



Review

Cerebral hemodynamics and the role of transcranial Doppler applications in the assessment and management of cerebral arteriovenous malformations



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ARTICLE INFO

Article history:

Received 31 October 2015

Accepted 26 January 2016

Keywords:

Arteriovenous malformation

Doppler

Hemodynamics

Management

Transcranial

Ultrasound

ABSTRACT

Dramatic hemodynamic changes occur following resection of brain arteriovenous malformations (AVM). Transcranial Doppler (TCD) records non-invasive velocity and pulsatility parameters. We undertook a systematic review to assess AVM hemodynamics including the time course of changes in velocity and pulsatility in patients undergoing AVM resection. The review employed the Embase and Medline databases. A search strategy was designed. An initial title search for clinical series on AVM and TCD was performed followed by a search for reports on AVM and TCD. A total of 283 publications were selected. Full text analysis produced 54 studies with extractable data regarding AVM, velocity and pulsatility. Two TCD techniques were utilized: conventional “blind” TCD (blind TCD); and transcranial color duplex Doppler (TCCD). Of these, 23 publications reported on blind TCD and seven on TCCD. The presence of high velocity and low pulsatility within AVM feeding arteries preoperatively followed by a postoperative decrease in velocity and subsequent increase in pulsatility of feeding arteries is established. The time sequence of hemodynamic changes following AVM resection using TCD remains uncertain, confounded by variations in methodology and timing of perioperative measurements. Of the two techniques, TCCD reported qualitative aspects including improved differentiation of feeding arteries from draining veins. However, there are a limited number of studies supporting this conclusion. Furthermore, none report reproducible changes with time from treatment. TCCD appears to be a useful technique to analyze the hemodynamic changes occurring following treatment of AVM, however little data is available. This is a field of research that is appropriate to pursue.

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1. Introduction

The presence of an arteriovenous malformation (AVM) is responsible for significant variations from the normal vascular physiology of the brain [1–6]. Furthermore, upon treating the AVM, before the vasculature returns to normal, the large diameter arteries and veins with dramatically lowered velocity of flow, and elevation of arterial pressure in the former feeding arteries may cause a number of clinically challenging problems, including intracranial hemorrhage and venous occlusive infarction (for example due to arterio-capillary venous hypertensive syndrome) [1]. The degree of change is likely to vary significantly between patients because of the variability in the magnitude of

arteriovenous shunting within the AVM. Because of the importance of these physiological changes and because these dramatic and dynamic changes occur mostly during the postoperative inpatient surgical period, this condition is ideally suited to monitoring by a repeatable non-invasive hemodynamic investigation by transcranial Doppler (TCD). The aim of this study was to establish to what extent that TCD has been utilized in the postoperative surgical period for assessing hemodynamic remodeling.

2. Materials and methods

A systematic review of the published literature was performed with the primary outcome to define the effectiveness of TCD during the management of AVM. A Preferred Reporting Items for Systematic Reviews and Meta Analyses (PRISMA; www.prisma-statement.org) protocol was adhered to where possible. The focus of the

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review was to summarize and document existing evidence to define our primary outcome.

2.1. Eligibility criteria

Eligibility criteria included original published, source manuscripts written in English, with data collection series of more than 10 patients. Data from series using TCD to identify and characterize hemodynamic parameters in cerebral AVM, including the term angioma, were included. Case reports of less than or equal to 10 patients were excluded. Included in the series were adults ranging from 18–65 years of age with varying duration of postoperative follow-up.

2.2. Search criteria

The Embase database was searched from 1974 to 29 January 2015, and the Medline database was searched from 1946 to 29 January 2015. The bibliographies of identified manuscripts were also reviewed and used as an additional data source. No unpublished studies were included. We designed a search strategy to include manuscripts relevant to any aspect of AVM or angioma using TCD. The search strategy used for Embase and Medline databases is shown in Table 1.

The publications extracted were grouped by title and duplicates were excluded. The abstracts were then reviewed according to the described inclusion and exclusion criteria.

2.3. Data extraction

Standardized data sheets were used for each study. Velocity and pulsatility measurements in AVM pre- and postoperatively were recorded from each publication. In postoperative studies where parameters were reported along a time course this trend data was also recorded to identify hemodynamic changes. Normal remote vessels and normal preoperative reference values were also recorded.

2.4. Statistical analysis

Statistical assessments were performed primarily with descriptive data. AVM TCD velocity and pulsatility measurements, postoperative changes in TCD parameters and time courses were summarized. Multi-study statistical analysis was not feasible due to heterogeneity of methodology, parameters and techniques.

3. Results

3.1. Literature review results

The search of Embase and Medline produced a total of 261 studies written in English. Additional records, identified through bibliographic and referencing resources, yielded a further 22 studies that were included in the analysis; thus, a total of 283 studies were reviewed. A total of 168 were excluded owing to irrelevant pathophysiologic processes in 140 (83%) or duplication in 28 (17%). Following review of 115 abstracts, a further 61 studies were excluded: 36 (31%) were irrelevant, 10 (9%) were review articles, 14 had less than or equal to 10 patients (12%) and there was one pediatric study. The selection process is outlined in Figure 1. The remaining 54 articles relating TCD to AVM were subjected to full-text assessment. Of these, 11 had no extractable data (20%), five were case studies and studies with fewer than or equal to 10 cases (9%), and four were editorial letters (7%). These papers were excluded. A total of 33 papers were analyzed for narrative summary.

Two different TCD techniques were identified: conventional (blind) TCD monitoring (blind TCD) and transcranial color duplex Doppler (TCCD). Given each technique will yield a slight variance in velocities, when numerical values are quoted, the technique used is specified accordingly. Twenty-three were series using blind TCD, and seven used TCCD. Two studies using a Doppler flow meter were also included for relevant background hemodynamic data (Fig. 1).

3.2. Assessment of AVM using TCD

Full text analysis produced 33 studies with extractable data regarding assessment of AVM with TCD.

Crude TCD measurements of velocity (peak and mean) and pulsatility index (PI) are the predominantly used parameters pertaining to the basal cerebral arteries including those with AVM (Table 2). Using these measurements it has been established that AVM feeding arteries can be differentiated from normal remote arteries by the presence of high velocity [2–24] and low PI [2–22]. Further significant differences in velocity and PI are found in tapering and non-tapering feeding arteries [12,13,24]. Table 3 summarizes velocity and PI in AVM. Of note, an increased velocity and decreased resistance may be detected in the contralateral anterior cerebral artery, consistent with contribution via the anterior communicating artery [3–5,7,9,13,15,16,21,25,26].

Variations of these basic velocity and pulsatility measurements have been adapted and applied to AVM as follows. (1) Mean velocity ratios from the ipsilateral middle cerebral artery to the ipsilateral extracranial internal carotid artery (ICA), to assist in differentiating velocity increases associated with hyperdynamic

Table 1

Ovid Embase search strategy (similar modified version used in Medline)

1. brain arteriovenous malformation/or brain malformation/or cerebrovascular malformation/
2. transcranial doppler/
3. ultrasound/
4. echography/
5. 2 or 3 or 4
6. color ultrasound flowmetry/or echoencephalography/or vascular ultrasound/
7. 5 or 6
8. 1 and 7
9. limit 8 to (human and english language and article and (adult <18 to 64 years> or aged <65+ years>))
10. angioma/
11. 1 or 10
12. 7 and 11
13. limit 12 to (human and english language and article and (adult <18 to 64 years> or aged <65+ years>)) = 164 results

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