Top 50 most-cited articles on craniovertebral junction surgery

ABSTRACT

Background: Craniovertebral junction is a complex anatomical location posing unique challenges to the surgical management of its pathologies. We aimed to identify the fifty most-cited articles that are dedicated to this field.

Methods: A keyword search using the Thomson Reuters Web of Knowledge was conducted to identify articles relevant to the field of craniovertebral junction surgery. The articles were reviewed based on title, abstract, and methods, if necessary, and then ranked based on the total number of citations to identify the fifty most-cited articles. Characteristics of the articles were determined and analyzed.

Results: The earliest top-cited article was published in 1948. When stratified by decade, 1990s was the most productive with 16 articles. The most-cited article was by Anderson and Dalonzo on a classification of odontoid fractures. By citation rate, the most-cited article was by Herms and Melcher who described Goel's technique of atlantoaxial fixation using C1 lateral mass screws and C2 pedicle screws with rod fixation. Atlantoaxial fixation was the most common topic. The United States, Barrow Neurological Institute, and VH Sonntag were the most represented country, institute, and author, respectively. The significant majority of articles were designed as case series providing level IV evidence.

Conclusion: Using citation analysis, we have provided a list of the most-cited articles representing important contributions of various authors from many institutions across the world to the field of craniovertebral junction surgery.

Key words: Bibliometrics; citation; craniovertebral.

Introduction

Surgical approach to the craniovertebral junction requires intimate knowledge of the skeletal, ligamentous, neural and vascular anatomy, and the natural history of its pathologies. Our knowledge of this unique anatomical location has undergone advancements through the work of many authors.

Citation analysis is a bibliometric tool that can be utilized to quantitatively evaluate the influence of an article on a given field. The goal of this study was to select the fifty most-cited articles pertaining to the surgical management of craniovertebral junction pathologies published between 1900 and 2015.

Methods

Inclusion criteria

Following the initial search process, studies were selected for inclusion in the final list of fifty based on several inclusion criteria. Eligible studies were required to have focused primarily on the study of pathologies or interventions involving the craniovertebral junction. Studies involving nonhuman subjects and studies published in languages other than English were excluded from the final list. Studies that discussed other related conditions, such as cervical spine pathologies, were included as long as patients with...
craniovertebral pathologies constituted the majority of the patient population in the study.

Eligible articles were selected from all journals and databases indexed on the Thomson Reuters Web of Science at the time of this analysis.

Data collection
A two-step query of the Thomson Reuters Web of Science was conducted to assemble the final list of fifty articles.

The first stage consisted of a topic search for the term “craniovertebral.” This search yielded 2190 results, which were subsequently sorted from the most-cited articles to the least-cited articles. The top 100 relevant studies in the list were analyzed to compile a list of keywords to be used in the subsequent search phase.

Seventy-six keywords were chosen from the aforementioned articles [Table 1] based on the following four categories: Location, approach, pathology, and therapy. These keywords were then used to search the database a second time using a compiled search term [Table 2]. This phase of the search yielded 31,965 papers, which were similarly sorted in order from most to least citations. We eliminated self-citations by conducting a “cited reference search” which provides all citing articles, followed by an “author search.” Results of the latter search, which yielded all articles published by authors of the article of interest, were then subtracted from the “cited reference search.”

The fifty most-cited papers in this list were selected out of the first 298 results for final inclusion in the list presented in this report.

The following information was extracted from each article selected for the final list: Article title, year of publication, total number of citations, citation rate, article topic, study type, and level of evidence. Citation rate was defined as the number of citations per year since the year of publication. Article topic categories included atlantoaxial fixation, atlantoaxial instability, occipitocervical fusion, trauma, anterior approach to craniovertebral junction, mixed, and others. Study type pertains to whether a study is nonclinical or clinical in which case the study design, potentially ranging from randomized controlled trial to case report, is determined. Level of evidence is determined for clinical studies, potentially ranging I–V.

Results
Table 3 provides information on the articles including their citations’ count, citation rate, article topic, article summary, article type, and level of evidence. Our final list consisted of articles published between 1948 and 2004. Publications peaked in 1985 with four articles [Figure 1];[20,31,49,40] however, the most productive decade was the 1990s with 16 articles [Table 4].[18,22,33,15,30,51,6,48,9,11,10,7,42,12,46,8]

The top journal was the Journal of Bone and Joint Surgery: American Volume which produced 12 out of the fifty articles.

Table 1: Keywords, in 4 categories, determined based on the first query

| Location                  | Approach          | Pathology            | Therapy  |
|---------------------------|-------------------|----------------------|----------|
| Cranial                   | Dorsolateral      | Rheumatoid           | Fix*     |
| Cervical                  | Suboccipital      | Ankylosing           | Fus*     |
| Craniovertebral           | Transcondylar     | Down syndrome        | Plat*    |
| Occipitocervical          | Transoral         | Chiropractic         | Screw*   |
| Atlanto-occipital         | Transpharyngeal   | Trisomy 21           | Rod*     |
| Atlantoaxial              | Retropharyngeal   | Trauma*              | Cabi*    |
| Occipito-atlanto-axial    | Transarticular    | Jefferson*            | Instrument* |
| Atlantal                  | Intralaminar      | Hangman*             | Arthro*  |
| Atlas                     | Endoscopic*       | Injur*               | Distract* |
| Axial                     |                   | Fractur*             | Stabiliz*|
| Condyl*                   |                   | Disloc*              | Mobiliz* |
| Dens                      |                   | Sublux*              | Reduc*   |
| Odontoid*                 |                   | Burst*               | Decompress* |
| Clivus                    |                   | Rota*                | Biomechanic* |
| Clival                    |                   | Rupture*             | Gallo    |
| C1                        |                   | Congenital*          |         |
| C2                        |                   | Anomal*              |         |
| Basilar                   |                   | Invag*               |         |
| Transverse ligament*      |                   | Impress*             |         |
| Alar ligament*            |                   | Migrat*              |         |
| Atlantal ligament*        |                   | Setti*               |         |
| Vertebrabasilar           |                   | Degen*               |         |
|                           |                   | Instab*              |         |
|                           |                   | Unstab*              |         |
|                           |                   | Obstruct*            |         |
|                           |                   | Fistul*              |         |
|                           |                   | Myelopathy*          |         |
|                           |                   | Radiculopathy*       |         |

Table 2: Search terms used in the second query

| Location                | Approach         |
|-------------------------|------------------|
| Cranial                 |                  |
| Cervical                |                  |
| Craniovertebral         |                  |
| Occipitocervical        |                  |
| Atlanto-occipital       |                  |
| Atlantoaxial            |                  |
| Occipito-atlanto-axial  |                  |
| Atlantal                |                  |
| Basilar                 |                  |
| Dorsolateral            |                  |
| Suboccipital            |                  |
| Transcondylar           |                  |
| Transoral               |                  |
| Transpharyngeal         |                  |
| Retropharyngeal         |                  |
| Transarticular          |                  |
| Intralaminar            |                  |
| Endoscopic*             |                  |

Table 3: Information on the articles

| Location | Article title | Year of publication | Total number of citations | Citation rate | Article topic | Study type | Level of evidence |
|----------|--------------|---------------------|---------------------------|--------------|---------------|------------|-------------------|
|          |              |                     |                           |              |               |            |                   |

Table 4: Articles published in the 1990s

| Location | Article title | Year of publication | Total number of citations | Citation rate | Article topic | Study type | Level of evidence |
|----------|--------------|---------------------|---------------------------|--------------|---------------|------------|-------------------|
|          |              |                     |                           |              |               |            |                   |
This was followed by the Journal of Neurosurgery and Spine, with nine and seven articles, respectively [Figure 2]. The authors with the most top 50 publications included VKH Sonntag\(^{[15,30,48,35,40,34,42,12,46]}\) (9), CA Dickman\(^{[15,30,48,35,42,12]}\) (6), and MN Hadley\(^{[30,48,40,35,24]}\) (5).

From Figure 3, it can be observed that atlantoaxial fixations (14) was the most common topic among the articles in the final list.

Articles in the final list originated from 13 different countries, with the majority having been based in the United States (26 articles). Table 5 displays the top ten institutions affiliated with articles on the final list. The most productive institutions were Barrows Neurological Institute (six articles) and St. Luke’s Hospital (three articles).

The most-cited article pertaining to the craniovertebral junction was the 1974 study by Anderson and D’Alonzo on odontoid fractures.\(^{[1]}\) The article with the highest citation rate was Harms and Melcher’s report on the use of C1 lateral mass screws and C2 pedicle screws with rod fixation for atlantoaxial fixation.\(^{[2]}\)

**Discussion**

We used citation analysis to identify the most-cited articles on the topic of craniovertebral junction surgery. This list represents the authors, institutions, and countries, which have been instrumental in the advancement of the field. We characterized the most-cited research topics and the study design utilized by the authors to investigate it, providing a perspective on the trends within the field and the level of evidence available for the surgical management of this complex anatomical location.

The years of publication ranged from 1948 to 2004. The article from 1948, ranked 19th overall and authored by McGregor, provides an alternative to Chamberlain’s line for the diagnosis of basilar impression. This line, which later known as McGregor line, is a line that connects the posterior edge of the hard palate to the most caudal end of the occipital bone’s curve. If the tip of the odontoid process is 4.5 mm rostral to this line, the diagnosis of basilar impression is made.\(^{[19]}\) The article in 2004, ranked 16th overall and authored by Wright,\(^{[16]}\) is the first description of the use of bilateral crossing C2 laminar screws in rigid constructs that include

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**Table 2: Finalized search terms used in the second query**

| Search terms |  |
|--------------|---|
| cranial OR cervical OR craniocervical OR occipitocervical OR atlantooccipital OR atlantoaxial OR occipito-atlanto-axial OR atlantal OR atlas OR axial OR axis OR condyl* OR dens OR odontoid* OR clivus OR clival OR C1 OR C2 OR basilar OR "transverse ligament*" OR "alar ligament*" OR "atlantal ligament*" OR vertebrobasilar) AND (dorsolateral OR suboccipital OR transcondylar OR transoral OR transpharyngeal OR retropharyngeal OR transarticular OR intralaminar OR endoscopic* OR rheumatoid OR ankylosing OR "down syndrome" OR "trisomy 21" OR chiropract* OR trauma* OR Jefferson* OR hangman* OR injur* OR fracture* OR disloc* OR sublux* OR burst* OR rota* OR rupture* OR congenital* OR anormal* OR invag* OR impress* OR migrat* OR settl* OR degen* OR instab* OR unstab* OR obstruct* OR fistul* OR myelopath* OR radiculopath* OR fix* OR fus* OR plat* OR screw* OR rod* OR cabl* OR instrument* OR arthro* OR distract* OR mobiliz* OR stabiliz* OR reduc* OR decompress* OR biomechanic* OR galle OR halo) |
### Table 3: List of top 50 most-cited articles on craniovertebral surgery

| Rank | Article | Article topic | Article summary | Study type | Level of evidence | Total citations | Citation rate |
|------|---------|---------------|-----------------|------------|-------------------|----------------|---------------|
| 1    | Anderson and D’Alonzo, 1974[1] | Trauma- odontoid fracture | Outcome of 49 odontoid fractures stratified by three types of fracture patterns | Case series | IV | 526 | 12.5 (4th) |
| 2    | Harms and Melcher 2001[2] | Atlantoaxial fixation- surgical technique | First description of the technique and outcome of 37 patients who underwent atlantoaxial fixation using C1 lateral mass screws and C2 pedicle screws with rod fixation | Case series | IV | 493 | 32.9 (1st) |
| 3    | Brooks and Jenkins 1978[3] | Atlantoaxial fixation- surgical technique | First description of the technique and outcome of 15 patients who underwent atlantoaxial fusion by wedge compression technique | Case series | IV | 411 | 10.8 (8th) |
| 4    | Ranavat et al., 1979[4] | Mixed (rheumatoid arthritis, atlantoaxial fusion, OC fusion) | Outcome of 35 patients with rheumatoid arthritis and cervical instability, of whom 13 underwent atlantoaxial Gallie fusion and 12 underwent occipitovertbral fusion | Case series | IV | 330 | 8.9 (13th) |
| 5    | Fielding and Hawkins 1977[5] | Atlantoaxial instability-outcome | Outcome of 17 patients with atlantoaxial rotatory subluxation, of whom 11 underwent atlantoaxial Gallie fusion | Case series | IV | 286 | 7.3 (17th) |
| 6    | Goel and Laheri 1994[6] | Mixed (atlantoaxial fixation and OC fusion) | First description of technique and outcome of 30 patients with atlantoaxial subluxation who underwent atlantoaxial fusion with C1 and C2 lateral mass screws, or OC fusion with C2 lateral mass screws connected with plate | Case series | IV | 271 | 12.3 (5th) |
| 7    | Madavi et al., 1997[7] | Atlantoaxial fixation-outcome | Outcomes and complications of 61 patients who underwent atlantoaxial transarticular fusion with discussion of optimal screw trajectories | Case series | IV | 262 | 13.8 (3rd) |
| 8    | Wright and Lauryssen 1998[8] | Atlantoaxial fixation-surgical technique | Risk of vertebral artery injury during atlantoaxial transarticular screw fixation based on survey of 847 neurosurgeons | Case series | IV | 222 | 12.3 (6th) |
| 9    | Grob et al., 1992[9] | Atlantoaxial fixation-biomechanics | In vitro biomechanical evaluation of four methods of atlantoaxial fixation: Gallie’s, Brooks’, Magerl’s, and Halifax’s techniques | Case-control | III | 220 | 9.2 (11th) |
| 10   | Jeanneret and Magerl 1992[10] | Atlantoaxial fixation-outcome | Outcome of 12 patients with odontoid fractures who were managed by transarticular atlantoaxial fusion | Case Series | IV | 214 | 8.9 (14th) |
| 11   | Grob et al., 1991[11] | Atlantoaxial fixation-outcome | The outcome of 38 patients who underwent transarticular atlantoaxial fusion due to atlantoaxial instability | Case series | IV | 196 | 9.8 (10th) |
| 12   | Paramore et al., 1996[12] | Atlantoaxial fixation-surgical technique | Evaluation of the atlantoaxial anatomy, mainly the location of transverse foramen of C2 on unenhanced cervical CT, in 94 patients with cervical trauma to determine suitability for atlantoaxial transarticular fusion | Case series | IV | 196 | 7.8 (15th) |

Contd...
| Rank | Article | Article topic | Article summary | Study type | Level of evidence | Total citations | Citation rate |
|------|---------|---------------|----------------|------------|-------------------|----------------|---------------|
| 13   | Sharp and Purser 1961[13] | Atlantoaxial instability-rheumatoid arthritis, ankylosing spondylitis | Report of atlantoaxial dislocation in 12 patients with ankylosing spondylitis and 24 patients with rheumatoid arthritis | Case series | IV | 187 | 3.4 (40<sup>th</sup>) |
| 14   | Menezes and VanGilder 1988[14] | Anterior approach to CV junction-outcome | Outcome of transoral transpharyngeal approach to the anterior CV junction in 72 patients, with more than half of the patients presenting with basilar invagination | Case series | IV | 186 | 6.6 (21<sup>st</sup>) |
| 15   | Dickman and Sonntag 1998[15] | Atlantoaxial fixation-outcome | Outcome of 121 patients who underwent atlantoaxial transarticular fusion | Case series | IV | 182 | 15.2 (2<sup>nd</sup>) |
| 16   | Wright 2004[16] | Mixed (atlantoaxial fixation, OC fusion) | First description of the technique of using C2 laminar screws during atlantoaxial, OC, or subaxial fusion | Case series | IV | 182 | 10.1 (9<sup>th</sup>) |
| 17   | Fielding et al., 1974[17] | Trauma-ligamentous injury | Biomechanical evaluation of atlantoaxial ligaments in anterior subluxation of atlas on axis based on cadaveric studies with clinical correlation to 11 patients | Case series | IV | 181 | 4.3 (32<sup>nd</sup>) |
| 18   | Bertalanffy and Seeger 1991[18] | Anterior approach to CV junction-surgical technique | Description of technique for dorsolateral approach to the anterior aspect of CV junction in 6 patients with intradural mass lesion | Case series | IV | 179 | 7.2 (19<sup>th</sup>) |
| 19   | McGregor 1948[19] | Other | Diagnosis of basilar impression based on specific measurements of the skull, including modified Chamberlain’s line and skull base angle | Case series | IV | 178 | 5.7 (24<sup>th</sup>) |
| 20   | Clark and White 1985[20] | Trauma-odontoid fracture | Survey of the members of the Cervical Spine Research Society on management of the fractures of the dens | Case series | IV | 178 | 2.6 (49<sup>th</sup>) |
| 21   | Pellicci et al., 1981[21] | Atlantoaxial instability-rheumatoid arthritis | Progression of cervical spine disease over an average of 6.1 years in 106 patients with rheumatoid arthritis, 81% of which included atlantoaxial subluxation | Case series | IV | 171 | 4.9 (26<sup>th</sup>) |
| 22   | Boden et al., 1993[22] | Atlantoaxial instability-rheumatoid arthritis | Description of neurological deficit and its predictors in 73 patients with rheumatoid arthritis, of whom 61 patients had atlantoaxial subluxation, over 20-year study period | Case series | IV | 169 | 7.3 (18<sup>th</sup>) |
| 23   | Smith et al., 1972[23] | Atlantoaxial instability-rheumatoid arthritis | Natural history of cervical subluxation in rheumatoid arthritis based on 962 patients with the disease, of whom 150 developed cervical subluxation, with 91 patients at C1–C2 level | Case series | IV | 167 | 3.8 (36<sup>th</sup>) |
| 24   | Martel 1961[24] | Atlantoaxial instability-rheumatoid arthritis, ankylosing spondylitis | Radiographic evaluation of occipito-atlantoaxial joint complex based on lateral flexion-extension cervical X-ray of 34 patients with rheumatoid arthritis and 32 patients with ankylosing spondylitis | Case series | IV | 161 | 2.9 (44<sup>th</sup>) |

Contd...
| Rank | Article | Article topic | Article summary | Study type | Level of evidence | Total citations | Citation rate |
|------|---------|---------------|----------------|------------|------------------|----------------|---------------|
| 25   | Goel et al., 2002[25] | Atlantoaxial fixation-surgical outcome | Outcome of atlantoaxial fusion using plate and screw method based on 160 patients over a 14-year period | Case series | IV | 154 | 11.0 (7th) |
| 26   | Effendi et al., 1981[24] | Trauma-axial fracture | Classification of type of fractures of the ring of C2, based on displacement of anterior fragment, flexion of body of C2, and involvement of C2–C3 facet joints | Case series | IV | 151 | 4.3 (33rd) |
| 27   | Schneider et al., 1965[27] | Trauma-Hangman’s fracture | First description of Hangman’s fracture based on the author’s experience in 8 cases | Case series | IV | 149 | 2.9 (45th) |
| 28   | Böhler 1982[28] | Anterior approach to CV junction-outcome | Outcome of 12 patients with dens fractures who underwent combined anterior cervical approach for impaction of bone into the body of C2 in addition to posterior fusion | Case series | IV | 148 | 4.4 (31st) |
| 29   | Greenberg 1968[26] | Atlantoaxial instability-classification | Categorization of types of atlantoaxial dislocations with review of anatomy, embryology, and radiological measurements of atlantoaxial complex | Case series | IV | 147 | 3.1 (43rd) |
| 30   | Dickman et al., 1991[29] | Atlantoaxial fixation-surgical technique | First description of atlantoaxial interspinous fusion and outcome of 36 patients | Case series | IV | 143 | 5.7 (25th) |
| 31   | Levine and Edwards 1985[31] | Trauma-Hangman’s fracture | Outcome of 52 patients with Hangman’s fracture requiring conservative or surgical management | Case series | IV | 140 | 4.5 (30th) |
| 32   | Anderson and Montesano 1988[32] | Trauma-occipital condyle fracture | Description of three different types of occipital condyle fractures and their outcomes based on 6 patients | Case series | IV | 136 | 4.9 (27th) |
| 33   | Coyne et al., 1995[32] | Atlantoaxial fixation-outcome | Comparison of long-term outcome of atlantoaxial fusion using different techniques based on 32 patients | Case series | IV | 134 | 6.4 (22th) |
| 34   | Hadley et al., 1989[34] | Anterior approach to CV junction-outcome | Outcome transoral approach for management of anterior compression of brainstem and/or cervical cord in 53 patients, 44 with odontoid pathology and 9 with extradural tumors | Case series | IV | 132 | 4.9 (28th) |
| 35   | Hadley et al., 1989[36] | Trauma-axial fractures | Management and outcome of 229 patients with fractures of the C2 vertebra | Case series | IV | 131 | 4.9 (29th) |
| 36   | Abumi et al., 1999[34] | OC fusion-surgical technique | First description of OC fusion using pedicle screws and OC rod systems and clinical outcome of 26 patients | Case series | IV | 130 | 7.6 (16th) |
| 37   | Apuzzo et al., 1978[33] | Trauma-odontoid fractures | Management and outcome of 45 patients with fractures of odontoid process | Case series | IV | 129 | 3.4 (41st) |
| 38   | Melcher et al., 2002[26] | Atlantoaxial fixation-biomechanics | In vitro biomechanical comparison of the stability of atlantoaxial fusion constructs between transarticular-wiring technique versus screw-rod system | Nonclinical | N/A | 128 | 9.1 (12th) |

Contd...
| Rank | Article | Article topic | Article summary | Study type | Level of evidence | Total citations | Citation rate |
|------|---------|---------------|----------------|------------|------------------|----------------|---------------|
| 39   | Weissman et al., 1982[^33] | Atlantoaxial instability-rheumatoid arthritis | Clinical and radiological findings of 194 patients with rheumatoid arthritis who developed atlantoaxial subluxation | Case series | IV | 128 | 3.8 (37[^40]) |
| 40   | Hadley et al., 1985[^40] | Trauma-axial fractures | Management and outcome of 107 patients with fractures of C2 categorized into odontoid fractures, traumatic spondylolisthesis, and miscellaneous fractures | Case series | IV | 122 | 3.9 (35[^40]) |
| 41   | Fielding et al., 1976[^41] | Mixed (atlantoaxial fixation, OC fusion, atlantoaxial instability) | Outcome of 57 patients with atlantoaxial instability who underwent fusion including 46 atlantoaxial fusions and 11 OC fusions | Case series | IV | 121 | 2.9 (46[^40]) |
| 42   | Naderi et al., 1998[^42] | Atlantoaxial instability- biomechanics | Biomechanical investigation of C1–C2 motion after posterior fixation in four combination of cable, graft, and transarticular screw | Case series | IV | 120 | 6.7 (20[^40]) |
| 43   | Mikulowski et al., 1975[^43] | Atlantoaxial instability-rheumatoid arthritis | Case report and review of literature for sudden death due to atlantoaxial instability secondary to rheumatoid arthritis | Case series | IV | 120 | 6.3 (23[^40]) |
| 44   | Mathews 1974[^44] | Atlantoaxial instability-rheumatoid arthritis | 5-year natural history of atlantoaxial instability in 76 consecutive patients with rheumatoid arthritis | Case series | IV | 120 | 3.2 (42[^40]) |
| 45   | Spence et al., 1970[^45] | Trauma-atlantal fractures | Case report of burst of the atlas, associated with rupture of transverse ligament indicated by lateral mass displacement of more than 6.9 mm, which is later known in the literature as "rule of Spence" | Case report | IV | 117 | 4.2 (34[^40]) |
| 46   | Stillerman et al., 1993[^46] | Atlantoaxial fixation-surgical technique | Description of a modification of atlantoaxial transarticular fusion with screw fixation and bony fusion without wiring, and outcome of 22 patients | Case series | IV | 117 | 3.8 (38[^40]) |
| 47   | Dvorak et al., 1988[^47] | Atlantoaxial instability-biomechanics | Biomechanical properties of alar and transverse ligaments in stability of CV junction | Nonclinical | N/A | 116 | 2.9 (47[^40]) |
| 48   | Greene et al., 1997[^48] | Trauma-axial fractures | Management and outcome of 340 fractures of C2 divided into odontoid fracture, traumatic spondylolisthesis of axis and miscellaneous fractures | Case series | IV | 113 | 3.8 (39[^40]) |
| 49   | Crockard 1985[^49] | Anterior approach to CV junction-surgical technique | Description of the technique of transoral approach to the CV junction | Review | V | 109 | 2.7 (48[^40]) |
| 50   | Crockard et al., 1986[^50] | Mixed - (atlantoaxial instability, anterior approach to CV junction, OC fusion) | Outcome of 14 patients with rheumatoid arthritis with atlantoaxial instability who underwent transoral decompression followed by OC fusion | Case series | IV | 108 | 2.6 (50[^40]) |

CV - Craniovertebral; CT - Computed tomography; N/A - Not available; OC - Occipitocervical
C2 in occipitocervical, atlantoaxial, and subaxial fusion. The author discusses the advantage of this previously unreported technique, including the low risk of vertebral artery injury.

The distribution of the year of publication of the top 50 articles reveals interesting trends. Our search criteria began in 1900 and ended in 2015. There were a total of five articles in the first 70 years of the 20th century, with no articles in the 1950s on our list. In the 1970s, the number of articles increased to 11, followed by another increase to 14 articles in the 1980s, peaking in the 1990s with 16 articles. This was followed by a stark decrease in the 2000s to four articles. There were no articles from the 2010s that qualified for the top 50 list.

We identified the most-cited articles stratified by the decade of publication. In the 1940s, the most-cited article, and also the only article from this decade in our list, was McGregor’s study, which was discussed earlier. In the 1960s, the most-cited article was a case series by Sharp and Purser who reported the incidence and the diagnostic criteria of atlantoaxial subluxation in patients with rheumatoid arthritis and ankylosing spondylitis. In the 1970s, the most-cited article was by Anderson and D’Alonzo. This article is also the most-cited article in our top 50 list. The authors provide their well-known classification of the dens fracture into type I, fracture of the tip of dens, type II fracture at the base of dens, and type III fracture of the dens extending to the lateral masses of the axis. All the above articles are concerned primarily with the radiologic diagnosis of pathology concerning the craniovertebral junction.

The most-cited articles in the subsequent decades (1980s–2000s) are focused on surgical management of the pathologies that involve the craniovertebral junction. In 1980s, Menezes and VanGilder described their 10-year experience in using transoral approach to the craniovertebral junction in 72 patients with various pathologies. Although this article is not the first to describe the anterior approach to this anatomical location, it may be considered the most-cited article that promoted this surgical technique, its efficacy and safety. This article was ranked 14th overall.

In the 1990s, the most-cited article, ranked 6th overall, was by Goel and Laheri who described for the first time the technique of using lateral mass screws of C1 and C2 with plates in atlantoaxial or occipitocervical fusion constructs. In the 2000s, the most-cited article was by Harms and Melcher who described the incorporation of rods, instead of plates, in connecting C1 lateral mass and C2 pedicle screws in atlantoaxial fixation. This article is ranked 2nd overall. Of note, the Harms’ paper unfortunately did not cite the Goel’s paper.

Ranking based on citation rate revealed that the aforementioned article by Harms and Melcher was the 1st. The second-ranked article was by Dickman and Sonntag, from 1998, whereby the authors described the outcome of patients undergoing atlantoaxial transarticular fixation. This article was not the first to describe the technique of transarticular atlantoaxial fixation which is attributed to Magerl. This article was published in German, thus not meeting our inclusion criteria (due to the language of publication). The Dickman and Sonntag study was not the first to describe the outcome and complications of this technique either, which is credited to Grob et al.’s study from 1991, ranked 11th overall and 10th based on citation rate. It should be noted that Dickman and Sonntag’s study included 121 patients compared to the 38 patients in Grob et al.’s study. The 3rd ranked article based on citation rate was by Madawi et al. in 1997, which, interestingly, also described the outcome of transarticular fusion of C1 and C2 in 61 patients. Thus, the top three ranked articles based on citation rate are all related to atlantoaxial fixation.

In fact, article topics were predominantly concerned with atlantoaxial fixation comprising 28% of the studies, with six of the top ten articles dedicated to this topic. Trauma and atlantoaxial instability were the second most common topics with 24% each. Among the articles on trauma, nine articles were concerned with fractures of C2. Of the 12 articles on atlantoaxial instability, eight were dedicated to patients with rheumatoid arthritis. Mixed topic articles were 10% of the top 50 cited articles in the field. All five of the mixed articles included the topic of occipitocervical fusion. Among all the fifty studies, only one was dedicated solely to this surgery as described by Abumi et al. The authors described for the first time the technique of occipitocervical fusion using cervical pedicle screws and occipitocervical rod system. This article was ranked 36th overall.

The most productive country, institution, and author in our list of top 50 most-cited articles were the United States of
Absence of high level of evidence among the top 50 cited articles was unambiguous. There are 46 clinical studies, all of which provide a class IV evidence with the predominant majority designed as case series. This could be attributed to the complexity, diverse, and rare pathologies affecting the craniovertebral junction, which have proved the design of higher quality studies difficult. The other four articles are in vitro biomechanical studies, to which the designation of level of evidence does not apply.

This study has limitations. Citation analysis is biased. Citation does not necessarily imply the impact of an article on the study that is citing it. Authors often provide extensive background information in the introduction section of their articles citing various previous related articles or they may cite an article without fully reading it. Another important bias of citation analysis is the issue of self-citation, whereby authors refer to their own work.[54] Although it is seldom the intention of the authors, self-citation inflates the number of citations of a given article which may be misinterpreted as the extent of its influence in the field. To eliminate this bias, we removed self-citation. On average, the total number of citations was reduced by an average of 11 citations per article. Another bias arises from the fact that the total number of citations for an article may increase merely based on how old a publication is: An older study would have a higher chance of accumulating citations than a newer study. To circumvent this bias, we also provide citation rate, the total number of citations divided by the number of years since publication. This is an attempt to take into consideration the date of publication. A review of the top ten articles in our list reflects this phenomenon, whereby four articles are from 1970s, five articles from 1990s, and only one article from 2000s. However, citation rate is not flawless either. The older the study, the higher the denominator of the equation to determine citation rate. This, in essence, “dilutes” the total number of citations of a given article. This is reflected, at least partially, in the fact that based on citation rate, the top 3 articles are from 2001, 1998, and 1997, respectively. Therefore, we believe that both the total number of citations and citation rate, when considered together, provide a more comprehensive perspective of which articles in the field of craniovertebral junction surgery are the most cited. Finally, implicit citations is another bias of citation analysis, whereby an article whose contribution to the field has been absorbed to the body of knowledge becomes cited less and less over time. As described above, we have made every attempt to consider and account for the inherent biases of citation analysis. Importantly, the flaws of citation analysis is a reminder that citation does not imply influence. Therefore, we have deliberately avoided referring to the articles in our top 50 list as “most influential.”

**Conclusion**

We identified the fifty most-cited articles related to the craniovertebral junction pathologies. This field has attracted the attention of various centers from various countries. Although until the 1970s, the most-cited articles were primarily focused on the diagnostic evaluation of the pathologies of this complex anatomical location, the most-cited articles thereafter are concerned with surgical management of these pathologies, with the advent of multiple new techniques, the majority of which are posterior approaches. The omnipresence of level IV evidence through case series in this list underlines the paucity of high-level evidence and the necessity to design appropriate studies toward developing such evidence.
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Conflicts of interest
There are no conflicts of interest.

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