Lateral Mass Screw Fixation in the Cervical Spine

A Systematic Literature Review

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Background: Lateral mass screw fixation with plates or rods has become the standard method of posterior cervical spine fixation and stabilization for a variety of surgical indications. Despite ubiquitous usage, the safety and efficacy of this technique have not yet been established sufficiently to permit ''on-label'' U.S. Food and Drug Administration approval for lateral mass screw fixation systems. The purpose of this study was to describe the safety profile and effectiveness of such systems when used in stabilizing the posterior cervical spine.

Methods: A systematic search was conducted in MEDLINE and the Cochrane Collaboration Library for articles published from January 1, 1980, to December 1, 2011. We included all articles evaluating safety and/or clinical outcomes in adult patients undergoing posterior cervical subaxial fusion utilizing lateral mass instrumentation with plates or rods for degenerative disease (spondylosis), trauma, deformity, inflammatory disease, and revision surgery that satisfied our a priori inclusion and exclusion criteria.

Results: Twenty articles (two retrospective comparative studies and eighteen case series) satisfied the inclusion and exclusion criteria and were included. Both of the comparative studies involved comparison of lateral mass screw fixation with wiring and indicated that the risk of complications was comparable between treatments (range, 0% to 7.1% compared with 0% to 6.3%, respectively). In one study, the fusion rate reported in the screw fixation group (100%) was similar to that in the wiring group (97%). Complication risks following lateral mass screw fixation were low across the eighteen case series. Nerve root injury attributed to screw placement occurred in 1.0% (95% confidence interval, 0.3% to 1.6%) of patients. No cases of vertebral artery injury were reported. Instrumentation complications such as screw or rod pullout, screw or plate breakage, and screw loosening occurred in <1% of the screws inserted. Fusion was achieved in 97.0% of patients across nine case series.

Conclusions: The risks of complications were low and the fusion rate was high when lateral mass screw fixation was used in patients undergoing posterior cervical subaxial fusion. Nerve root injury attributed to screw placement occurred in only 1% of 1041 patients. No cases of vertebral artery injury were identified in 758 patients. Screw or rod pullout, screw or plate breakage, and screw loosening occurred in <1% of the screws inserted.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

The use of lateral mass screw fixation with plates or rods in the subaxial cervical spine has become the standard method of posterior cervical spine fixation and stabilization over the past two decades. Such screw fixation techniques have been used for a variety of cervical spine indications including spondylosis, trauma, deformity, inflammatory disease, revision surgery, and tumor. Since the technologies utilized for the screw fixation are derivatives of technologies developed for long bone and thoracolumbar fixation, none of the lateral mass screw fixation systems currently on the market

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TABLE I Inclusion and Exclusion Criteria for Studies of Posterior Cervical Subaxial Fusion with Lateral Mass Instrumentation*

Study Component	Inclusion	Exclusion
Participants	Adults	Children (age, <18 yr)
	A pathology of spondylosis (degenerative disease), trauma, deformity, inflammatory disease, or revision surgery	A pathology of infection or tumor
Intervention	Patients undergoing posterior cervical subaxial fusion utilizing lateral mass instrumentation with plates or rods	Laminectomy without fusion
		Laminoplasty
		Fusions extended to the upper cervical spine and/or skull
		Fusions extended to the thoracic spine
		Pedicle screws
		Facet screws
		Anterior fusion
Comparators	No fixation (bone graft only, with or without external immobilization†)	
	Wiring (interspinous, sublaminar, Bohlman triple wire)	
	Hooks and/or rods	
Short and long-term outcomes	Complication rates: reoperation, pseudarthrosis, neurological, vascular, infection, complications due to instrumentation, complications due to type and length of external immobilization	Nonclinical outcomes
	Fusion rates	Radiographic (excluding fusion): alignment, range of motion, etc.
	Pain	
	Neurological outcomes	
	Functional and/or activities-of-daily-living outcomes	
	Type, length, and duration of external immobilization	
Study design	Studies assessing complication rates following LMSF	Case reports
	Studies assessing clinically meaningful improvement in outcomes for LMSF	Nonclinical studies
	Comparative studies and, if need be, case series	
Publication	Studies published in English in peer-reviewed journals	Abstracts, editorials, letters
		Duplicate publications of the same study that do not report on different outcomes
		Single-center reports from multicenter trials
		Studies reporting on the technical aspects of the surgery
		White papers or narrative reviews
		Articles identified as preliminary reports when results are published in later versions

*LMSF = lateral mass screw fixation. †Halo vest, rigid cervical-thoracolumbosacral orthosis (e.g., two or four-posters), other collars (e.g., Philadelphia, Miami-J), soft collar, or none.

have been subject to the rigors of an investigational device exemption (IDE) pivotal study, and thus none of these systems have so-called "on-label" U.S. Food and Drug Administration (FDA) approval for use in the subaxial posterior cervical spine. Most such screw fixation systems have approval simply as "bone screws." Despite ubiquitous usage, surgeon education regarding the application of lumbar mass screw fixation in the posterior cervical spine is hampered by this lack of "on-label" FDA approval.

The ubiquitous use of such screw fixation for posterior cervical stabilization and the rarity of complications reported from its usage imply a degree of safety; most importantly, however, it indicates a need for standardized teaching methods to avoid complications related to its usage. To date, we are

aware of no rigorous evidence synthesis of lateral mass screw fixation sufficient to establish safety or efficacy in the eyes of the FDA. Therefore, this systematic review was designed to answer the following questions: What is the safety profile of such screw fixation when used in stabilizing the posterior cervical spine, and is it similar to that of other stabilization techniques? Also, what is the effectiveness of such screw fixation when used in stabilizing the posterior cervical spine, and is it similar to that of other stabilization techniques?

Materials and Methods

Electronic Database Search

A systematic search, following well-prescribed procedures[1], was conducted in MEDLINE and the Cochrane Collaboration Library for literature published from January 1, 1980, through December 1, 2011. The search results were limited to studies in humans published in the English language. The reference lists of included articles were also systematically checked to identify additional eligible articles. Articles to summarize were selected on the basis of the inclusion and exclusion criteria in Table I. As a general rule, studies were excluded when >15% of the total cohort met one of the established exclusion criteria. We initially searched for comparative studies evaluating the safety and effectiveness of lateral mass screw-and-plate or screw-and-rod fixation compared with no fixation, wiring, or hooks and/or rods. Finding only two small retrospective comparative studies, we expanded our search to include case series consisting of single-arm studies of patients receiving lateral mass screw fixation (see Appendix for details of all clinical outcomes reported).

Data Extraction

Each retrieved citation was reviewed by two independently working reviewers (E.D.B. and J.R.D.). Over half the articles were excluded on the basis of information provided in the title or abstract. Citations that appeared to be appropriate or that could not be excluded unequivocally on the basis of the title and abstract were identified, and the corresponding full text reports were reviewed by the two reviewers and the lead author (J.D.C.). Disagreement was resolved by consensus. We identified articles with overlapping patient populations and sought to determine the extent of overlap. In cases in which the overlap was substantial (i.e., the patients in one article were a subset of those in a larger study), the smaller study was excluded. This occurred in three instances: in the 1994 study by Fehlings et al.[2], which was a continuation of the 1988 study by Cooper et al.[3]; in the 2006 study by Sekhon[4], which involved a subset of patients from a larger study published in 2005[5]; and in the 2011 study by Audat et al.[6], which included a smaller sample of patients from the same population described in 2011 by Al Barbarawi et al.[7]. Therefore, we excluded the study by Cooper et al., the 2006 study by Sekhon, and the study by Audat et al. In another set of articles, the overlap was judged to be small: in 2004, Katonis et al. reported on seventy patients (nineteen with myelopathy) recruited from the University of Texas and the University of Crete[8], and in 2011 Katonis et al. reported on 225 patients with myelopathy from the University of Crete[9]. Thus, both of these studies were retained for this review. The data extracted from the included articles consisted of patient demographics, diagnosis, surgical intervention, complications, fusion success (the primary effectiveness outcome), pain, and function.

Statistical Methods

Our initial approach to summarizing the data from the case series was to stratify by diagnostic category, with the three categories being spondylosis, trauma, and mixed (spondylosis and trauma, plus other diagnoses such as infection and tumor as long as <15% of the cohort had these diagnoses). Studies were included in one of the former two diagnostic categories if >80% of the study group had that diagnosis. Upon review, the results were consistent across the three diagnostic categories, indicating that diagnosis was likely not a confounding factor, and we therefore pooled the data from all of the studies. (The stratified data can be found in the Appendix.) Pooled means or proportions, weighted by sample size, were calculated for all demographic information. Risk proportions from individual studies were pooled together, and a meta-analysis was conducted to obtain combined risk estimates with accompanying 95% confidence intervals (CIs). The sample size was used to determine the relative weight of each study within a pooled outcome. The standard error, SE, of a binomial proportion was calculated as $(p[1 - p]/n)^{1/2}$, and the 95% CI was calculated by the Wald method as the risk estimate ± 1.96 × SE. When zero events were reported for an outcome in all studies, the CI was found by using the "rule of three" estimation[10]. This method approximates the upper bound of the 95% CI as 3/n. Complication risks were reported as the proportion of patients experiencing an event, except when reporting instrumentation complications, for which the risks were reported as the proportion of events per screws inserted. Pain and functional outcomes were assessed in a variety of ways across the included studies.

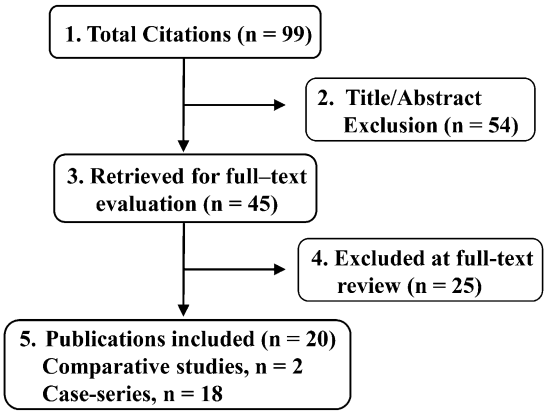

Fig. 1

Flowchart showing the results of the literature search.

Source of Funding

This work was supported by a grant from the Cervical Spine Research Society.

Results

A total of ninety-nine articles were identified through the literature search, and forty-five of these were selected to undergo full text review. After full text review, twenty-five articles were excluded because >15% of patients underwent fusion extending to the thoracic spine, axis, atlas, and/or occiput (n = 6); >15% underwent a combination of anterior and posterior cervical spine surgery (n = 6); fewer than ten patients were included in the report (n = 4); the patient population was identical to that in another report, or there was a very large overlap (n = 3); >15% of patients were less than eighteen years of age (n = 2); a tumor was the sole indication for surgery (n = 2); no mention of lateral mass screw fixation was made (n = 1); and results were not reported separately for a mixed surgical population (n = 1) (see the Appendix for a list of the excluded articles). The remaining twenty studies satisfied the inclusion and exclusion criteria and are summarized in this report (Fig. 1). Only two retrospective comparative studies examining lateral mass screw fixation with plates or rods compared with wiring were identified. The remaining eighteen studies were case series.

In the two comparative studies, a total of ninety-nine patients underwent subaxial posterior cervical fusion (Table II).

TABLE II Demographics of the Retrospective Comparative Studies Evaluating Lateral Mass Screw Fixation*

Study	Surgical Indications	N	Male *(%)*	Age† *(yr)*	Follow-up† *(yr)*
Lowry[12]	DDD, 29.2% (14/48); trauma, 52.1% (25/48); other*, 20.8% (10/48)	Screws/plates, 14; bands, 34‡	Screws/plates, 93.0; bands, 50.0	Screws/plates, 54.0 (22-78); bands, 39.4 (18-76)	Screws/plates, 2.9 (1.8-3.9); bands, 1.9 (0.3-4.7)
Shapiro[11]	Trauma, 100%	Total, 51; screws/plates, 22 with follow-up; wire, 24 with follow-up§	Overall, 83.6	Overall, 30 (19-52)	Overall, NR (1-10); screws/plates, 3.3; wire, 8.5

*DDD = degenerative disc disease, NR = not reported, and other = prior operation, rheumatoid arthritis, metastatic cancer, and unknown. †The values are given as the mean, with the range in parentheses. ‡Two patients were lost to follow-up. §A total of five patients were lost to follow-up by 1 yr.

The most common indication for surgery was trauma, in seventy-six patients (76.8% overall, and 100% of the population in one study[11]), followed by degenerative disc disease, in fourteen patients (14.1%), and other diagnoses, in ten patients (10.1%). Of the ninety-two patients (93%) available for follow-up, thirty-six were treated with lateral mass screw and plate fixation and fifty-six underwent either tension band wiring[12] or interspinous and facet wiring with placement of iliac crest bone graft[11]. One study included almost twice as high a proportion of men in the lateral mass screw group (93.0%) as in the wire group (50.0%); the mean age was also greater in the screw group (54.0 years) compared with the wire group (39.4 years)[12]. The mean duration of follow-up in that study was 2.9 years (range, 1.8 to 3.9 years) in the screw group and 1.9 years (range, 0.3 to 4.7 years) in the wire group. In the other comparative study, demographics were not reported according to treatment group; 83.6% of the population was male and the mean age was thirty years[11]. The mean duration of follow-up in that study differed widely between the lateral mass screw group (3.3 years) and the wire group (8.5 years).

Outcomes for a total of 1257 patients were reviewed in the eighteen case series evaluating subaxial posterior cervical fusion utilizing lateral mass screws. Of the studies, eight involved patients with spondylosis (n = 555)[9,13-19], two involved patients with trauma (n = 73)[2,20], and eight involved patients with mixed diagnoses (n = 629)[5,7,8,21-25]. Two of the case series were actually arms of studies comparing lateral mass screw fixation with a comparator that did not meet our inclusion criteria (i.e., anterior corpectomy and open-door laminoplasty); the results were reported in such a way as to allow us to treat the lateral mass screw group as a case series[13,15]. Mean ages ranged from 32.4 to 68 years across the studies (with individual patient ages ranging from sixteen to eighty-four years); the younger patients were primarily in the trauma studies. With the exception of one study in which only 23.7% of the patients were male[19], the majority of patients across all studies were male (range of percentages, 50% to 84.1%). Mean follow-up durations ranged from nine to 47.5 months.

Safety in the Comparative Studies (Table III)

In the two comparative studies, overall complication risks were 0% to 7.1% in the lateral mass screw groups and 0% and 6.3% in the wire (control) groups. In the study by Lowry et al.[12], the infection rate was 0% in the lateral mass group compared with 3.1% (n = 1) in the wire group, and the rate of wound seroma was 7.1% (n = 1) in the lateral mass group compared with 0% in the wire group. In that same study, no patient in the lateral mass screw group had loss of reduction or the need for implant removal compared with one patient (3.1%) and two patients (6.3%), respectively, in the wire group. Loosening of three (3.9%) of seventy-six lateral mass screws and of none of the wires was reported. Shapiro et al. reported no complications in the lateral mass screw group; in the wire group, the only complication encountered was one reoperation (4.2%) for subluxation[11].

Local Safety in the Case Series (See Appendix)

Overall, local safety complications were low as reported in fifteen studies. The greatest risk was seen for superficial infection (2.9%; 95% CI, 1.9% to 3.9%) in fourteen studies (n = 1111)[2,5,7,9,13,14,16,17,19,20,22-25], followed by hematoma and/or seroma (1.0%; 95% CI, 0.3% to 1.7%) in six studies (n = 704)[5,7,9,14,18,24], evacuation surgery for hematoma (0.9%; 95% CI, 0% to 1.7%) in four studies (n = 454)[5,7,14,24], dysphagia (0.6%; 95% CI, 0% to 1.9%) in one small study (n = 158)[14], and deep infection (0.6%; 95% CI, 0.1% to 1.2%) in seven studies (n = 680)[5,7,9,13,20,23,25].

Neurological Events in the Case Series (See Appendix)

The overall risk of neurological events was also low as reported in fourteen studies with mean follow-up durations ranging from nine to 47.5 months. Nerve root injury (including radiculopathy, nerve root palsy, and nerve root pain) occurred in 3.9% (95% CI, 2.8% to 5.1%) of patients as reported in eleven studies (n = 1041)[5,7-9,14,16,17,20,22,24,25]; the rate of nerve root injury attributable to screw placement was only 1.0% (95% CI, 0.3% to 1.6%). Furthermore, in eight of these studies in which the total

TABLE III Effectiveness and Safety Outcomes in the Retrospective Comparative Studies Evaluating Lateral Mass Screw Fixation*

Study	Outcome	Lateral Mass Screw Group	Control Group
Lowry[12]†	Efficacy		
	Fusion	100% (14/14)	96.9% (31/32)
	Symptom resolution‡	90.9% (10/11)	80.8% (21/26)
	Safety		
	Loss of reduction	0	6.3% (2/32)
	Infection	0	3.1% (1/32)
	Wound seroma	7.1% (1/14)	0
	Screw or wire breakage	0	3.1% (1/32)
	Screw or wire loosening	3.9% (3/76 screws)	0
	Hardware removal	0	6.3% (2/32)
Shapiro[11]§	Efficacy		
	Neck pain affecting ADLs	9.1% (2/22)	16.7% (4/24)
	Safety		
	Construct failure, undefined	0	0
	Screw/wire breakage	0	0
	Screw backout	0	—
	Reoperation	0	4.2% (1/24)

*ADLs = activities of daily living. †Two patients in the band group were lost to follow-up; outcomes are reported in the remaining thirty-two patients. ‡Three patients in the plate group and six in the band group presented without any preoperative symptoms (i.e., intact) and are therefore not included in the denominator for this outcome. Symptoms included neck pain only, radiculopathy, or myelopathy. §Five patients were lost to follow-up by 1 yr. Outcomes are reported for the remaining forty-six patients only.

number of screws placed in the patients was reported (n = 5661), the risk of nerve root injury per screw inserted was 0.72% and the risk due to screw placement was 0.14%[5,7-9,20,22,24,25]. Of these eight studies, three utilized lateral mass screws with plate fixation only and two utilized lateral mass screws with rods only. The risks of nerve root injury caused by screws utilized for plate fixation and rod fixation were 0.31% (95% CI, 0.1% to 0.61%) and 0.07% (95% CI, 0.0% to 0.20%), respectively, per screw inserted. In the six studies in which the authors attempted to explain the reason for nerve root symptoms not attributable to screw placement, four studies indicated the cause to be C5 nerve root traction or stretching of the spinal cord as it shifted posteriorly after decompression[7,9,17,20]; other possible causes included injury secondary to an overaggressive foraminotomy (one study)[5] and "iatrogenic foraminal stenosis" (one study)[22].

The risk of dural injury or tear was 1.9% (95% CI, 0.7% to 3.1%) in three studies (n = 478)[5,7,9], and cerebrospinal fluid (CSF) leakage occurred in 1.4% (95% CI, 0% to 3.3%) of patients in two studies (n = 144)[7,23]; no instance of either complication was attributed to screw insertion. Unspecified neurological adverse events were reported in six studies, with only one complication (0.3%; 95% CI, 0% to 0.7%) reported in 404 patients[2,7,17,18,22,25].

Other Complications in the Case Series (See Appendix)

Other complications, including vascular and cerebrovascular adverse events, death, and lateral mass fracture, were reported in ten studies with mean follow-up durations ranging from fourteen to 45.6 months. Overall risks were low. No cases of vertebral artery injury were reported across seven studies (n = 758)[2,5,7,9,22,24,25]. Two cases (0.4%; 95% CI, 0% to 1.0%) of spinal cord injury occurred across four studies (n = 488); neither case was attributable to screw insertion[8,9,22,25]. Ten deaths (1.7%; 95% CI, 0.6% to 2.7%), none of which were attributed to the use of lateral mass screws and plates, were reported in a total of 603 patients across six studies[2,5,7,9,16,24]. The risk of deep vein thrombosis (DVT) or pulmonary embolism (PE) was 4.5% as reported in two studies (n = 154)[2,7]. Only one study included reporting of stroke incidence, with no cases reported in 110 patients[7]. Lateral mass fracture was reported in three studies as a function of the number of screws placed (n = 405). A total of fifty-five fractures (1.9%; 95% CI, 1.4% to 2.5%) occurred with placement of 2829 screws[7-9]. Two of the reports indicated that no associated neurovascular impairment occurred as a result of the lateral mass fractures[8,9], and one report did not indicate the subsequent consequences, if any, of the fractures[7].

Instrumentation Complications in the Case Series (See Appendix)

Overall, instrumentation complications occurred infrequently as reported in twelve studies with mean follow-up durations ranging from nine to 45.6 months. Across eight studies, screw and/or rod pullout occurred in thirteen (0.2%; 95% CI, 0.1% to 0.4%) of 5450 screws placed in 818 patients[5,7-9,22-25]. Similarly,

TABLE IV Proportion of Patients with Spondylosis, Trauma, and Mixed Diagnoses in the Lateral Mass Screw Fixation Case Series Who Achieved Fusion*

Studies†	Demographics			Follow-up† *(mo)*	Successful Fusion (95% CI) *(%)*
	N	Male *(%)*	Age† *(yr)*		
9[2,8,9,17,19,21,23-25]	637	60.8	53.6 (32.4-68.0)§	19.8 (9-46)#	97.0 (95.7-98.4)

*For assessment of fusion, four studies[8,9,19,23] used radiography and CT and five studies[2,17,21,24,25] used radiography only. Fusion criteria (when reported) varied slightly across the studies and consisted primarily of evidence of stability on dynamic radiographs, bone trabeculation across facet joints or disc spaces, and absence of radiolucency on CT. †Probable small overlap of populations in the 2004 and 2011 studies by Katonis et al.[8,9]. ‡The values are given as the mean, with the range of the means in the individual studies in parentheses. §Mean age was not reported in one study[21]. #Mean duration of follow-up was not reported in one study[8].

screw and/or plate breakage was reported in sixstudies[5,7,9,22,24,25] in which 4827 screws were placed in 714 patients, and screw loosening was reported in four studies[2,22,24,25] in which 1818 screws were placed in 280 patients. The risk of breakage was 0.2% (95% CI, 0.1% to 0.3%) (eight cases), and the risk of loosening was 0.8% (95% CI, 0.4% to 1.2%) (fifteen cases). The risks of screws violating the facet joint, vertebral artery foramen, or spinal canal were very low: 0.6% (95% CI, 0.3% to 0.9%) of 2746 screws (four studies)[5,7,22,24], 1.5% (95% CI, 1.1% to 2.0%) of 2715 screws (five studies)[5,7,8,23,24], and 0% (95% CI, 0% to 0.1%) of 2092 screws (three studies)[5,7,24], respectively. The method for assessment of screw violation involved computed tomography (CT) scan in four studies[5,7,8,23] and radiography in two studies[22,24].

Subsequent Surgical Procedures in the Case Series (See Appendix)

Subsequent surgical procedures were reported in thirteen studies with mean follow-up durations ranging from nine to 45.6 months. Revision, defined as a surgical procedure that modified or adjusted the original implant because of signs and symptoms such as pain or radiculopathy, was reported in 2.3% (95% CI, 0.9% to 3.7%) of patients across five studies (n = 435)[2,7,9,13,17]. Implant removal, defined as a surgical procedure to correct malpositioned screws, screw breakout, or loosening, was necessary for twenty-seven (1.2%; 95% CI, 0.8% to 1.7%) of 2185 screws placed in 294 patients across five studies[7,20,22-24]. Two studies did not indicate the number of screws used but did indicate a similarly low risk of implant removal (1.0% in 196 patients)[14,16]. Supplemental fixation (surgery to provide additional stabilization to the index site) was reported in one small study (n = 78), with a risk of 1.3% (95% CI, 0% to 3.8%)[22]. Other reoperations, defined as additional procedures at the index level other than a revision, implant removal, or supplemental fixation, were reported in 3.7% (95% CI, 2.4% to 5.1%) of patients across nine studies (n = 721)[2,5,7,9,15,20,22-24].

Effectiveness in the Comparative Studies (Table III)

The rate of successful fusion, as defined by radiographic evidence of ossification within the fused motion segments and/or lack of motion on flexion-extension radiographs, was reported in only one of the comparative studies. The success rates in the lateral mass screw group (100%, n = 14) and the wire fixation (control) group (97%, n = 32) were similarly high at mean follow-up durations of 35.1 and 23.3 months, respectively[12]. In this same study, a higher proportion of patients reported resolution of symptoms (neck pain only, radiculopathy, or myelopathy) in the lateral mass screw group (91%) compared with the control group (81%). In the second study, 9.1% of patients in the lateral mass screw group (n = 22) compared with 16.7% in the control group (n = 24) had neck pain affecting activities of daily living at one year[11].

TABLE V Functional Outcomes of Patients with Spondylosis and Trauma in the Case Series*

Outcome	Studies	Demographics			Follow-up† *(mo)*	Improvement from Baseline
		N	Male *(%)*	Age† *(yr)*		
Spondylosis						
Nurick grade	1[17]	32	75.0	67.8 (50-79)	15.2 (NA)	30.8% (NA)†
mJOA scale	2[13,16]	62	67.9	65.5 (65-66.2)	29.3 (28-30)	23.4% (20.9%-27.4%)†
Odom criteria	2[13,14]	182	60.6	61.7 (61-66.2)	16.3 (15-28)	Improvement in 80.2% (146/182)
Trauma						
ASIA score	1[2]	44	84	32.4 (16-80)	45.6	Improvement in 25.7% (9/35)†

*NA = not applicable. †The values are given as the mean, with the range of means in parentheses. ‡Thirty-five of forty-four patients had preoperative and final follow-up ASIA scores.

Effectiveness in the Case Series (Tables IV and V)

Fusion was achieved in 97.0% (95% CI, 95.7% to 98.4%) of patients across nine studies (n = 637) with mean follow-up durations ranging from 9 to 45.6 months[2,8,9,17,19,21,23-25].

Functional outcomes were reported in a variety of ways across five studies, four involving patients with spondylosis and one involving patients with trauma. The Nurick grade, which is based on nerve root signs, spinal cord involvement, ambulation, and employment status, was reported in one small study with a total of thirty-two patients[17]. The mean percentage improvement from baseline to a mean of 15.2 months was 30.8%. Two studies indicated modified Japanese Orthopaedic Association (mJOA) scores. The mean percentage improvement from baseline in the mJOA score was 23.4% in a total of sixty-two patients with a mean of 29.3 months of follow-up[13,16]. The criteria developed by Odom, which are based on relief of preoperative symptoms and improvement in abnormal findings, were reported in two studies with a total of 182 patients[13,14]. Excellent or good results were reported in 80.2% of the patients after a mean of 16.3 months of follow-up. The American Spinal Injury Association (ASIA) score was reported in the one study (n = 44) of patients with spinal injury[2]. Of the thirty-five patients available for final follow-up at a mean of 45.6 months, 25.7% had improved ASIA scores compared with baseline and none had a poorer score.

Discussion

The purpose of this systematic review was to describe the safety profile and effectiveness of lateral mass screw fixation when used in stabilizing the posterior cervical spine. We found that the risks of complications following this procedure were low and that the rate of successful fusion was high (97%).

Although nerve root injuries and secondary radiculopathy were reported, most reports indicated resolution of any neurological deficit and pain with screw removal. This was an uncommon complication, ranging from 0% to 13.6% in the series reviewed. We were unable to find any reports of vertebral artery injury associated with lateral mass screw fixation in the subaxial spine, in contrast with several reports of vertebral artery injury associated with screw fixation in the upper cervical spine[26,27].

This review has limitations. The twenty papers included for review employed a variety of lateral mass screw fixation techniques for a variety of diagnoses with variable durations of follow-up and variable outcome measures, none of which involved validated patient-based outcome instruments. CT scanning to evaluate screw placement was performed in all patients in only one of the studies[9] and routinely in only three other studies[7,8,23]. This paucity of CT imaging data may also indicate an underestimation of implant loosening, lateral mass fractures, and nonunions in the reviewed studies. Acceptable trials comparing screw fixation with wiring for posterior fusion were limited to two studies, although both supported the hypothesis that fusion with lateral mass screws is at least equivalent, if not superior, to fusion with wiring. It is also conceivable, but unlikely, that some asymptomatic vertebral artery injuries may have been missed and thus not reported in the twenty reviewed studies. Despite these limitations, however, we believe that there is sufficient information in this systematic review to gain reasonable insight into the safety and effectiveness of lateral mass screw fixation.

In conclusion, the risks of complications were low and fusion rates were high when lateral mass screw fixation was used in patients undergoing posterior cervical spine subaxial fusion. Nerve root injury attributed to screw placement occurred in only 1% of 1041 patients. No cases of vertebral artery injury were identified in 758 patients. Screw or rod pullout, screw or plate breakage, and screw loosening occurred in <1% of the screws inserted. On the basis of this evidence, it appears that lateral mass screw fixation is both safe and effective for stabilizing and achieving fusion in the posterior cervical spine.

Appendix

eA Studies excluded after full text review and tables with more detailed data are available with the online version of this article as a data supplement at jbjs.org. ■

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