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Review article

The diagnostic accuracy of magnetic resonance angiography for blunt vertebral artery injury detection in trauma patients: A systematic review and meta-analysis

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ABSTRACT

The role of magnetic resonance angiography (MRA) in the evaluation of patients with blunt vertebral artery has not been fully established. Our aim is to define the diagnostic accuracy of MRA in comparison to digital subtraction angiography (DSA) for the detection of blunt vertebral artery injury in trauma patients. A computer-assisted literature search of the PubMed, Scopus, Highwire, Web of Science, and LILACS was conducted, in order to identify studies reporting on the sensitivity and specificity of MRA in comparison to DSA for the detection of blunt vertebral artery injury in trauma patients. The Database search retrieved 91 studies. Five studies fulfilled our eligibility criteria. Two authors assessed the risk of bias and applicability concerns using QUADAS-2. Two-by-two contingency tables were constructed on a per-vessel level. Heterogeneity was tested by the statistical significance of Cochran's Q, and was quantified by the Higgins's I^2 metric. The pooled estimates of sensitivity and specificity for blunt vertebral artery injury detection with MRA in comparison to DSA were calculated based on the bivariate model. The meta-analysis was supplemented by subgroup and sensitivity analysis, as well as analysis for publication bias. There was significant clinical heterogeneity in the targeted population, inclusion criteria, and MRA related parameters. The reporting bias and applicability concerns were moderate and low, respectively. In the overall analysis, the sensitivity ranged from 25% to 85%, while the specificity varied from 65% to 99%, across studies. According to the bivariate model, the pooled sensitivity and specificity of MRA in the evaluation of patients with blunt vertebral artery was as high as 55% (95% CI 32.1%–76.7%), and 91% (95% CI 66.3%–98.2%), respectively. Subgroup analysis in terms of MRA sequence sensitivity of phase, the contrasted MRA (75% [95% CI 43%–92%]) seemed to be superior to the TOF MRA (46% [95%CI 20%–74%]). The addition of contrast enhancement did not seem to improve the diagnostic yield of MRA. The Egger's test did not identify any significant publication bias ($p = 0.2$). An important limitation of the current meta-analysis is the small number of eligible studies, as well as the lack of studies on newer, high-field MR scanners. We concluded that MRA has a moderate diagnostic accuracy in the diagnosis of blunt vertebral artery injuries. Further studies on high-field magnetic resonance scanners are recommended.

1. Introduction

1.1. Background

Blunt vertebral artery injury (BVAI) is an increasingly recognized clinical entity among trauma patients. Along with blunt carotid artery injury are collectively known as blunt cerebrovascular injuries. Its incidence has been reported to be as high as 1% of trauma cases, and this has been demonstrated to be up to 34% of patients suffering blunt neck trauma [1]. Despite the recent rising of awareness regarding these injuries, most of them still remain undetected. Up to one fourth of the affected patients suffer from serious neurological disability, which is unfortunately manifested when neurological damage is already irreversible [1–4].

Digital subtraction angiography (DSA) is considered the gold standard imaging modality in the detection of BVAI. However, it is an invasive methodology, with up to 0.1% and 1% mortality and morbidity, respectively [5,6]. Computerized tomographic angiography (CTA) is

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currently considered as an optimal tool for BVAI screening, especially at an emergency setting [5]. Magnetic resonance imaging and angiography (MRI/MRA) are reserved for patients with concomitant neurological damage, to identify and characterize vessel injury, and also to evaluate the presence and the extent of any associated cerebral ischemic events [5]. Moreover, MRI of the cervical spine may further elucidate an underlying spinal cord injury.

MRA is a non-invasive MR-based technique, which uses no ionizing radiation, and is usually performed without intravenous contrast administration [7–10]. Moreover, it may be combined with other advanced MRI techniques, such as Diffusion Weighted Imaging (DWI), which may identify cerebellar ischemia, at a very early stage [11]. Nevertheless, it is a costly, and time-consuming modality, which may be limited by all known MR contraindications [7]. MRA is currently considered inadequate and suboptimal for the screening of BVAI [5].

The diagnostic accuracy of MRA for blunt vertebral artery injury detection in trauma patients been studied sporadically through single center case series (Level of Evidence 4) [2,12–16]. In addition, the results of these studies are often contradictory [2,12]. Thus, there is an obvious need for reviewing the relevant literature, and for meta-analyzing the available data, in order to provide the overall diagnostic accuracy of this imaging modality in patients with BVAI (Level of evidence 1) [16]. Exact knowledge of the MRA's diagnostic accuracy is important for its appropriate use in the management and treatment modification of patients with BVAIs.

2. Methods

2.1. Literature search − data sources

We performed a computerized search of Pubmed, Scopus, Highwire, Web of Science, and LILACS medical databases. Our search criteria included only adult human studies, published in English, during the last 25 years. Our search terms were: "blunt vertebral artery injury", "BVAI", " magnetic resonance angiography", "MRA", "DSA", "Digital subtraction angiography", "diagnosis", "sensitivity", and "specificity", in any possible combination (Table 1).

2.2. Eligibility

Duplicate articles were eliminated. Two authors (AB and GK) assessed the titles and abstracts of the gathered articles, in order to eliminate irrelevant items (experimental studies, unpublished data or congress presentations/abstracts, review articles). The full texts of the remaining studies were retrieved and were further analyzed. Studies with inappropriate target population (pediatric cases), underpowered (included < 5 patients), and those using other imaging modality than DSA as the reference tool were discarded. The reference lists of the resulting full-texts were meticulously searched for any additional relevant citations. Finally, we eliminated studies that did not provide the necessary data (true positive, false positive, true negative, and false negative rates) for constructing 2 × 2 contingency tables for the diagnostic accuracy estimation. The results of this literature search are depicted on Fig. 1.

2.3. Quality appraisal

Two authors (AB and GK) independently performed a quality appraisal of the gathered articles, based on the form suggested by the Quality Assessment of Diagnostic Accuracy Studies −2 (QUADAS-2) [17]. The risk of bias and concerns of applicability were assessed in four main domains ("patient selection", "index test", "reference standard", and "flow and timing") as "low", "medium", or "high". In the case of disagreement, the two authors reached a consensus after consulting one of their senior co-authors (EK).

2.4. Data extraction and synthesis

The authors collected the following data: 1) the name of the first author and the year of publication, 2) the type of study, 3) the targeted population and the diagnostic criteria, 4) the size of patient sample, its demographic characteristics, and the disease prevalence, 5) the number of patients who underwent both DSA and MRA, 6) the risk of bias and applicability concerns, and 7) a number of technical characteristics of the index test including the strength of the magnetic field, and the type of MRA. In addition, the authors constructed 2 × 2 contingency tables with the number of true positive, false positive, true negative, and false negative data for each of the included studies.

2.5. Statistical analysis

The inter-study heterogeneity of sensitivities and specificities was assessed by the significance of the Cochran's Q-metric (pQ), and quantified by the Higgins I^2 statistics.

Initially, we estimated the primary diagnostic accuracy estimators including sensitivity, specificity, positive, and negative likelihood ratios [LR(+), LR(−)], and the diagnostic odds ratio (DOR). The results were visualized by forests plots, and were summarized in tables. The pooled estimates of LR (+), LR (−), and their 95% CIs were calculated based on the random-effect model in anticipation to the "threshold effect".

In addition, we estimated the pooled sensitivity and specificity according to bivariate approaches (bivariate and HSROC models) in anticipation of a positive correlation between sensitivity and false positive rate [18]. Thus, we estimated the HSROC pooled sensitivity and specificity and their 95% CIs based according to the bivariate model of Reitmsa [18,19]. In addition, coupled forest plots and SROC plots visualized the correlation between the two metrics. We used 0.5 values for continuity correction whenever necessary. Significance was set at $p < 0.05$ for all analyses.

Subgroup analysis was planned to compare the diagnostic accuracy of MRA in the diagnosis of BVAI according to 1) the acquisition technique (time-of-flight [TOF] vs. phase contrast [PC]), 2) the use of contrast enhancement (with vs. without contrast), and 3) the strength of the scanner's magnetic field. On the other hand, sensitivity analysis

Table 1
Details of electronic database search strategy.

Frame	Mesh terms	Search	Exclusion Criteria	Sources
P (patients, participants, population)	#1. "BVAI" OR "blunt vertebral artery injury" OR "BCVI" OR "blunt cerebrovascular artery injury"	#1 AND #2 AND #3 AND #4	Irrelevant Title or abstract, irrelevant full text, letter to the editor, editorial, reviews, meta-analysis, studies with less than 5 subjects, no MRA as the index test, no DSA as the reference test	Databases (Pubmed, EMBASE, Scopus, Web of Science, High Wire, LILACS)
I (index test).	#2. "MRA" OR "magnetic resonance angiography"			
C (comparator/reference test)	#3. "DSA" OR "digital subtraction angiography"			Reference list
O (outcome)	#4. "diagnosis" OR "sensitivity" OR "specificity" OR "accuracy"			