A Wearable Transcranial Doppler Ultrasound Phased Array System

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The central objective of critical care for patients affected by traumatic brain injury (TBI), cerebrovascular accident (i.e., stroke), and other neurovascular pathologies is to monitor patient state and provide suitable medical intervention to mitigate secondary injury and aid in recovery. Transcranial Doppler (TCD) sonography is a specialized Doppler ultrasound technique that allows characterization of blood flow from the basal intracerebral vessels. While several non-invasive cerebrovascular diagnostic modalities exist, including positron emission tomography (PET), computed tomography (CT), and magnetic resonance angiography (MRA), the use of TCD sonography is highly compelling for certain diagnostic needs due to its safety in prolonged studies, high temporal resolution, modest capital equipment costs, and relative portability.

Despite a growing list of potential diagnostic applications, several constraints— notably operator-dependent measurement results, bulky instrumentation, and the need for manual vessel location— have generally confined the use of TCD ultrasound to highly specific clinical environments (e.g., neurocritical care units and vascular laboratories). This project seeks to develop a low-power miniaturized TCD ultrasound system for measuring blood flow velocity at the middle cerebral artery (MCA) in support of continuous cerebrovascular monitoring with limited operator interaction.

The TCD ultrasound system shown in Figure 1 employs multi-channel transceiver electronics and a two-dimensional transducer array to enable electronic steering of the ultrasound beam. The discrete prototype electronics measure 6.5” x 5.5” x 1” and are worn at the chest; the transducer array is affixed at the temporal region with an adjustable headframe. Electronic beam formation allows for algorithmic vessel location and tracking, thereby obviating the need for manual transducer alignment and operator expertise. Following automated vessel location, the system computes the flow velocity spectrogram and spectral envelope, as presented in Figure 2.

Although human validation is preliminary, this work demonstrates a compact, wearable, and algorithmically steered TCD system that largely resolves several key shortcomings of established TCD measurement techniques. The successful execution of our current objectives can profoundly alter the standard clinical approach to neurovascular evaluation, especially in applications where the role of non-invasive diagnostics has not yet been clearly established (e.g., extended monitoring, emergency assessment).

FURTHER READING