

## Neurological outcomes following iatrogenic vascular injury during posterior atlanto-axial instrumentation

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### ARTICLE INFO

#### Article history:

Received 30 June 2016

Received in revised form 10 August 2016

Accepted 13 August 2016

Available online 30 August 2016

#### Keywords:

Vascular injury

C1

C2

Atlas

Axis

Atlanto-axial injury

Atlanto-axial instrumented fusion

### ABSTRACT

**Background:** Iatrogenic vascular injury is a feared complication of posterior atlanto-axial instrumentation. A better understanding of clinical outcome and management options following this injury will allow surgeons to better care for these patients. The object of the study was to systematically review the neurologic outcomes after iatrogenic vascular injury during atlanto-axial posterior instrumentation.

**Methods:** We performed a systematic review of the Medline database following PRISMA guidelines. In our analysis, we included any retrospective cohort studies, prospective cohort studies, case reports, cases series, or systematic reviews with patients who had undergone posterior atlanto-axial fusion via screw rod constructs (SRC) or transarticular screws (TAS) that reported a patient with an injury to an arterial vessel directly attributable to the surgical procedure.

**Results:** Sixty cases of vascular injury were reported in 2078 (2.9%) patients over 27 publications. The average age for this patient population was 55.7+/-17.9. Vascular injury following posterior C1/2 instrumentation resulted in ipsilateral stroke in 10.0% (n=6/60) and non-persistent neurologic deficit in 6.7% (n=4/60) of cases with the deficit being permanent (not including death) in 1.7% (n=1/60) of cases. Four patients (6.7%) died. Arteriovenous fistula or pseudoaneurysm occurred in 8.3% (n=5/60) and 3.3% (n=2/60) of cases, respectively. Eight patients (13.3%) underwent endovascular repair of the injury with no permanent deficit.

**Conclusion:** Neurological morbidity after iatrogenic vascular injury during posterior C1/2 fixation is higher than previously reported in literature. Some patients may benefit from endovascular treatment. Surgeons should be aware of normal and anomalous vertebral artery anatomy to avoid this potentially catastrophic complication.

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### 1. Introduction

The region that surrounds the atlanto-axial joint consists of complex anatomical relationships among structures such as the

**Abbreviations:** TAS, transarticular screw; SRC, screw rod constructs; VA, vertebral artery; PICA, posterior inferior cerebellar artery; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; CT, computed tomography; AVF, arteriovenous fistula; TIA, transient ischemic attacks; DSA, digital subtraction angiogram; BTO, balloon test occlusion.

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vertebral artery, upper cervical nerve roots, ligaments, and horizontal articular surfaces. These features allow for significant mobility, but escalate the complexity of atlanto-axial fusion surgery. The first reported attempt of surgical stabilization of the C1/2 joint was in 1910, by Mixter and Osgood, using a heavy silk thread to secure the posterior elements [32]. Modern day instrumentation techniques for posterior fixation of the C1/2 joint include transarticular screw (TAS) fixation and screw-rod constructs (SRC). Magerl first described TAS instrumentation in 1986 [29]. The use of separate C1 and C2 screws was first described by Goel in 1994 [18] and later modified by Harms using polyaxial SRC in 2001 [22]. With increased surgical experience and advances in instrumentation, spine surgeons have seen an increase in the fusion rates and fewer complications from this procedure.

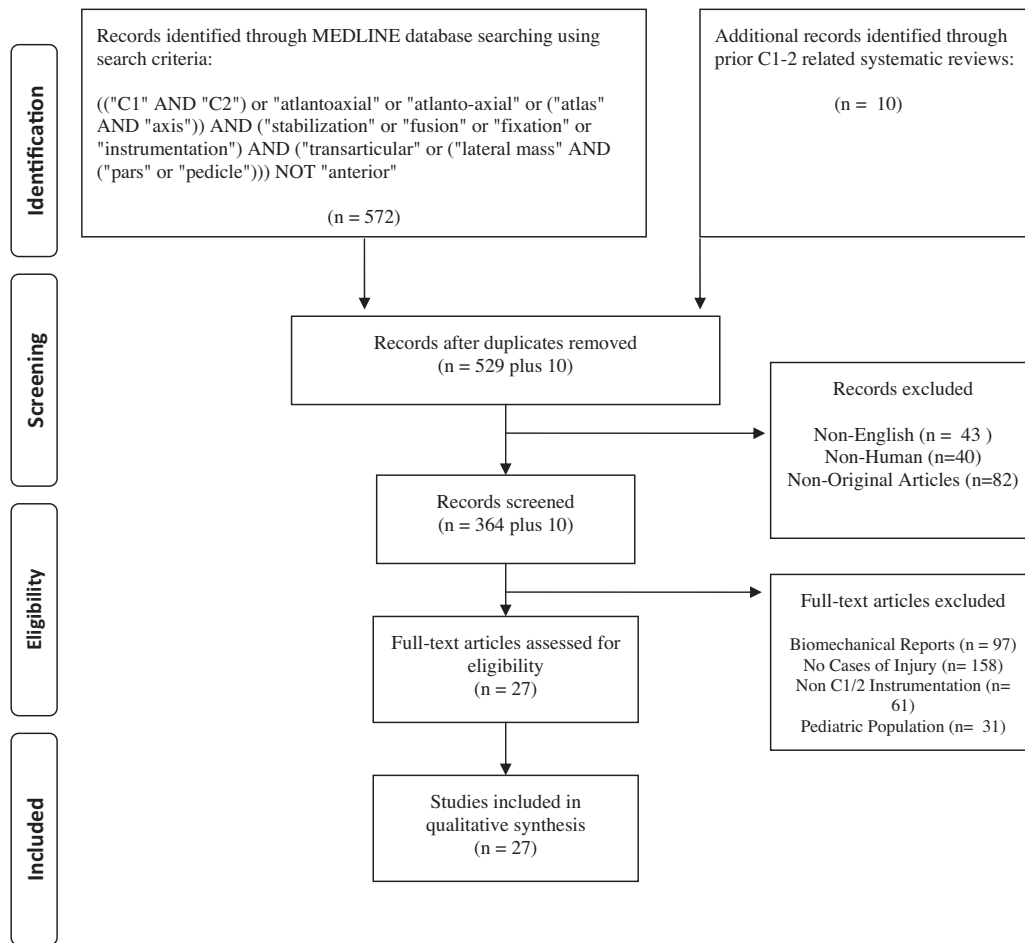


Fig. 1. Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) Flow chart for search and study selection.

In terms of non-bony anatomy in the region, the 3rd segment of the vertebral artery exits the foramen transversarium of the axis then curves posteromedially in the sulcus arteriosis before entering the skull through the foramen magnum. Anomalous and variant vascular anatomy such as high riding vertebral artery (VA), ponticulus posticus, and low lying posterior inferior cerebellar artery (PICA) adds to the complexity of this segment [38]. Iatrogenic vascular injury can be a catastrophic complication of posterior instrumentation of the C1/2 joint space, which may result in permanent neurological deficit or death. Neurological deficit after iatrogenic vascular injury during TAS fixation is reported to be 3.7%, but this value is subject to significant bias since it was collected from a retrospective surgeon survey [47]. The literature contains several case series that describe individual surgeons' experience complications associated with atlanto-axial fusion [34,20,23,48]. However, to date, no comprehensive study has been published in which clinical outcomes after iatrogenic vertebral artery injury were analyzed. Therefore, we systematically reviewed all available cases of vascular injury associated with TAS or SRC to better characterize the rate of vascular complications from fusion of the C1/2 joint to include etiology, clinical outcomes, and management.

## 2. Methods

### 2.1. Literature search

A systematic review of the MEDLINE database was performed, following the guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). The search

criteria were as follows: ((“C1” AND “C2”) or “atlantoaxial” or “atlanto-axial” or (“atlas” AND “axis”)) AND (“stabilization” or “fusion” or “fixation” or “instrumentation”) AND (“transarticular” or (“lateral mass” AND (“pars” or “pedicle”))) NOT “anterior”. Duplicates were removed and non-English, non-human, and non-original articles were excluded. We screened the remaining articles in addition to records identified through prior C1/2 related systematic reviews. During the screening process, we excluded biomechanical reports, articles with no cases of injury, articles with no C1/2 instrumentation, and articles that included pediatric patients. The date of the last search for this review was October 20, 2015.

### 2.2. Inclusion and exclusion criteria

Inclusion criteria were as follows: 1) Must be a prospective cohort, retrospective cohort, randomized clinical trial, case series, or case study; 2) Must include patients undergoing fusion of the C1/2 joint using posterior instrumentation; 3) Have one or more patients with injury to an arterial vessel; 4) Injury must be directly attributable to the surgical procedure. Reports of vascular injuries that occurred below the level of C2 were excluded [36]. We excluded articles in which the type of instrumentation was unknown [41]. Articles that contained duplicated patients from other studies were excluded. Table 1 outlines the inclusion and exclusion criteria used during the screening process.

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