorrhagic stroke on rabbit brain in a non-invasive, continuous, and bulk monitoring manner by using a simple and inexpensive apparatus.

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Index Terms—Magnetic inductive phase shift (MIPS), Hemorrhagic stroke, Ischemic stroke

I. BACKGROUND

Stroke can be classified into two kinds, namely, hemorrhagic and ischemic. The incidence rate of this medical condition continuously increases with the aging of the global population and the intensification of social pressure. The latest statistics issued by the Ministry of Health of the People's Republic of China reveal that stroke is the first cause of death among all diseases in China, and its standardized mortality

rate in the country ranks first in the world. Besides, such a mortality rate continues to increase at a yearly rate of 9%. Approximately 2 million people suffer a stroke each year. Among this population, nearly half die, and roughly 3/4 of the survivors experience varying degrees of disability. Stroke has brought severe economic burdens to China and its people, and this situation emphasizes the urgency for the prevention and control of such a medical condition [1]. Ischemic stroke (obstruction of blood flow) accounts for nearly 80% of all stroke cases, and hemorrhagic stroke (bleeding into brain or on the surface of the brain) accounts for the remaining 20% [2]. The early thrombolytic treatment of ischemic stroke is an established procedure today, but it could be disastrous when performed on patients with hemorrhagic stroke [3], [4], [5]. At present, computed tomography (CT) and magnetic resonance imaging (MRI) are used to differentiate hemorrhagic stroke from ischemic stroke. The early use of thrombolytic therapy immediately after the onset of ischemic symptoms could produce satisfactory outcomes [6]. However, such a treatment is not advised to be adopted beyond 4.5 h after the onset of such symptoms because its potential benefits do not outweigh the risk of hemorrhagic complications, which increase with time. The majority of the time after the onset of ischemic symptoms is wasted in transport to and from the diagnostic instruments and in imaging test; thus, only 1–8% of the entire stroke population is given such treatment [7]. This clinical challenge urges the development of new and simple pre-hospital methods that can distinguish between ischemic and hemorrhagic strokes from each other.

Several technologies for distinguishing ischemic from hemorrhagic stroke have been developed over the years. Doppler ultrasonography can accurately identify the states of the cerebral artery (e.g., stenosis, obstruction, convulsion, or ischemia), but it cannot exclude hemorrhagic transformation from the resulting ischemic regions [8]. Electrical impedance tomography (EIT) has been proposed as a possible technology to detect intracerebral hemorrhage (ICH) in an animal model [9] and impedance spectroscopy has been suggested as a method to detect stroke related brain asymmetries in man [10]. However, EIT requires the injection of current through an electrode-skull contact that could reduce the detection precision [11]. Besides, the current is difficult to pass the super-high resistivity skull and may therefore severely reduce the imaging quality [11]. The near-infrared spectroscopy (NIRS) detects hemorrhagic stroke because the hemoglobin absorbs more near-infrared light than other tissues. In a previous

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