Is External Cervical Orthotic Bracing Necessary After Posterior Atlantoaxial Fusion with Modern Instrumentation: Meta-Analysis and Review of Literature

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Key words
- Arthrodesis
- Atlantoaxial
- C1-2
- C1-C2
- Cervical orthotic
- Hard collar

Abbreviations and Acronyms
CSF: Cerebrospinal fluid
CT: Computed tomography
ECO: External cervical orthosis
NS: Not significant
SRC: Screw-rod construct
TAS: Transarticular screws
VAI: Vertebral artery injury

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BACKGROUND: **No guidelines exist regarding external cervical orthoses (ECO) after atlantoaxial fusion. We reviewed published series describing C1-2 posterior instrumented fusions with screw-rod constructs (SRC) or transarticular screws (TAS) and compared rates of fusion with and without postoperative ECO.**

METHODS: **Online databases were searched for English-language articles between 1986 and April 2011 describing ECO use after posterior atlantoaxial instrumentation with SRC or TAS. Eighteen studies describing 947 patients who had SRC (± ECO: 254 of 693 patients), and 33 studies describing 1424 patients with TAS (± ECO: 525 of 899 patients) met inclusion criteria. Meta-analysis techniques were applied to estimate rates of fusion with and without ECO use.**

RESULTS: **All studies provided class III evidence, and no studies directly compared outcomes with or without ECO use. There was no significant difference in the proportion of patients who achieved successful fusion between patients treated with ECO and without ECO for SRC or TAS patients. Point estimates and 95% confidence intervals (CI) for rates of fusion ± ECO were 97.4% (CI: 95.2% to 98.6%) versus 97.9% (CI: 93.6% to 99.3%) for SRC and 93.6% (CI: 90.7% to 95.6%) versus 95.3% (CI: 90.8% to 97.7%) for TAS. There was no correlation between duration of ECO treatment and fusion (dose effect).**

CONCLUSIONS: **After C1-2 fusion with modern instrumentation, ECO may be unnecessary (class III). Some centers recommend ECO use with patients with softer bone quality (class IV). Prospective, randomized studies with validated radiographic and clinical outcome metrics are necessary to determine the utility of ECO after C1-2 fusion and its impact on patient comfort and cost.**

INTRODUCTION

Numerous pathological conditions can affect the atlantoaxial osseoligamentous complex with resultant instability. Modern C1-2 instrumentation techniques include transarticular screws (TAS) and screw-rod constructs (SRC). In contrast to the relatively high rate of nonunion with wiring techniques, the rates of successful fusion with modern instrumentation and techniques exceed 95% and obviate the need for postoperative halo vest immobilization in most patients (12, 14, 15, 19, 29, 65).

Currently, no guidelines exist regarding the clinical utility of placing patients in external cervical orthoses (ECO, "hard collar") after posterior atlantoaxial instrumented fusions. The use of ECO after C1-2 fusion varies among centers. Some apply ECO in all patients (18, 23, 27, 32, 34, 52) and others do not use them postoperatively (3, 20, 28, 29, 35, 41, 68-70). Other surgeons use discretion and utilize postoperative bracing in patients with softer bone or those with significant pain (14, 36). The decision to apply ECO, however, seems to be based on anecdotal reports and the bias of each surgeon. We systematically reviewed published series describing C1-2 posterior instrumented fusions with either C1-2 SRC or TAS and compared the rates of fusion with and without postoperative ECO using meta-analysis techniques.

MATERIALS AND METHODS

Article Selection

Online databases Medline (PubMed) and Embase were searched for English-language articles published between 1986 and April 2011 containing the following search terms: "C1-C2" or "C1-2" or "atlantoaxial" or "atlantoaxial" or "rotatory subluxation" or "rheumatoid arthritis" or "os odontoideum" or "C2" or "C1" or "dens fracture" or "osteoarthritis" or "atlas" or "axis" or "transarticular" or "external cervical orthosis" or "external cervical orthoses" or "cervical orthosis" or "cervical orthoses" or "Miami J" or "Philadelphia collar" or "hard collar" and "fusion." The search identified 6481 abstracts, of which 1892 pertained to the cervical spine. The abstracts for these 1892 manuscripts were reviewed manually, and each article of interest was marked for further review. The full text of the marked studies was retrieved, and studies that satisfied our inclusion criteria were included in this meta-analysis. The references listed in

each article of interest were also reviewed for pertinent articles.

Analysis was limited to articles that included patients over 18 years of age at time of posterior atlantoaxial surgery and those published in 1986 or later given the advent of C1-2 posterior instrumented fusions with TAS as originally described by Magerl and Seeman in 1986 (42) and screw-plate constructs in 1994 reported by Goel and Laheri (24) and later modified to SRC by Harms and Melcher (29). Patients with screw-plate constructs were included in the SRC group given the use of separate instrumentation into both C1 and C2. Series that reported exclusively on unilateral TAS fixation were excluded. Case reports were excluded, and a given series had to report on at least 10 patients to be included. Articles that included posterior cervical instrumentation and fusion at subaxial levels or occipital incorporation were included only if the data on patients undergoing C1-2 fusions could be disaggregated or comprised less than 20% of cases in the series. Articles specifically reporting fusion after tumor resections were excluded. Series that combined oncological pathologies of C1-2 instability with traumatic and degenerative etiologies and children under 18 years of age were included if the data could not be disaggregated and only if these cases accounted for fewer than 20% of the patients in a given series. Patients who underwent C1-2 instrumentation without intended fusion with or without delayed hardware removal were excluded from fusion outcomes. No review articles were included in this analysis. Patients who had other methods of C1-2 fixation (wiring, clamps, noninstrumented fusions) were not included in this analysis.

Only studies that specifically reported the use or nonuse of ECO (+ECO or –ECO) after surgery were included. Soft collar use was considered –ECO. The studies from centers using halo vest immobilization (66) and those that did not disaggregate the outcomes of fusion of +ECO or –ECO patients were excluded (14). Duration of ECO use was also recorded.

Table 1 is a matrix showing the number of patients and studies for SRC and TAS patients by ECO use. Fifty-one articles reporting on 2371 patients who underwent C1-2 fusions with TAS or SRC were analyzed, having satisfied our inclusion criteria. The +ECO group comprised 254 SRC (10, 15, 23, 49, 52) and 525 TAS cases (1, 5, 15, 16, 18, 21, 22, 27, 32, 34, 36, 40, 50, 61, 63, 65, 72, 75). The –ECO group comprised 693 SRC cases (3, 13, 28, 29, 35, 37, 55, 60, 62, 64, 68, 70, 74) and 899 TAS cases (6, 8, 9, 11, 19, 20, 25, 26, 36, 41, 43, 51, 53, 58, 69). The quality of evidence was based on the *Guidelines for the Surgical Management of Cervical Degenerative Disease* (44).

Data Extraction

Data from these articles were pooled to calculate the baseline characteristics of the patients and the prevalence of postoperative outcomes. Baseline data recorded included number of patients, gender, mean age, and diagnosis. Data regarding surgery included type of C2 instrumentation (pars interarticularis, pedicle, or a combination of both techniques), use of autograft or allograft, type of allograft (morselized or structural), use of ECO, duration of ECO, decortication and packing of the C1-2 joint with bone graft, 30-day perioperative mortality, and mean follow-up duration. Outcome variables recorded included the rates of bony fusion, clinically significant screw malpositions, neurological complications, vertebral artery injury (VAI), cerebrospinal fluid (CSF) leak, and wound infections. Clinically significant screw malpositions were defined as any screw that caused VAI or neurological deficit, directly resulted in pseudoarthrosis (i.e., failure to capture C1 lateral mass for TAS), or required operative revision or removal.

Hard collar use was tabulated as a dichotomous variable (used or not used). The duration of hard collar use in weeks was also recorded. Mean values of duration were calculated by a weighted average of the duration of use and the number of patients in each study. For studies that reported a range of values, the arithmetic mean of the higher and lower values of the range was calculated.

Different centers used varying criteria to determine successful arthrodesis including lack of hardware loosening, lack of movement on flexion-extension radiographs, presence of bony bridging across the C1-2 joint on radiographs, and presence of bridging trabecular bone between C1 and C1 on computed tomography (CT) imaging. Given the lack of a standardized definition of arthrodesis and similar to other literature reviews (73), we tabulated fusion as successful or unsuccessful based on each report's own definition.

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Statistical Analysis

The raw data were entered into Microsoft Excel (Office 2008 for Mac). Using the number of patients in each study with data available and the percentage of cases for each variable collected, weighted averages were calculated to determine the conglomerate values for all studies included. Fisher exact (χ^2) tests were used to compare proportions between the screw-rod and transarticular groups. Spearman correlations were used to analyze the association of ECO duration with fusion success. All statistics were calculated with SSPS (version 17.0 for Mac; SSPS, Inc., Chicago, Illinois, USA). Only mean values were reported for the variables of age at surgery and follow-up duration. Thus, these variables were only semiquantitatively compared.

We compared the rates of fusion via the meta-analysis software Comprehensive Meta-analysis, version 2.2 (Biostat, Englewood, New Jersey, USA). The random-effects model was used for analysis and result reporting. We assumed that the methodology of each study was unique and the studies were heterogeneous. Heterogeneity testing was also performed using Q-testing. A 2-tailed P value of $<.05$ was considered statistically significant for all analyses.

RESULTS

No studies directly compared C1-2 fusion with or without ECO. Three studies of 37 patients were performed in a prospective manner, but all were small case series that lacked a control group (6, 55, 65). The remaining 48 studies comprising 2334 patients were retrospective case series. All data were considered class III evidence.

Comparison of SRC Patients with and without ECO

Tables 2 and **3** summarize the baseline clinical data and outcomes for patients treated