**Emboli**

Emboli are particulate or gaseous elements that travel within the bloodstream reflecting ultrasound more intensely than surrounding red blood cells. They can usually be visualized within the spectral display of a Transcranial Doppler system as high intensity transient signals (HITS) and they typically generate a characteristic sound. Emboli are potentially harmful and may cause an ischemic stroke. Therefore, physicians can use the occurrence and proliferation of emboli as an indication of stroke risk from cardiac and vascular disease.

**Transcranial Doppler (TCD)**

TCD can be used to detect emboli for the following clinical applications:

- Localize an embolic source.
- Identify patients at high risk of Stroke due to presence of emboli.
- Identify patients with arterial or cardiac sources of embolism.
- Monitor patients during invasive procedures.
- Assess the effect of antithrombotic agents.
- Evaluate patients for the existence of a Patent Foramen Ovale (PFO).

The clinical value of identifying emboli is clearly established in various clinical publications, however, the actual process of detecting the embolic signal within the Doppler spectrum can be challenging. The ease of detecting an embolus is increased if the embolus to blood ratio (EBR) is high, that’s to say that the ultrasound reflection from the embolus is much higher than from the surrounding red blood cells. The embolic HITS generally appear as a unidirectional signal within the blood flow spectrum. The intensity increase of the embolic signal depends on the acoustic impedance difference between the embolic material and the surrounding blood (EBR). Another important phenomenon is the accompanying “chirping” or “clicking” sound that is characteristic of a travelling embolus as it passes through the Doppler sample volume. Doppler artifacts, on the other hand, are typically bi-directional, high intensity signals with maximum intensity near the zero line and varying duration. In addition, artifacts are not usually accompanied by the characteristic “chirping” or “clicking” sound.

In order to assist the physician in identifying typical embolic signals, commercially available automatic emboli detection algorithms can be utilized.
SONARA™ Emboli Detection Algorithm

The SONARA™ TCD Emboli Detection algorithm can assist the physician in identifying embolic signals and differentiating them from artifacts. Emboli are defined as short, transient, high intensity, unidirectional signals traveling through the sample volume and by contrast, artifacts are identified as uni or bi-directional transient high intensity signals of varying duration, but without a velocity component within the sample volume.

The SONARA’s algorithm performs the following assessment to help identify a potential embolus (HIT):

- Identifies a transient high intensity event (Between 8 and 320 msec)
- Determines whether event is unidirectional
- Defines background energy
- Determines whether a narrow range of frequencies characterizes an event
- Establishes whether the increase in amplitude occurring in both the In-Phase (I) and Quadrature (Q) signals is correlated, thus indicating a potential embolus

Potential emboli and artifacts are automatically saved and their position in the trend display is marked for easy data retrieval and analysis off line. Signals identified as potential emboli are given a yellow marker and those identified as artifacts are given a blue marker in the trend display, thus creating an overview of the timing and frequency of occurrence of all high intensity signals. The user can select any event from the list and the system will automatically display the spectral information surrounding the event. Alternatively, the complete examination, including audio can be played back in off-line mode to assist with further analysis.

The SONARA also offers a variety of analysis options, one of which is the complex mode (shown on the right) which displays the in-phase and quadrature components of the Doppler signal. A correlation between the two components displaying high frequency oscillations indicates a traveling signal, and as such indicates a potential embolus travelling in the blood stream.

Nicolet™ TCD systems are built to optimize performance and help clinicians improve patient care.
Depending on the source: intra-operative, carotid stenosis or PFO, the embolus will have different dimensions and characteristics, and as such will generate different embolus to blood ratio. In order to adequately accommodate the great variation in embolic characteristics, the latest version of SONARA software enables the algorithm threshold setting to be varied depending on the intended application.

Types of Emboli

Intra-operative Monitoring

PFO Monitoring – Emboli shower

Recommended Threshold Levels:
- 2.4 for carotid events
- 4.0 for heart valve and PFO events
- 6.0 for intra-operative events

References
5. King and Markus Stroke. 2009; 40: 3711-3717