# Differentiation of Emboli

## Background:

The difficulty of distinguishing solid from air emboli using transcranial Doppler has limited its use in situations where both types of emboli can occur, such as in mechanical heart valve patients. Particulate microemboli are thought to be the most damaging.

## Literature:

### Analysis of index modulation in microembolic Doppler signals part I: radiation force as new hypothesis-simulations.

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| Author | (Girault, Kouamé, Ménigot, Souchon, u. a., 2011) |
| Content/Summary | Finally, by measuring FMI (calculated frequency modulation index) from simulated Doppler signals and by using a constant threshold of 1 KHz, it was possible to discriminate gaseous from solid microemboli with ease. |
| Comment | No access to this article |
| Doppler-device | Not known |
| Quantification | New possibility to discriminate? |

### Analysis of index modulation of doppler microembolic signals part II: in vitro discrimination.

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|---|---|
| Author | (Girault, Kouamé, Ménigot, Guidi, u. a., 2011) |
| Content/Summary | Finally, we showed by using FMI (calculated frequency modulation index) and PMI (position modulation index) that it is possible to discriminate gaseous from formed elements (<100 microns) despite the presence of the skull. The discrimination based on the FMI is an off-line technique allowing the analysis of standard TCD recordings. However, discrimination based on the PMI requires recordings obtained exclusively from a multi-gate system. |
| Comment | Additional paper to Part I |
| Doppler-device | Not known |
| Quantification | In vitro analysis |

## A method to distinguish between gaseous and solid cerebral emboli in patients with prosthetic heart valves.

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| Author | (Rodriguez u. a., 2009) |
| Content/Summary | Since inhalation of 100% oxygen reduces the amount of air bubbles in mechanical heart valve patients, the ultrasonic features of the remaining emboli would be characteristic of solid particulates.<br>Administration of 100% oxygen during transcranial Doppler examination in mechanical heart valve patients decreased the count of embolic signals compared with room air (p=0.006)<br>A 16dB cut-off threshold achieved the best accuracy for differentiating non-gaseous from gaseous emboli (sensitivity: 60%; specificity: 82%; area: 0.721; p<0.0001) |
| Comment | Embolic signals were detected during room air (n=141) and 100% oxygen (n=45) from 17 mechanical valve patients at two Doppler examinations (4h and 4 days after surgery) |
| Doppler-device | MDT2, DWL, Sipplingen, Germany |
| Quantification | New cut-off point to improve accuracy? |

## Cerebral microemboli and brain injury during carotid artery endarterectomy and stenting.

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| Author | (Skjelland, Krohg-Sørensen, u. a., 2009) |
| Content/Summary | Solid and gaseous microemboli were increased in patients with procedure-related ipsilateral ischemic strokes or new diffusion-weighted cerebral MRI lesions, which suggests that both solid and gaseous emboli may be harmful to the brain during CEA and carotid angioplasty with stenting. |
| Comment | Eighty-five patients who were prospectively treated with CEA (61) or carotid angioplasty with stenting (30) for high-grade (>/=70%) internal carotid artery stenoses were monitored during the procedures using multifrequency transcranial Doppler with embolus detection and differentiation. |
| Doppler-device | Embo-Dop |
| Quantification | Both, gaseous and solid emboli may be harmful |

## Introduction of an embolus detection system based on analysis of the transcranial Doppler audio-signal.

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| Author | (Keunen u. a., 2008) |
| Content/Summary | Whether this algorithm can differentiate between gaseous and solid emboli has to be explored in future studies.<br>suggests that it is capable of detecting discrete cerebral embolization in patients, and can discriminate between emboli and movement artefacts to a level which is similar to human experts. The results showed agreement in MES and artefact classification of > 93%. |
| Comment | Data from patients in the post-operative phase of carotid surgery were used for the validation process |
| Doppler-device | Nicolet Pioneer TC 2000 |
| Quantification | System to distinguish between emboli and artefacts. |

## Solid and gaseous cerebral microembolization after biologic and mechanical aortic valve replacement: investigation with multirange and multifrequency transcranial Doppler ultrasound.

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|---|---|
| Author | (Guerrieri Wolf, Choudhary, u. a., 2008) |
| Content/Summary | Solid microemboli accounted for 16% of the total microembolic load in group B (bilogical) compared with 31% in group M (mechanical, (P = .05)) at 3 months.<br>Solid cerebral microemboli represent approximately one third of the total cerebral microembolic load after mechanical aortic valve replacement and are detectable in the majority of such patients both 5 days and 3 months after surgery (despite warfarin) |
| Comment | 60 patients |
| Doppler-device | Embo-Dop, DWL GmbH, Singen, Germany |
| Quantification | Working Embo-Dop System |

## Gaseous and solid cerebral microembolization during proximal aortic anastomoses in off-pump coronary surgery: the effect of an aortic side-biting clamp and two clampless devices.

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|---|---|
| Author | (Guerrieri Wolf, Abu-Omar, u. a., 2007) |
| Content/Summary | Avoidance of aortic side clamping results in a significant reduction in the proportion of solid microemboli detected with transcranial Doppler. As solid microemboli are probably the most damaging, use of the Enclose and Heartstring devices may represent an important strategy for minimizing cerebral injury during proximal aortic anastomoses. |
| Comment | Embo-Dop to avoid complications after aortic side clamping |
| Doppler-device | Embo-Dop, DWL GmbH, Singen, Germany |
| Quantification | It is important to detect emboli to avoid complications. |

## Multifrequency transcranial Doppler for intraoperative automatic detection and characterisation of cerebral microemboli during port-access mitral valve surgery.

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| Author | (Maselli u. a., 2006) |
| Content/Summary | In conclusion, brain embolism during port-access mitral valve procedures occurs predominantly at CPB start and during ascending aorta clamping and unclamping. Aortic arch navigation with catheters exposes to the risk of cerebral embolic events. |
| Comment | 20 patients (6 male; age 56.5+/-6.4 years; BSA 1.6+/-0.1 m(2)) undergoing port-access mitral valve surgery, automated intraoperative transcranial Doppler was used to monitor absolute amount, side distribution, and type of embolic events during selected phases of the procedure to evaluate the impact of specific surgical manoeuvres on cerebral microembolism |
| Doppler-device | Embo-Dop, DWL |
| Quantification | Embo-Dop in clinical use. |

## Analysis of emboli during carotid stenting with distal protection device.

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|---|---|
| Author | (Chen u. a., 2006) |
| Content/Summary | Microembolization frequently occurs during stenting even with deployment of the distal protection device. More solid emboli are seen during manipulations associated with lesion crossing. Although novel TCD methods yield a high frequency of embolic signals, further validation of this technique to determine the true nature, size, and number of emboli is needed. |
| Comment | Patients undergoing carotid angiography and stenting |
| Doppler-device | Embo-Dop, DWL.<br>Monitoring using the Filter Wire EX (Boston Scientific) and ACCUNET system (Guidant Corporation) was performed. |
| Quantification | Embo-Dop is useful to detect microembolisation, because they even occur during use of a protection device. |

## Can transcranial Doppler discriminate between solid and gaseous microemboli? Assessment of a dual-frequency transducer system.

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|---|---|
| Author | (Markus und Punter, 2005) |
| Content/Summary | The Embo-Dop dual-frequency system allows better discrimination than a simple intensity threshold but it is not accurate enough for use in clinical or research studies. Further work is needed to develop reliable clinical systems for discrimination of emboli. |
| Comment | 7 patients undergoing carotid surgery (= solid emboli) and 7 patients whom agitated saline was injected (= gaseous emboli). |
| Doppler-device | Embo-Dop, DWL |
| Quantification | Embo-Dop has a good specifity but worse sensitivity. |

## Letter to the Editor
## Embolus Detection and Differentiation Using Multifrequency Transcranial Doppler

| | |
|---|---|
| Author | (Russell und Brucher, 2006) |
| Content/Summary | Authors explain the limations of techniques, which were used by Markus and Punter and line out why they did not work. |
| Comment | In reply to Markus et Punter, 2005 |
| Doppler-device | Not known |
| Quantification | Publication of Markus et al. had limitations |

## Letter to the editor:
## Embolus Differentiation Using Multifrequency Transcranial Doppler

| | |
|---|---|
| Author | (Evans, 2006) |
| Content/Summary | The problem of distinguishing between signals from solid and gaseous emboli is clinically important, and the multifrequency technique an interesting approach. Unfortunately, its accuracy is limited by the impossibility of generating identical ultrasound beam shapes at different frequencies |
| Comment | In reply to: Markus HS, Punter M., 2005 |
| Doppler-device | Embo-Dop |
| Quantification | Emboli-differentiation is limited by technical reasons |

## Letters to the Editor
## EmboDop: Insufficient Automatic Microemboli Identification

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|---|---|
| Author | (Schoenburg u. a., 2006) |
| Content/Summary | The authors agree with Markus and Punter. They line out some limitations. |
| Comment | In reply to Markus and Punter, 2005 |
| Doppler-device | EmboDop |
| Quantification | Agreement to Markus et al., 2005 |

## Solid and gaseous cerebral microembolization during off-pump, on-pump, and open cardiac surgery procedures.

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|---|---|
| Author | (Abu-Omar u. a., 2004) |
| Content/Summary | The majority of microemboli occurring during cardiac surgery are gaseous, with a higher proportion of solid microemboli in the on-pump group, and may have a different significance for cerebral injury than solid microemboli. The ability to reliably discriminate gas and solid microemboli may have an important role in the implementation of neuroprotective strategies. |
| Comment | Patients undergoing on-pump and off-pump cardiac surgery |
| Doppler-device | Embo-Dop |
| Quantification | It is important to discriminate between gaseous and solid emboli |

### Automatic online embolus detection and artifact rejection with the first multifrequency transcranial Doppler.

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|---|---|
| Author | (Brucher und Russell, 2002) |
| Content/Summary | With multifrequency Doppler, 546 of these emboli (98.6%) and 791 of these artifacts (98.9%) were automatically detected and correctly classified as embolus or artifact (kappa=0.953, P<0.0001). |
| Comment | Ex-vivo analysis |
| Doppler-device | Embo-Dop |
| Quantification | Highly accurate working system |

### Online automatic discrimination between solid and gaseous cerebral microemboli with the first multifrequency transcranial Doppler.

| | |
|---|---|
| Author | (Russell und Brucher, 2002) |
| Content/Summary | This study has shown that multifrequency transcranial Doppler can be used to automatically differentiate between solid and gaseous microemboli online. |
| Comment | Patients undergoing cardiac valve or carotid surgery. |
| Doppler-device | Embo-Dop |
| Quantification | Well working system |

## Summary:

The automatic differentiation between solid and gaseous emboli is limited because of its technical limitations since it uses different frequencies like 2 and 2.5 MHz.
Varying of cut-off points like frequency threshold may leed to a higher accuracy as some authors postulated recently.

## Experts:

Markus
Brucher
Russell
Evans
Girault

## Literature


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