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Is MRA More Accurate In Diagnosing Cervical Vascular Injury In Trauma Patients Than CTA?

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Abstract

Aim

The aim of this systematic review was to evaluate the diagnostic accuracy of magnetic resonance angiography (MRA) versus computed tomography angiography (CTA) for cervical vascular injury secondary to trauma.

Background

CTA is widely used in practice to diagnose cervical vascular injuries, largely supplanting the gold standard of digital subtraction angiography (DSA). However, the use of CTA is limited by the exposure to ionising radiation and lack of sensitivity in some contexts. Hence, evaluation of the potential diagnostic accuracy of MRA in this context is justified.

Methods

A systematic literature review was completed using online databases and a clear search strategy. Diagnostic accuracy studies involving the use of CTA and/or MRA in the diagnosis of cervical vascular injuries were sought, with a focus on human studies, primary studies and literature published between 2011 and 2021. Studies were subjected to formal critical appraisal using the Critical Appraisal Skills Programme toolkit and were synthesised using a narrative framework.

Results

The results of the literature search identified seven studies that met the review inclusion criteria. Five studies evaluated the diagnostic accuracy of CTA, noting sensitivity ranging from 51% to 72% for cervical vascular injury, high specificity (63–97%) and a high overall diagnosti[1]c accuracy (95%) compared with DSA. MRA diagnostic accuracy was not as robustly assessed in the two included studies, although evidence suggests consistency with expert consensus imaging and CTA/DSA imaging standards in specific contexts. No study directly compared CTA and MRA in the diagnosis of cervical vascular injury secondary to trauma.

Conclusion

These findings suggest that CTA remains the imaging strategy of choice for suspected cervical vascular injury, as MRA does not have evidence supporting use in this context. The practical use of CTA and availability of this imaging approach further supports its use in trauma contexts.

Introduction

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Chapter 1: Introduction

Background

It is estimated that 5–10% of presentations to emergency departments involve significant trauma to the head and/or neck (Hussain and Javed, 2011). Of these injuries approximately 80% are thought to result from blunt injury, versus 20% due to penetrating injuries (Saito et al., 2014). However, data from international studies may be skewed by the relatively high level of injury attributed to gunshot wounds in the United States and other nations where firearm use is common relative to the United Kingdom (UK) (Kasbekar et al., 2017). However, data on these injuries from the UK are less robust and it is considered that penetrating neck injuries are relatively uncommon in the UK emergency setting, although increasing levels of urban violence has led to a steady increase in case presentations (Siau et al., 2013). Indeed, over 30,000 offences occur annually involving a knife or sharp weapon and 10% of trauma patients have a penetrating neck injury (Kasbekar et al., 2017). Furthermore, the mortality rate of these injuries remains relatively high, ranging from 3–10% (Jenkins and Rezende-Neto, 2020). Mortality typically results from the resulting injury to vascular structures and the risk of exsanguination, highlighting the clinical importance of these injuries (Kasbekar et al., 2017).

The definition of cervical vascular injury is broad and includes any form of vascular injury or trauma-related pathology that has the potential to compromise morbidity or mortality. This includes carotid artery dissection or occlusion, intimal flaps, arteriovenous fistula, transection, pseudoaneurysms, and vertebral artery pathology (LeBlang and Nunez Jr, 2000; Payabvash et al., 2014; Evans et al., 2018). The injuries with the greatest risk of immediate mortality, due to massive blood loss, include carotid artery injuries, particularly dissections and transections, and these are also the most common forms of injury, accounting for 80% of cases of neck trauma (LeBlang and Nunez Jr, 2000; Siau et al., 2013). Vertebral artery injury is also a common finding in patients with cervical spine trauma and indiscriminate screening is considered in guidance when cervical injury has occurred (Tobert et al., 2018). Within the context of trauma patient management, multiple injuries may be sustained across various sites of the body, contributing to the complexity of patient assessment and management (Jenkins and Rezende-Neto, 2020). The mechanism of traumatic injury may have important implications for the types of injuries sustained, including within the cervical region, as blunt traumatic injuries may be less overt then penetrating injuries (Payabvash et al., 2014). It is vital that neck vasculature is assessed within the context of any traumatic injury, even if other regions are affected, due to the high level of risk of exsanguination and the frequency of injury to vessels in this region linked to both blunt and penetrating trauma (Kasbekar et al., 2017). Grading of cervical vascular injuries is also commonly performed, with the grading system of Biffl et al. (1999) utilised, which is specific to blunt carotid artery injuries. The grades of injury are shown in Table 1, which correlate with the risk of stroke and the mortality rate of the injury, highlighting the clinical value of the grading process.

Table 1. Cerebrovascular injury grading scale (Biffl et al., 1999: 847)

Injury grade	Description	Stroke rate (%)	Mortality rate (%)
I	Luminal irregularity; <25% narrowing of the lumen	3	11
II	Dissection or intramural haematoma; 25% of greater narrowing, intraluminal thrombus or raised intimal flap	11	11
III	Pseudoaneurysm	33	11
IV	Occlusion	44	22

V	Transection with extravasation	100	100

Diagnosis of vascular injury following trauma is crucial to effectively managing the patient in an emergent context (Jenkins and Rezende-Neto, 2020). While diagnosis may be facilitated by clinical evaluation, including any obvious exterior penetrating injuries to the cervical region, internal injuries due to trauma require imaging strategies. Indeed, cervical vessel damage may occur secondary to both penetrating and blunt trauma and these injuries may be difficult to detect in a clinical examination (Schroeder et al., 2010) and it is reported that clinical examination alone has only a 61% sensitivity for detecting significant vascular injury in the neck and head (Sclafani et al., 1991), consistent with more recent estimates of sensitivity (57%) for vascular injury detection following penetrating trauma to the cervical region (Mohammed et al., 2004). The level of trauma and the consequences to the patient can vary significantly, depending on the nature of trauma and the clinical characteristics of the patient (such as the presence of comorbidities, including bleeding disorders), although any cervical vessel injury is linked to the risk of complications and poor outcomes (Patterson et al., 2012). Trauma to major arteries in the neck can present a serious risk of morbidity and mortality unless identified urgently (O'Brien and Cox, 2011).

Over the last half a century, the approach to diagnosing and managing cervical vessel trauma has modified in response to the increasing role of diagnostic imaging strategies (Rutman et al., 2018). While traditional approaches to diagnosis and management were often combined within surgical exploration and intervention in the affected region, increasing selective non-operative treatment is viewed as the optimal strategy (Van Waes et al., 2012). Indeed, endovascular repair of vascular trauma is a common procedure indicated for serious cervical vessel injury and has been shown to be highly effective and life-saving treatment when such trauma is identified (Simon and Brown, 2020). This strategy relies on accurate non-invasive imaging assessment of the patient (Patterson et al., 2012). Consequently, there is an increasing recognition of the need for rapid and sensitive imaging strategies that may be used prior to or during operative procedures in trauma patients, in order to guide diagnosis (Meghoo et al., 2012).

Imaging strategies in diagnosing cervical vascular injury

The need for accurate imaging studies developed over the course of the Twentieth Century and into the Twenty-First Century, as result of changes to management of blunt and penetrating neck injury during World Wars and the Vietnam War, among others (Feliciano, 2017; Kasbekar et al., 2017). The role of imaging was recognised as increasingly important in avoiding exploratory surgical interventions that had a risk of complications and adverse outcomes (Feliciano, 2017). The use of conventional angiography (digital subtraction angiography; DSA) emerged as an important imaging strategy in this context, utilising X-ray imaging in a two-dimensional plane and the use of contrast agents within the affected vessels (Feliciano, 2017). This imaging strategy was proposed as a gold standard in haemodynamically stable patients with clinical signs suggestive of cervical vessel trauma (Strickland et al., 2019). Indeed, studies showed that the use of angiography facilitated an opportunity to diagnose pathology in a significant proportion of patients, while potentially guiding the nature of surgical interventions and impacting on mortality (Thomas et al., 1978; Fakhry et al., 1988; Strickland et al., 2019). However, limitations to this strategy were evident in practice and challenged the routine use of angiography in this context. Firstly, the technique was time-consuming in nature and delayed the initiation of surgical interventions in patients, which may contribute to a risk of mortality (Strickland et al., 2019). The time-consuming nature of the technique was particularly hard to justify given the low sensitivity for detection of vascular injury, with more than 80% of cases showing a negative result following screening, despite the presence of a treatable lesion (Ofer et al., 2001). Finally, the risks associated with the invasive nature of the procedure, particularly in patients with penetrating injuries and complex management issues (Strickland et al., 2019).

The consequences of the notable limitations of angiography (DSA) was that alternative imaging strategies were sought that met specific criteria in this clinical context. Firstly, imaging strategies had to be sensitive (i.e. accurate) in detecting vascular injury in the cervical region, with a diagnostic accuracy far greater than conventional angiography (Ofer et al., 2001). Secondly, the technique should limit the delay between initial patient assessment and subsequent management as much as possible. Thirdly, the imaging strategy should be non-invasive in nature to facilitate rapid use and to avoid complications linked to invasive imaging (Saito et al., 2014).

Non-invasive imaging studies emerged as important alternatives in practice and included ultrasonography. Indeed, the role of Doppler ultrasonography has been described in the context of vascular imaging in the cervical region but is generally not performed in contemporary practice in the context of traumatic injury (Feliciano, 2015). Other imaging strategies are often preferred due to the limitations of the technique, including relatively low sensitivity for detection of traumatic injury, operator and injury location variability in diagnostic accuracy and a limited field of imaging evaluation (precluding assessment of wider injuries linked to trauma) as noted in the wider literature (Feliciano, 2015). Consequently, the use of common, non-invasive imaging strategies, including computed tomography (CT), have become more widespread in this context (Eastman et al., 2006; O'Brien and Cox, 2011).

CT angiography

CT angiography (CTA) has been used in the context of evaluating neck vasculature, both in traumatic and non-traumatic contexts for decades (Munera et al., 2000). The initial interest in this imaging approach for traumatic injuries stemmed from the recognition that CTA can be used to detect atherosclerotic disease in the carotid arteries with a high degree of accuracy, suggesting suitability for vascular imaging in the neck (Munera et al., 2000). The technique has advantages over the use of conventional angiography in that it is non-invasive and provided three-dimensional imaging planes, allowing for more detailed analytical assessment of vasculature in the cervical region (Wakao et al., 2014).

Studies evaluating the use of CTA in traumatic vascular imaging emerged in the literature and provided a basis for justifying the use of the imaging technique in emergency contexts (Ofer et al., 2011; Wakao et al., 2014). Munera et al. (2000) found in an early prospective study comparing CT angiography to conventional angiography, that sensitivity of CTA was 90% and specificity 100%. Subsequent studies found comparable results, with sensitivity and specific of CTA ranging from 90–100% for a range of pathological lesions linked to cervical vascular injury, including occlusions, pseudoaneurysms, fistulae, thromboses and dissections (Gracias et al., 2001; Munera et al., 2002; Hollingworth et al., 2003). However, a significant proportion of studies are now over a decade in age and may reflect older CT technologies and protocols. The evolution of CT imaging over time, including the use of multi-slice imaging increase the detail captured in imaging studies and reduce the time needed for image capture (Hanning et al., 2017). Therefore, as technology evolves with CT imaging, there is a need to ensure that evaluation of CTA in the context of trauma remains up-to-date and reflects the advantages of newer technologies in practice (Hanning et al., 2017). Furthermore, the adoption of CTA within trauma management protocols has led to refinement of the use of this imaging approach, maximising the clinical relevance of the findings and improving the potential to modify treatment options and surgical intervention approaches (Hagedorn et al., 2014). Despite these protocols and technological advances, the use of CTA remains a point of discussion in the literature regarding the diagnostic value and accuracy of the approach, as imaging may not routinely influence or alter surgical treatment of cervical spine injuries (Hagedorn et al., 2014). While imaging can influence detection of lesions that increase the risk of stroke, and may indicate the need for antithrombotic therapy, questions over their diagnostic accuracy may limit the degree to which these findings influence care, particularly where other traumatic injuries may influence clinical interventions and priorities (Hagedorn et al., 2014).

Magnetic resonance angiography

While CTA has been identified as an emerging gold standard imaging strategy for diagnosing vascular trauma in the cervical region (Sporns et al., 2019), there is an increasing interest in the value of magnetic resonance angiography (MRA) in this context (Four). MRA is a technique based on magnetic resonance imaging, a non-invasive technique that does not require exposure of the patient to ionising radiation (Saito et al., 2014). The key advantages of MR imaging versus CT imaging rest with the potential to discriminate soft tissue margins with a greater degree of accuracy, which allows for more detailed characterisation of tissues and anatomical injury in many contexts (Fourman et al., 2019).

Both CTA and MRA have been associated with clinical value and diagnostic accuracy in a range of vascular imaging contexts, including peripheral artery disease (Varga-Szemes et al., 2017), stroke (Mair et al., 2017), and in the assessment of the cerebrovascular system Figueiredo et al., 2012). However, in the context of traumatic injury and the assessment of cervical vascular injury, the comparative diagnostic accuracy and value of these imaging modalities, particularly MRA, is not as clear. While the evidence base supporting CTA is based on a range of studies that support the use of the approach in practice, the evidence for the use of MRA, particularly when contrasted with gold standard assessment, remains uncertain (Fourman et al., 2019).

Studies evaluating the use of MRA in trauma contexts do provide some support for the theoretical advantages of the modality. For instance, Vaccaro et al. (1998) provided an early estimation that MRA could be used in trauma contexts, although this reflected long-term outcome evaluation rather than initial diagnosis of lesions/injury. However, Weller et al. (1999) established that MRA with flow-sensitivity could provide an accurate assessment of cervical vascular injury following trauma, although the diagnostic accuracy of the method was not evaluated in detail. Other studies have suggested that MRA may be used to effectively isolate traumatic injury to cervical vasculature, including arterial occlusion, dissection, and pseudoaneurysm (Taneichi et al., 2005; Buerke et al., 2007; Yang et al., 2008; Tan et al., 2009). Furthermore, the use of MRA in practice suggests that the imaging approach may also have an influence on clinical decision-making and intervention choices where cervical pathology has been detected (Jacob et al., 2016). However, to promote wider use of MRA in practice, there is a need to evaluate diagnostic accuracy in comparison with established imaging modalities, including CTA.

Current debates and gaps in the knowledge base

Despite the potential advantages of the MRA approach to imaging soft tissue and associated trauma in the neck compared to CTA, there remain important considerations to using this approach widely in practice. Firstly, there is a need for clarity regarding the comparable diagnostic accuracy of CTA and MRA in this context, ideally demonstrated through head-to-head studies (Patel et al., 2012). However, imaging outcomes based on discrimination of anatomical features of injury alone may not be sufficient to recommend one technique over another, particularly if artefactual data may be more common with one modality, potentially complicating diagnosis of injuries. Furthermore, sensitivity and specificity of the imaging strategies need to be compared, with the use of a clear gold standard approach as a baseline for comparison of these strategies (Eusebi, 2013). As CTA is considered a gold standard technique in the literature, direct comparison of the value of MRA can be considered against CTA, along with the potential added value of sequential CTA and MRA imaging (Hagspiel et al., 2015). Therefore, a robust approach is needed to determine the optimal imaging strategy in terms of anatomical visualisation and diagnostic accuracy.

Practical issues regarding imaging also need to be considered, particularly in light of the costs and time required to obtain MRA imaging assessments in a trauma context (Patel et al., 2012). The feasibility of the approach should be balanced with the potential benefits in terms of imaging quality, potential to identify neurological and vascular damage in detail, and the lack of ionising radiation associated with the modality (Greenspan and Beltran, 2020). Consideration of other practical features of imaging within a trauma context also need to be considered to ensure the application of theoretical findings to the practice setting, including the contraindications for CT and MR imaging and aspects of the imaging protocols that may be used to optimise patient assessment. Furthermore, the identification of vascular injuries alone may be valuable, but unless these injuries require intervention or have marked clinical significance, their detection may not add to the assessment process and could delay management of other trauma-related injuries (Dunn et al., 2020). There is a need to ensure that all imaging studies are therefore aligned with the wider aim of managing trauma and play a key role in assessment without delaying other assessments or interventions. Hence, there is a need not only to evaluate diagnostic accuracy of these modalities in a comparative manner but also to establish the practical benefits and drawbacks of both, which may determine uptake among emergency practitioners (Greenspan and Beltran, 2020).

Justification for study

The evidence gaps provide an important focus for the present paper, namely the need to improve the knowledge base and provide a clear evaluation of data to provide an opportunity for promoting evidence-based practice. Imaging strategies for cervical vascular injuries have been recognised as playing an important role in the diagnosis of injuries and can facilitate the use of endovascular techniques and selective non-surgical management that have been shown to have high efficacy and lower rates of complications than surgical management (Seth et al., 2013). However, for these imaging strategies to guide interventions effectively, there is a need for clear evaluation of the diagnostic accuracy of these modalities and an appreciation of contemporary evidence to take into account advances in technology for both CT and MR imaging approaches. The evaluation of the comparable diagnostic accuracy of these strategies can provide an important guide to practitioners in radiography, radiology and emergency department settings, all of whom play a key role in facilitating the management of patients experiencing acute trauma and traumatic cervical injury (Greenspan and Beltran, 2020).

Evidence-based practice forms a cornerstone of contemporary trauma management and the use of imaging should be subject to the rigorous evaluation of the evidence base to guide application in trauma contexts (Beckmann et al., 2019; Long et al., 2020). Debates over the need for focused imaging on specific anatomical sites, versus the value of whole-body imaging in trauma contexts have been noted in the literature (Long et al., 2020). Therefore, the value of the CTA approach and/or the MRA approach should be considered within the need for anatomically focused evaluation of traumatic injury in the cervical region. While both modalities may have value in practice, the need for evidence-based assessment has the potential to optimise not only the diagnostic accuracy of assessments, but also to optimise wider practice and trauma management (Merrill et al., 2020).

Conclusion and aims

This chapter provides an insight into the importance of evaluating the diagnostic accuracy of CTA and MRA for cervical vascular injury secondary to trauma. While CTA is commonly used in practice and represents a gold standard technique, the advantages of MRA need to be considered in the context of improving diagnosis and management of this complex condition. There is a need to compare the diagnostic accuracy of CTA and MRA to fundamentally determine the potential for MRA to serve as an alternative or replacement for CTA in this context, in order to guide best practice.

The findings of this chapter highlighted key gaps in knowledge regarding the optimal imaging strategy in patients with potential cervical vascular injury following trauma. While the use of CTA in this context is common in practice, there is uncertainty over the potential for MRA to replace or serve as a valid and reliable alternative to CTA for diagnosing cervical vascular injury. This is an important issue, as the use of imaging strategies with a high level of diagnostic accuracy can facilitate clear diagnosis of cervical vascular injury, as well as facilitating rapid and accurate assessment and management decisions in the context of trauma.

The review question is as follows: is MRA more accurate in diagnosing cervical vascular injury in trauma patients than CTA? To answer this question, the following objectives were defined for this review:

- To evaluate the diagnostic accuracy of CTA for cervical vascular injury in trauma patients
- To compare the diagnostic accuracy of MRA with CTA in this context
- To evaluate the practical and clinical implications of using CTA or MRA for cervical vascular injury assessment in trauma patients

Chapter 2: Methodology

Rationale and approach

The aim and objectives defined in the previous chapter focus on a clear comparison of the diagnostic accuracy of two imaging modalities. Diagnostic imaging study comparisons should be based on quantitative data sets, as quantitative data provide an insight into objective, measurable outcomes related to a specific outcome (Cronin et al., 2018). This contrast with the use of qualitative data, which is generally more valuable in appreciating experiences or subjective aspects of phenomena in practice, without providing objective evaluations that can inform a comparison of imaging modalities (Mills et al., 2015). Hence, a quantitative approach was employed in the present analysis in order to address the aim and objectives defined above.

Numerous research approaches may be used to perform a quantitative comparison of diagnostic accuracy of imaging modalities, including both primary and secondary research (Blankenbaker, 2016). While primary research, which involves a novel study design and collection of data from participants, can be valuable in this regard, it was not considered feasible given the time constraints of a dissertation and the limitations on data collection presented by the COVID-19 pandemic. In contrast, secondary research methods rely on published data and literature, allowing for an analysis and synthesis of the existing knowledge base, without the need for primary data collection (Dawson, 2019). This approach was used in this instance, as it not only provided a feasible strategy compared to primary research but allowed for analysis of a potentially large body of literature, while providing a synthesis of the published literature to date (Remler and Van Ryzin, 2014). This is useful as it provides an opportunity to compare and contrast literature and to perform an overall analysis of the evidence to date, providing a basis for summarising knowledge in the field and remaining gaps in the evidence base. Various approaches to secondary research have been reported (Bowling, 2014) but the literature review method is considered the most common in healthcare literature (Garrard, 2020). Specifically, the systematic literature review (SLR) is considered a gold standard approach to literature appraisal, due to the adoption of clear criteria for identifying, analysing and synthesising literature, minimising the risk of bias in these processes (Bettany-Saltikov, 2012). Therefore, the remainder of this chapter provides a detailed discussion of the SLR method as applied to the defined review question, aim and objectives.

Search strategy

Multiple databases were used in the search strategy in order to maximise the number of relevant studies for inclusion in the review (Bramer et al., 2017). Combinations of databases containing healthcare-related, peer-reviewed literature has been advocated in the wider literature, providing an opportunity to overcome the indexing and search limitations of individual databases (Aagaard et al., 2016). The CINAHL, Embase, and Medline databases were included in this review, as this combination has been shown to provide a substantial body of literature in the context of diagnostic accuracy and imaging studies (Tanon et al., 2010; Kim et al., 2018).

Key search terms were identified based on a number of methods. Firstly, the population-intervention-comparison-outcomes (PICO) framework was used to define the review question and to identify key criteria for search term selection (Aveyard, 2014). This framework is presented in Table 2. The PICO structure reflects a focus on adult patients who have experienced traumatic injury, the evaluation of MRA and CTA and the key outcomes linked to diagnostic accuracy assessments, as noted in the wider literature (Cohen et al., 2017). The search terms for the search strategy were derived using the PICO structure, with key terms selected based on evaluation of 'key words' within articles used in the background section of the review and synonyms generated by the reviewer (Aromataris and Riitano, 2014). Search terms were also developed from the Medical Subject Headings (MeSH) terminology used in the Medline database, which provides a structured approach to indexing key words relating to specific clinical topics or conditions (Kable et al., 2012). Search terms were combined using Boolean operators (e.g. AND, OR) which allows for optimal combination of terms and efficiency in the search process (Peters, 2015). Additional search tools were also considered, including truncation (*) of search terms and accommodation of alternative spellings ($), both of which allowed for maximisation of the identification of relevant studies across international literature, although were not necessary based on the terms selected (Table 3).

Table 2. PICO criteria

PICO criteria	Definition
Population	Adults with cervical vascular injury associated with trauma
Intervention	Computed tomography angiography
Comparison	Magnetic resonance angiography
Outcomes	Diagnostic accuracy

Table 3. Search terms

PICO criteria	Search terms and strategy
Population	"vascular injury" AND "cervical" OR "cerebrovascular injury" AND "blunt" OR "penetrating" OR "blunt cerebrovascular injury" OR "BCVI" OR "vertebral artery injury" OR "VAI" OR "carotid artery injury" OR "CAI" OR "dissection"
Intervention	AND "computed tomography angiography" OR "CTA"
Comparison	AND "magnetic resonance angiography" OR "MRA"
Outcomes	AND "diagnostic accuracy" OR "sensitivity" OR "specificity" OR "predictive value"

Delimiters within the search databases were used to further refine the search process and to apply the inclusion and exclusion criteria defined in Table 4. Delimiters included a focus on human studies, the date range of published studies, and selection of English language publications (Porritt et al., 2014). These criteria were important in ensuring a contemporary data set for analysis (reflective of the most recent practice standards and technology), maximising relevance of studies to human/clinical contexts, and ensuring that translation was not needed, which is costly and may potentially introduce errors into the data set (Jesson et al., 2011). Other inclusion and exclusion criteria are noted in Table 4 and highlight the focus on primary, quantitative studies related to the PICO criteria.

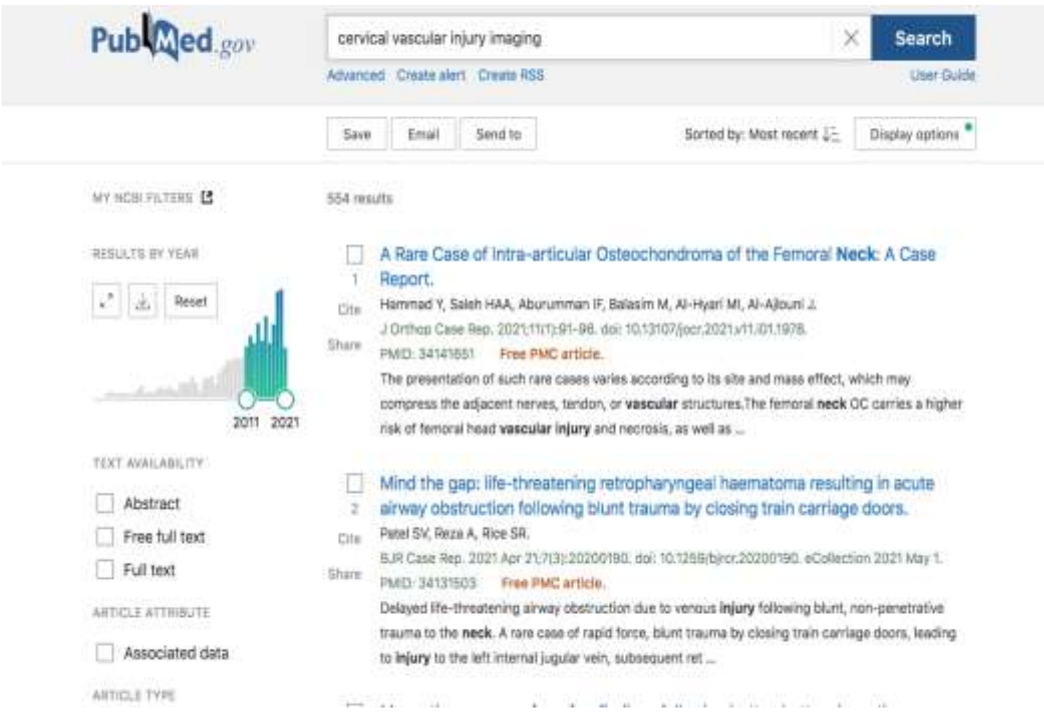
Table 4. Inclusion and exclusion criteria.

Inclusion criteria	**Exclusion criteria**	**Justification**
English language studies	Non-English language studies	Precludes the need for translation
Human studies	Laboratory or animal studies	Greater relevance to clinical care
Studies published 2011-2021	Studies published prior to 2011	Contemporary literature is more likely to reflect current practice and imaging protocols/technology
Primary research studies	Secondary studies	Secondary studies may be biased in their interpretation
Studies reporting diagnostic accuracy outcomes	Studies without any consideration of diagnostic accuracy	Diagnostic accuracy outcomes are crucial in comparing the performance of CT and MRA

Of note only primary studies were included to avoid the risks of including secondary research (which may have bias introduced by authors interpreting data), while specific types of study were preferred to align the review with evidence-based practice standards (Jesson et al., 2011). The hierarchy of evidence (Ingham-Broomfield, 2016) is a conceptual model that illustrates the methodological design of studies of greatest relevance to evidence-based practice, based on bias and other factors (Creswell and Creswell, 2017). Within the context of diagnostic accuracy studies, methodologies of relevance to the evaluation of evidence-based imaging practice may be further limited, with a focus on experimental methods (randomised controlled trial) and non-experimental methods (cross-sectional, cohort and case-control studies) (Karkada, 2015). Therefore, the review only included these study designs, while case studies and other methodologies were excluded to maintain a focus on high-quality evidence (Elamin and Montori, 2012).

An example of the search strategy applied to the PubMed interface, with specific isolation of Medline database results, is presented in Figure 1. Following the search strategy, a formal process was used to refine the studies and ensure relevance for inclusion in the final review data set (Moher et al., 2015). The preferred reporting items for systematic reviews and meta-analyses (PRISMA) statement was used to guide this process, as this is widely used and recommended in SLRs (Moher et al., 2015). The PRISMA refinement stages included amalgamation of search findings across all databases (with data management facilitated by Mendely software) and exclusion of duplicate entries (Stovold et al., 2014). A series of refinement stages were then completed based on analysis of the study titles, abstracts and full-text versions, with comparison of the study content to the defined inclusion and exclusion criteria. This led to exclusion of irrelevant articles and the selection of the final review data set (Figure 2).

Figure 1. Screenshots of search results in the Medline database (via PubMed interface)



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3 Magnetic resonance **imaging** findings following button battery ingestion.
Grey NEO, Malone LJ, Miller AL, Carroll HF, Khalaf RT, Kramer RE, Browne LP.
Pediatr Radiol. 2021 Jun 1. doi: 10.1007/s00247-021-05085-w. Online ahead of print.
PMID: 34075452
OBJECTIVE: Our goal was to review MRI/MR angiography **imaging** in button battery ingestion cases and compare with other **imaging**, clinical data and outcomes in these patients. ...Severe complications were found in 48% of patients (11/23), including esophageal perforati ...
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4 Proximity of the middle meningeal artery and maxillary artery to the mandibular head and mandibular **neck** as revealed by three-dimensional time-of-flight magnetic resonance angiography.
Schönegg D, Ferrari R, Ebner J, Blumer M, Lanzer M, Gander T.
Oral Maxillofac Surg. 2021 May 23. doi: 10.1007/s10006-021-00980-0. Online ahead of print.
PMID: 34024006
PURPOSE: The close topographic relationship between **vascular** and osseous structures in the condylar and subcondylar region and marked variability in the arterial course has been revealed by both **imaging** and cadaveric studies. ...Extensive surgical experience and tho ...
Cite Share

5 Computed Tomography Angiography for Aero-digestive **Injuries** in Penetrating **Neck** Trauma; A Systematic Review.
Paladino L, Baron BJ, Shan G, Sinert R.
Acad Emerg Med. 2021 May 21. doi: 10.1111/acem.14298. Online ahead of print.
PMID: 34021515
OBJECTIVES: Management of hemodynamically stable patients with penetrating **neck** trauma (PNT) has evolved in recent years with improvements in **imaging** technology. Computed Tomography Angiography (CTA) encompassing all zones of the **neck** has become part of the s ...
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6 Aberrant internal carotid artery in the oropharynx space poses a life-threatening risk of surgery.
Huang S, Li J, He T, Wang Y.
Surg Radiol Anat. 2021 May 21. doi: 10.1007/s00276-021-02771-0. Online ahead of print.
PMID: 34021391
METHODS AND RESULTS: We report two different pathologies of retropharyngeal ICAs, which presented with otolaryngological symptoms. Case 1 Retropharyngeal right ICA. The vessel's minimum distance to the pharyngeal wall was 1 mm (very high risk of **vascular injury** ...
Cite Share

7 Traumatic chylothorax: a dilemma to surgeons and interventionists.
Dar PMUD, Gamanagatti S, Priyadarshini P, Kumar S.
BMJ Case Rep. 2021 May 21;14(5):e238981. doi: 10.1136/bcr-2020-238981.
PMID: 34020985
Chylothorax is generally seen due to iatrogenic **injury** to the thoracic duct during thoracic or **neck** surgery. It can also be encountered secondary to chest trauma either blunt or penetrating. ...
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8 Bone Mineral Density Measurements and Association With Brain Structure and Cognitive Function: The Framingham Offspring Cohort.
Stefanidou M, O'Donnell A, Himali JJ, DeCarli C, Satizabal C, Beiser AS, Seshadri S, Zaldy T.
Alzheimer Dis Assoc Disord. 2021 May 11. doi: 10.1097/WAD.0000000000000453. Online ahead of print.
PMID: 33973881
We examine the association between BMD in the "young old" with **imaging** biomarkers of brain aging and cognitive performance. METHODS: Offspring participants (N=1905, mean age 66) of a population-based cohort who had BMD, brain **imaging** and detailed cognitive assessmen ...
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9 Transient global amnesia after radiofrequency catheter ablation of supraventricular tachycardia: a case report.
Cite Share
Sun S, Huang Q, Chen X, Liu Q, Wang C.
Cardiovasc Diagn Ther. 2021 Apr;11(2):472-477. doi: 10.21037/cdt-20-895.
PMID: 33968625 Free PMC article.
Tests were performed immediately and normally including blood routine examination, liver and kidney function, electrolyte, blood glucose, thyroid function, blood coagulation function, D-dimer, myocardial **injury** markers, blood gas analysis and other hematological. There is ...

10 Endoscopic Endonasal Surgery of a Large Vidian Nerve Schwannoma With Preparation for Avoiding Major **Vascular Injury**.
Cite Share
Tanaka C, Kikuchi M, Matsunaga M, Omori K, Nakagawa T.
Cureus. 2021 Mar 31;13(3):e14230. doi: 10.7759/cureus.14230.
PMID: 33959429 Free PMC article.
Based on the above, we suspected a vidian nerve schwannoma, and endoscopic endonasal surgery was performed with particular attention to avoid **vascular injuries**. An endoscopic transmaxillary approach was used to expose the anterior surface of the tumor. ...Endoscopic ...

Page 2

11 A case report of cervicothoracic penetrating **injury** with retention of foreign body.
Cite Share
Hui Y, Yang X, Ma D, Yao M, Liu X, Dai Y, Huang Q, Liu T, Xu J, Li X.
BMC Surg. 2021 May 3;21(1):232. doi: 10.1186/s12893-021-01234-y.
PMID: 33941158 Free PMC article.
CASE PRESENTATION: A male patient suffered from a serious **injury** caused by a thick branch that pierced through his **neck** in a traffic accident between an electric car and a tricycle carrying wood. There were also local **injuries** in the left scapular region. Aft ...

Data analysis and synthesis

Data Extraction is defined as the process of evaluating the findings of studies on an individual basis, identifying the relevant data within those studies, and then isolating and documenting that data in a formal and consistent manner (Hart, 2018). The data extraction process should be reliable in nature, emphasising the importance of utilising a structured framework or tool for this purpose (Bettany-Saltikov, 2012). A widely used approach is a data extraction table or form, which comprises key criteria and data that should be derived from each study and then may be completed upon reading and evaluating each study (Bryman, 2016). An example data extraction form is used in Cochrane systematic reviews and according to the Joanna Briggs Institute for evidence-based medicine (e.g. Munn et al., 2014). The key criteria (data) extracted from individual studies varies across examples in the literature but should be individualised to the review topic (Aveyard, 2014). In this instance, the focus of the review is on diagnostic accuracy of studies and therefore the key data extracted from the review were defined according to specific diagnostic accuracy features, as well as broader features of studies that highlight quality and reliability. These criteria were as follows: study author and date, study design, population studied and sample size, imaging protocol details, sensitivity, specificity, positive and negative predictive values.

Methodological quality assessment was also completed in order to support the data extraction process and provide additional insights into the quality of the data set (LoBiondo-Wood and Haber, 2017). A range of tools are available to support critical appraisal, although many are limited by their application to one specific type of study or a focus that is too broad to take into account methodological issues that apply to specific study methodologies (Schneider et al., 2016). The Critical Appraisal skills Programme (CASP) toolkit was employed for this purpose, as this toolkit contains a range of checklists (tools) that are designed to critically appraise individual study methodologies (Grove and Gray, 2018). The CASP toolkit is widely used in the context of systematic reviews, is flexible in application to a range of studies, and provides a detailed insight into the strengths and weaknesses of each study (Schneider et al., 2016). Each study underwent formal critical appraisal in order to highlight methodological issues within the study. The CASP tool is not designed to provide a numerical quality score or to provide a basis for excluding studies (Bankhead and Stevens, 2018) and therefore the critical appraisal process was used as a basis for informing wider critique of the literature following data synthesis (Boswell and Cannon, 2018).

In addition to the CASP toolkit, the QUADAS-2 instrument was also used to guide evaluation of bias in primary diagnostic imaging studies in this review, as recommended in the wider literature (Mallett et al., 2012). The QUADAS-2 instrument evaluates bias in four key domains: patient selection, index test, reference standard, and flow and timing (Whiting et al., 2011). These elements are considered within wider discussion of the quality of individual studies and the collective data set to support primary analysis with the appropriate CASP tool, allowing for further insights into sources of bias specific to primary diagnostic imaging studies. This is an important point to consider, as bias in diagnostic testing studies may influence the relative interpretation of the value of CTA or MRA, which may influence the key results of the review.

Data Synthesis was the final stage in the review process and involves a comparison of the literature and identification of consistencies and trends across the literature. While a meta-analysis method may be used to combine and evaluate the results of quantitative studies in a robust manner (Moule et al., 2016), this was not considered feasible due to reviewer inexperience and the likely heterogeneity of the included studies (Bettany-Saltikov, 2012). An alternative approach to synthesis was employed, based on evaluation of methods used in other reviews and wider theoretical literature on the topic (Lisy and Porritt, 2016). Narrative synthesis is considered one of the most widely used and valuable approaches to synthesis in SLR contexts, outside of meta-analysis, and has the opportunity to develop a theory of the intervention or test and how this works, allows a clear synthesis of the results of studies, provides a basis for exploring relationships in the data, and allows for robustness to be assessed within the synthesis (Popay et al., 2006).

The narrative synthesis method was performed according to the framework of Campbell et al. (2020), which is defined as the synthesis without meta-analysis (SWiM) framework. This framework involves grouping studies for the synthesis, standardising and describing the synthesis methods, prioritising the key findings across studies, identifying heterogeneity, analysing methods and evaluating the certainty of evidence (Campbell et al., 2020). The narrative synthesis was therefore facilitated by reading the entirety of the incuded studies, identifying consistencies and trends within the literature, and then generating themes/narratives relating to core topics and findings. The reporting phase of this framework involves a structured comparison of the findings of studies, along with reliability and critical appraisal data (Campbell et al., 2020). This framework is beneficial in that it takes into account a range of important factors linked to critical appraisal and is linked to the PRISMA criteria used in this review, aligning the review elements (Campbell et al., 2020).

Chapter 3: Findings

Search Finding

The findings of the search strategy led to identification of 823 unique studies, as shown in the PRISMA flow diagram (Figure 2). These studies were refined, as defined in the previous chapter. Seven studies were suitable for inclusion in the final review data set. A lack of focus on the PICO criteria, failure of studies to report outcomes relating to diagnostic accuracy, and the adoption of secondary research methods were the study exclusion reasons. Importantly, there was a paucity of literature reflecting the use of MRA in the context of blunt or penetrating cerebrovascular injury or other forms of cervical vascular trauma within the body of literature. Five of the included studies focused on evaluating the diagnostic accuracy of CTA (DiCocco et al., 2011; Paulus et al., 2014; Shahn et al., 2016; Grandhi et al., 2017; Ares et al., 2019), while the remaining two studies evaluated the diagnostic accuracy of MRA (Takano et al., 2013; Vranic et al., 2020).

Summary of study quality and characteristics

The findings of formal critical appraisal of the studies using the CASP toolkit are shown in Table 5 and the findings of the QUADAS-2 bias assessment are summarised in Table 6. The summary of the data extraction process is presented in Table 7. The critical appraisal findings generally established the data set as including moderate-to-high quality evidence, based on the strictness of the methods used and the detail of reporting within the studies, according to CASP criteria. Some key methodological limitations were evident across the literature, however. Similarly, heterogeneity was evident across the literature, which included some important differences in patient characteristics, imaging strategies employed, and outcomes assessed.

Figure 2. PRISMA flow diagram

1256 *Is MRA More Accurate In Diagnosing Cervical Vascular Injury In Trauma Patients Than CTA?*

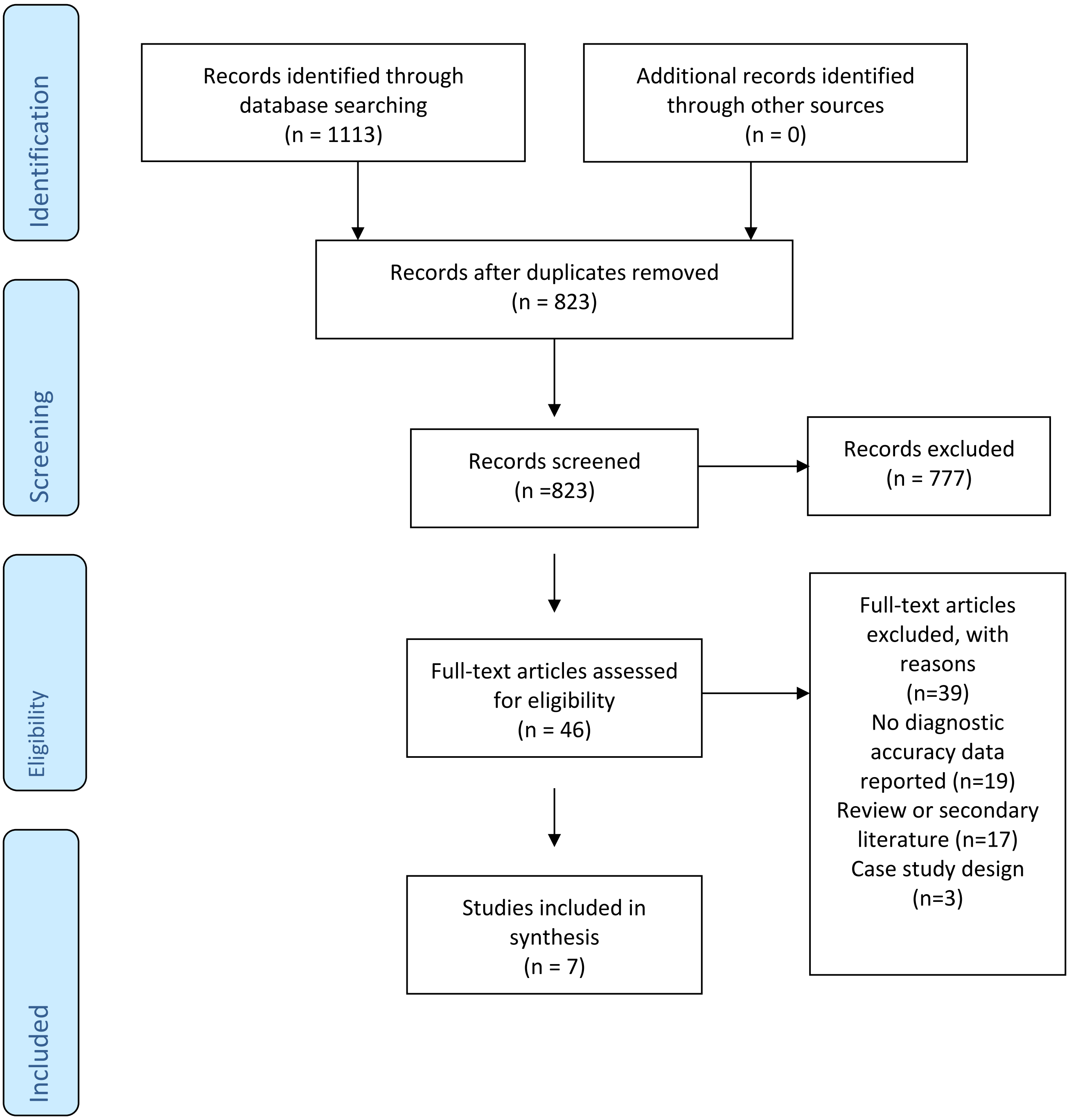

Table 5. CASP critical appraisal findings. The CASP diagnostic checklist was used to inform critical appraisal of all seven included studies. The response to appraisal are noted in the table, according to the following key: yes,Y; No, N; uncertain, ?.

Question	**Dicocco et al., (2011)**	**Takano et al. (2013)**	**Paulus et al., (2014)**	**Shahan et al. (2016)**	**Grandhi et al. (2017)**	**Ares et al. (2019)**	**Vranic et al. (2020)**
Clear question?	Y	Y	Y	Y	Y	Y	Y
Reference standard?	Y	Y	Y	Y	Y	Y	?
Diagnostic test and reference standard for all patients?	Y	N	Y	Y	Y	Y	N
Influence of reference standard?	N	?	N	?	N	N	?
Disease status described?	Y	Y	Y	Y	Y	Y	Y
Detailed test information?	N	Y	N	Y	Y	Y	Y
Clear results?	Y	Y	Y	Y	Y	Y	Y
Certainty of results?	Y	Y	Y	Y	Y	Y	Y
Local application of findings?	Y	?	Y	Y	Y	Y	?
Local application of tests?	Y	?	Y	Y	Y	Y	?
All important outcomes considered?	?	?	?	?	?	?	?
Impact of test in local population?	?	?	?	?	?	?	?

Table 6. QUADAS-2 bias assessment findings. Risk of bias for each of the four criteria are noted as high, low or unclear.

Author and date	**Patient selection**	**Index test**	**Reference standard**	**Flow and timing**
DiCocco et al. (2011)	Low	Low	Low	Unclear
Takano et al. (2013)	Unclear	Low	Low	Unclear

Paulus et al. (2014)	Low	Low	Unclear	Low
Shahan et al. (2016)	Low	Low	Low	High
Grandhi et al. (2017)	Low	Low	Low	High
Ares et al. (2019)	Low	Low	Unclear	Low
Vranic et al. (2020)	Low	Low	Low	High
DiCocco et al. (2011)	Low	Low	Low	Low

Table 7. Summary of study characteristics. CTA, computed tomography angiography; DSA, digital subtraction angiography; MRA, magnetic resonance imaging; NPV, negative predictive value; NR, not reported; positive predictive value; VWI, vessel wall imaging

Study author and date	Design	Imaging modalities	Reference standard	Sensitivity	Specificity	Other findings
DiCocco et al. (2011)	Diagnostic accuracy study	32-slice CTA	DSA	51%	97%	PPV 43%, NPV 98%, diagnostic accuracy 95%
Takano et al. (2013)	Diagnostic accuracy study	MRA, MR imaging	CTA/DSA	NR	NR	3/16 haematomas missed with MRA, a 12.5% failure to distinguish intramural haematomas, and a 50% rate of detection of characteristic imaging signs
Paulus et al. (2014)	Diagnostic accuracy study	64-slice CTA	DSA	68%	92%	PPV 36.2%, NPV 97.5%
Shahan et al. (2016)	Diagnostic accuracy study	CTA	DSA	NR	55%	PPV 55%
Grandhi et al. (2017)	Diagnostic accuracy study	CTA	DSA	52.6%	52.6%	PPV 53%
Ares et al. (2019)	Diagnostic accuracy study	CTA	DSA	72%	63%	NR
Vranic et al. (2020)	Diagnostic accuracy study	MRA, VWI	Expert consensus/CTA	NR	NR	82% agreement with expert consensus (VWI) versus 36% (CTA); MRA agreed with consensus for low grade lesions

The studies showed a moderate degree of heterogeneity based on the characteristics of the participants included and the nature or protocols used for CTA or MRA within the context of cervical vascular imaging. The characteristics of the patients included in the studies showed variation based on the specific injury assessed. While all studies included consecutive patients or purposively identified patients based on records, with no evidence of inappropriate exclusions, the specific focus on certain injuries may influence patient selection criteria and comparability, an important potential point of bias in QUADAS-2 criteria. For instance, blunt cerebrovascular injury was the focus of the studies by DiCocco et al. (2011), Paulus et al. (2014), Shahan et al. (2016) and Grandhi et al. (2017); these studies all evaluated the carotid artery and vertebral artery as potential sites of injury during a trauma situation. Similarly, for MRA analysis, the study by Vranic et al. (2020) evaluated all instances of blunt cerebrovascular injury following acute trauma, with a focus on carotid and vertebral arteries. Ares et al. (2019) focused on penetrating injury to the cervical region, rather than blunt injury, although the focus remained on the same vessels (i.e., carotid, and vertebral vasculature). The study by Takano et al. (2013) focused exclusively on imaging of intramural haematomas in vertebral arteries following dissection, without consideration of other lesions or sites of injury. Therefore, it should be noted that differences in sites of injury and types of injury (blunt or penetrating) may preclude comparability of the studies to some degree, including generalisability of findings.

In addition to the injuries assessed, there was some variability in the patient characteristics related to severity or nature of the injury sustained. Blunt and penetrating injuries were noted in studies, as suggested above, while the severity of the injury may have been a source of heterogeneity. Certainly, Vranic et al. (2020) used an assessment process where CTA screening was performed, and subsequent analysis justified using expert consensus and MRA where findings were suspicious for carotid artery lesions. Therefore, this group of patients may represent cases where lesions posed a specific diagnostic challenge due to the need for expert consensus and MRA where equivocal findings were seen on CTA. Similarly, the studies by Shahn et al. (2016) and Grandhi et al. (2017) included protocols where lesions that were equivocal on CTA were confirmed using DSA. Therefore, these studies may have only included lesions that posed diagnostic challenges, representing a unique group compared to patients routinely screened for pathology, as in other studies (DiCocco et al., 2011; Paulus et al., 2014).

The protocols used in the studies, including characteristics of the CTA or MRA approaches varied to a large extent. The details of the study protocols were often limited in the included studies, but the main features of the technology and the imaging strategy used for CTA tended to vary according to the number of channels (or slices) included in the imaging strategy (e.g., 32-channel versus 64-channel), reflecting changes to imaging technology over time (DiCocco et al., 2011; Paulus et al., 2014). While the use of DSA was typically a primary imaging study, against which subsequent CTA or MRA findings were compared, the study by Shahan et al. (2016) used a new protocol where CTA was the primary modality and DSA was only employed in equivocal cases. The same protocol was employed by Grandhi et al. (2017), which reflected institutional use of CTA as a primary imaging modality and the use of DSA as a confirmatory diagnostic test only. Similarly, where a suspected cervical vascular injury was evident on CTA in the study by Vranic et al. (2020), this was an indication for subsequent MRA assessment. Therefore, over time (from 2011 to 2020, when studies were published) the use of CTA became a primary imaging strategy and preferred screening approach rather than DSA.

The outcomes reported across the studies, related to diagnostic accuracy, were prone to some variation. Typical outcomes of sensitivity and specificity compared to a reference standard were noted in most studies, often with the reporting of positive or negative predictive values and other criteria (DiCocco et al., 2011; Paulus et al., 2014; Ares et al., 2019). However, some studies focused on reporting false-positive rates of injury detection or specific imaging findings that were indicative of accuracy, including inter-rater agreement of findings and confirmation of findings using other imaging studies (Takano et al., 2013; Shahan et al., 2016; Grandhi et al., 2017; Vranic et al., 2020). These differences in reported outcomes represented important factors to consider during the synthesis of the literature in the following section of this chapter.

Chapter 4: Discussion

Overview of the SLR findings

This SLR was designed to meet a gap in the current knowledge base regarding the relative diagnostic accuracy of MRA and CTA in patients with suspected cervical vascular injury secondary to trauma. Seven studies were identified that met the inclusion criteria and the PICO criteria defined for the SLR, generating three themes for discussion.

The first theme explored the diagnostic accuracy of CTA in the context of cervical vascular injury. This theme found that while there was heterogeneity in studies and changes to sensitivity of CTA over time, there was a general finding that the diagnostic accuracy of CTA was high (95%) and that this reflected a high specificity and moderate or high sensitivity. Sensitivity appeared to be a key diagnostic outcome that has improved over time (DiCocco et al., 2011; Paulus et al., 2014), while specificity remained high across the time period of the included studies (2011–2019). The second theme explored the diagnostic accuracy of MRA relative to any reference standard. This analysis was limited by the inclusion of two studies only and the lack of robust diagnostic accuracy assessment of MRA in the context of general cervical vascular injury. Indeed, assessment by Takano et al. (2013) focused on intramural haematoma diagnosis, while the assessment by Vranic et al. (2020) focused on carotid artery pathology in patients with equivocal findings on CTA. These studies are therefore hard to generalise to the cervical trauma context and may be difficult to compare in terms of diagnostic outcomes. The final theme suggested that the diagnostic accuracy of the imaging studies (particularly CTA) was influenced by several factors related to the patient and the clinical characteristics of the injury. While there was a lack of general agreement across studies for all of the potential modifying factors (e.g. gender), severity of the lesion (i.e. grade) and indication or site of the traumatic injury may all influence sensitivity of the diagnostic imaging strategy. These issues are considered further in this chapter, with reference to the wider literature, following a discussion of the key quality or methodological issues noted in the review data set.

Overview of methodological quality

The methodological quality of studies included in a SLR can have an important bearing on the quality of that review and the strength of the conclusion that can be drawn (Phan et al., 2015). The present review included two distinct methodological quality assessment process: the CASP toolkit, which provides an overall methodology-specific assessment of quality, and the QUADAS-2 tool, which assessed bias in relation to diagnostic imaging studies specifically (Whiting et al., 2011). The CASP appraisal provided a general insight into overall methodological quality of the collective data set, suggesting that most studies were limited by the inclusion of a relatively small sample size, lack of consistent or clear recruitment data, the potential for differential exposure to treatment or imaging protocols (based on heterogeneity in severity of lesions and patient characteristics), and based on inconsistencies in reporting of diagnostic accuracy outcomes.

One important methodological challenge was the lack of clarity in how patients were assigned to imaging modalities and the risk of bias therein (Goldzweig et al., 2015). Indeed, the use of MRA, CTA or other imaging approaches may have been influenced by practitioner preferences or clinical assessment not only of the cervical region and risk of vascular injury, but also with respect to other injuries and patient features. Furthermore, local guidelines may have influenced the preferred imaging strategy and sequence of imaging studies: Shahan et al. (2016) prioritised the use of CTA according to local protocols, while Paulus et al. (2014) utilised DSA as a primary imaging modality, with CTA used as a secondary strategy. This may influence the value and interpretation of imaging studies (particularly if other modalities may be consulted to support analysis) and may reflect differences in patient populations and injury severity, as diagnosis in equivocal cases may reflect a challenging patient group to manage effectively (Han et al., 2016).

Another methodological issue was the reporting of outcomes related to diagnostic accuracy. Only one study provided an overall summary of diagnostic accuracy (DiCocco et al., 2011), where a value of 95% was reported. Subsequent studies showed improvements in sensitivity associated with CTA imaging (Paulus et al., 2014; Shahan et al., 2016) but no overall reporting of diagnostic accuracy. There was also significant variability in the reporting of positive and negative predictive values and other features of the diagnostic accuracy of CTA. This limits the degree to which the overall accuracy of studies may be assessed in detail (Eusebi, 2013). This is particularly problematic for the use of MRA, as the studies included in this review did not provide detailed assessment of sensitivity or specificity (Takano et al., 2013; Vranic et al., 2020). This reflects the focused nature of the evaluations on specific sites of pathology (e./g. intramural haematoma) and the small number of patients included in the analyses, which limits the degree to which robust assessment of diagnostic accuracy can be completed (Whiting et al., 2011).

The bias related to diagnostic imaging assessment also reflected differences and inconsistent in the reference standard used, which is an important factor in providing a consistent evaluation of accuracy (Whiting et al., 2011). The reference standard of DSA is considered appropriate for the evaluation of cervical trauma and vascular injuries related to trauma, although this may be considered less feasible for use in routine practice than CTA in present practice (Wang et al., 2012). The studies included in this SLR included those published a decade ago, where DSA would have been a clear reference standard (e.g. DiCocco et al., 2011) and therefore the use of DSA in these studies was appropriate. However, other studies used expert consensus as the equivalent of a reference standard for evaluating CTA and MRA/VWI (Vranic et al., 2020), while the assessment of MRA in the study by Takano et al. (2013) was based on CTA as a reference standard with or without DSA. Hence, the lack of a consistent reference standard across studies may be considered a weakness (Ochodo et al., 2013). In particular, expert neuroradiologist consensus on outcomes is a challenging standard to apply in studies, as this is subjective in nature and reflects aspects of imaging quality and protocol use (Austein et al., 2019).

Chapter 5. Conclusion

The assessment of cervical vascular injury in the context of trauma is important in preventing morbidity and mortality. The optimal imaging approach to diagnosing these injuries is an area of discussion as the widespread use of DSA has largely been supplanted by CTA. However, the relative value of MRA is unclear, although offering theoretical advantages to CTA in terms of avoiding exposure to ionising radiation. However, the diagnostic accuracy of both CTA and MRA need to be carefully evaluated to support the use of these imaging strategies in this context.

The present review identified seven studies that assessed the diagnostic accuracy of CTA or MRA in the context of cervical vascular injury in trauma patients, following a multidatabase search strategy. These studies did not directly compare the diagnostic accuracy of CTA with MRA in the context of cervical vascular injury secondary to trauma, which is a major limitation of the review and reflective of a lack of evidence in the published literature. This likely reflects the findings of older studies where MRA was considered to have inferior sensitivity and specificity for cervical vascular trauma injury diagnosis, limiting the application of this technique in practice and subsequent appearance of data in clinical studies. Therefore, the lack of contemporary data on the use of MRA reflects a shift in focus towards the use of CTA in practice, justified based on early research findings and improving diagnostic accuracy as technology advances. However, MRA remained in use in specific contexts and in combination with other MR imaging approaches, allowing for some analysis of relative diagnostic value of these approaches in the present review.

The diagnostic accuracy of CTA for cervical vascular injury in trauma patients was assessed in five of the included studies, typically in the context of blunt traumatic injuries, with one study (Ares et al., 2019) focusing on penetrating injuries. Overall, the findings suggested that the diagnostic accuracy of CTA was high compared to DSA, with a moderate to high sensitivity and high specificity for lesion diagnosis. Advances in imaging technology and in user experience with CTA in this clinical context appears to be associated with increased diagnostic accuracy and has led to CTA emerging as a key screening and diagnostic tool in practice, often in the place of the more invasive DSA procedure.

The diagnostic accuracy of MRA was not assessed in detail in the included literature and none of the studies provided a clear and robust assessment of MRA with CTA in this context. While MRA findings may be linked to increased diagnostic accuracy in specific contexts, including intramural haematoma detection and demonstrates a high level of agreement with expert consensus in equivocal CTA findings, overall the wider literature suggests that MRA may lack suitable sensitivity and specific for routine use in assessment of cervical trauma.

Furthermore, the practical and clinical implications of using CTA or MRA for cervical vascular injury assessment in trauma patients need to be considered in justifying the use of specific approaches in practice. While MRA has advantages of not requiring contrast medium, potentially increased soft tissue imaging quality, and avoiding exposure to ionising radiation, the time needed for examinations, the limited availability compared to CTA, and the contraindications in trauma contexts (e.g. metallic foreign bodies in penetrating trauma) may limit the use of MRA in practical settings. However, where neurological damage is suspected and other indications support the use of MRA, this may be a valuable tool in practice and preferable to CTA.

The research and practice implications of this SLR are discussed in detail and include the need for more studies evaluating the use of MRA specifically in trauma contexts, including the use of MRA with adjunctive MR imaging strategies, such as VWI. Research comparing the use of CTA and MRA directly in trauma contexts may be challenging to justify given widespread adoption of CTA as a screening tool of choice, with little evidence supporting the use of MRA in this context. Unless MRA becomes more widespread in nature and used routinely in trauma contexts, CTA is likely to be the preferred imaging modality for the majority of patients. Practitioners in trauma contexts need to consider not only the potential for cervical vascular injury but also additional injuries and wider aspects of trauma-related injuries that may be of relevance for management. The use of CTA may be preferred depending on the wider context of injuries and the need for rapid patient assessment in trauma contexts. However, MRA may equally be valued where specific indications for MRA are relevant to wider trauma outcomes. Furthermore, practitioners need to balance not only the diagnostic accuracy of these studies for the detection of lesions in cervical vasculature, but also the relevance of these diagnoses for patient care and outcomes in the wider trauma context. Hence, there will always be limitations to assessing imaging protocols in the context of traumatic injury when focusing one specific aspect of trauma or injury site.

Given the complexity of trauma assessment and the risks associated with cervical vasculature injury, including a risk of stroke, practice and policy need to be aligned to support decision-making in emergency contexts. There is an important need for refinement of imaging protocols and trauma imaging guidelines to take into account the relative advantages and disadvantages of these imaging modalities in specific trauma contexts to optimise patient diagnosis and subsequent management.

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