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On Cervical Zygapophysial Joint Pain After Whiplash

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Study Design. Narrative review.

Objective. To summarize the evidence that implicates the cervical zygapophysial joints as the leading source of chronic neck pain after whiplash.

Summary of Background Data. Reputedly a patho-anatomic basis for neck pain after whiplash has been elusive. However, studies conducted in a variety of disparate disciplines indicate that this is not necessarily the case.

Methods. Data were retrieved from studies that addressed the postmortem features and biomechanics of injury to the cervical zygapophysial joints, and from clinical studies of the diagnosis and treatment of zygapophysial joint pain, to illustrate convergent validity.

Results. Postmortem studies show that a spectrum of injuries can befall the zygapophysial joints in motor vehicle accidents. Biomechanics studies of normal volunteers and of cadavers reveal the mechanisms by which such injuries can be sustained. Studies in cadavers and in laboratory animals have produced these injuries. Clinical studies have shown that zygapophysial joint pain is very common among patients with chronic neck pain after whiplash, and that this pain can be successfully eliminated by radiofrequency neurotomy.

Conclusion. The fact that multiple lines of evidence, using independent techniques, consistently implicate the cervical zygapophysial joints as a site of injury and source of pain, strongly implicates injury to these joints as a common basis for chronic neck pain after whiplash.

Key words: neck pain, whiplash, zygapophysial joint. **Spine 2011;36:S194–S199**

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Convergent validity arises when multiple, independent approaches point to the same conclusion. The independence of the approaches and their concordance allows for greater confidence in the conclusion than that allowed by any one or two approaches alone. In the field of whiplash, convergent validity has arisen with respect to one possible source of pain. Four lines of evidence implicate the cervical zygapophysial joints as the leading source of pain in patients with chronic whiplash-associated disorder.

MATERIALS AND METHODS

The literature was drawn from the personal library of the author, supplemented by a search on PubMed, using the terms: whiplash, neck pain, zygapophysial joint, and injury. Selected for inclusion were articles that provided any original data on the topic. Excluded were articles that referred to primary studies without adding information, or which offered no more than opinions. The biomechanics literature was searched back to 2000, at which time it had previously been reviewed.[1,2]

RESULTS

Postmortem Studies

Studies, conducted in Sweden[3] and in Australia[4,5] examined the cervical spines of victims of fatal motor-vehicle accidents, and have been the subject of a systematic review.[6] After discounting the lesions that were the cause of death, these studies identified a variety of nonlethal injuries to the cervical spine. Apart from nerve-root lesions and rim-lesions to the intervertebral discs, these injuries included a variety of lesions in the cervical zygapophysial joints, encompassing intraarticular haemorrhages, and various degrees of fractures affecting the articular cartilage, subchondral bone, or entire articular processes (Figure 1).

It is not possible to tell, from these studies or on any other basis, if the sublethal injuries to the zygapophysial joints occurred after the lethal injury to the head or craniocervical junction, or if they occurred before the lethal injury. If the latter applies, these studies provide two lines of evidence. They show that injuries to the zygapophysial joints and other structures can occur, and that the nature of the injuries is intraarticular lesions and small fractures. Most revealing is the fact, in both studies, that virtually none of the lesions

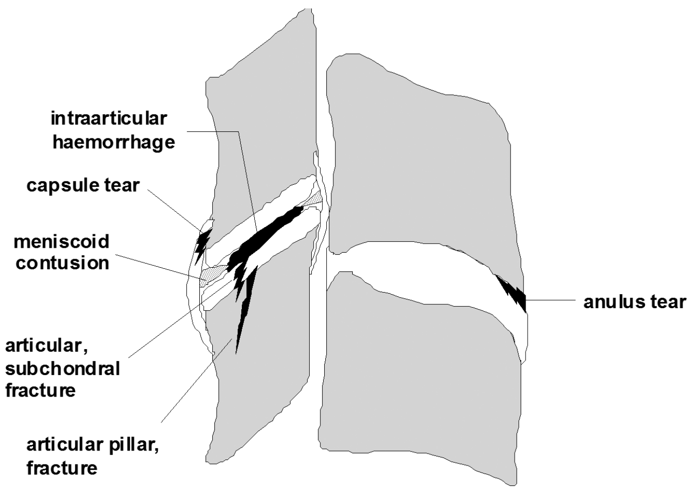

Figure 1. A sketch of the possible lesions of whiplash, as predicted by postmortem studies and biomechanics studies.

seen in the zygapophysial joints were evident on postmortem radiography.[4–6] This fact reinforces the principle that medical imaging *in vivo* may fail to identify lesions that are definitely present at postmortem. Consequently, in the context of whiplash injury, normal radiographs, or even normal magnetic resonance imaging, do not mean that the patient has no lesion.

Biomechanics Studies

Several types of study have addressed the possible mechanics of whiplash injury. They include studies of kinematics *in vivo* and studies of cadavers subjected to experimental rear-end impact.

The *in vivo* studies subjected normal volunteers to low-speed, rear impact under cineradiography.[7] They revealed several offending excursions of the cervical spine. First, the cervical spine is compressed from below, as the trunk rises toward the head. As a result, the cervical spine undergoes a sigmoid deformation (Figure 2). During this deformation the lower cervical vertebrae (typically C5, C6) undergo posterior sagittal rotation about an instantaneous axis of rotation that is abnormally high (Figure 3). This aberration occurs because the upper vertebra of the pair undergoes posterior sagittal rotation with virtually no posterior translation. In effect, it spins backwards *in situ*. The quality of this movement is highly abnormal. Anteriorly, the margins of the vertebral bodies are widely separated (Figure 4). Posteriorly, the inferior articular process of the upper vertebra chisels into the superior articular surface of the lower vertebra (Figure 4). The movements anteriorly predict that rim lesions of the intervertebral disc could occur, as a result of avulsion of the anulus fibrosus from the vertebral endplate. The movements posteriorly allow for a spectrum of lesions in the zygapophysial joints. Intraarticular meniscoids could be contused or ruptured, and impaction fractures of the articular processes could occur.

If cadavers are subjected to whiplash impacts, two types of observations can be made. Transducers can be applied to the zygapophysial joints to measure the relative excursions of their parts; and dissections can be performed, after the experiment, to identify any lesions that have been produced.

Studies looking at the motion of cervical zygapophysial joints during whiplash have shown that these joints initially undergo compression that exceeds physiological limits, and subsequently their capsules undergo strains beyond normal limits.[8–16] In both instances, the abnormal strains are greater as the magnitude of impact increases. Meanwhile, strains in the anulus fibrosus can exceed normal limits.[16,17] At low accelerations, the strains are greatest in the C4–5 disc, but become abnormal also at C3–4, C5–6, and C6–7 as impact accelerations increase.

Studies looking at lesions after whiplash agree on their results. One found injuries to the intervertebral discs in 90% of 21 cadavers, tears of the anterior longitudinal ligament in 80%, and tears of the zygapophysial joint capsules in 40%.[18] The other found tears in the anulus fibrosus, the anterior longitudinal ligament, and in the zygapophysial joints of four

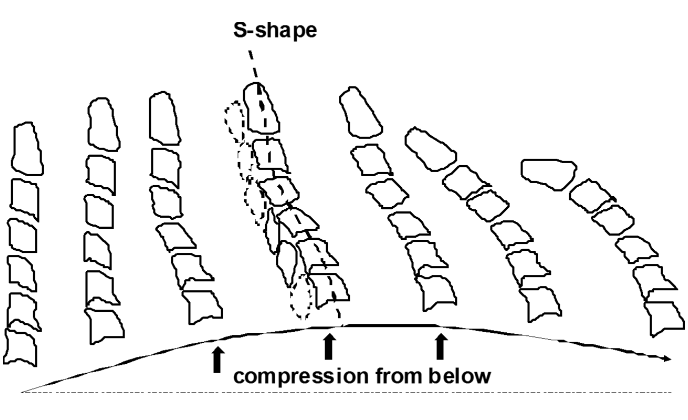

Figure 2. A sketch of the radiographic appearance of the cervical spine during phase 1 of whiplash, based on Kaneoka *et al*.[7] The base of the neck rises. At about 110 ms after impact, the cervical spine is compressed into a sigmoid shape. Extension is completed as the base of the neck descends.

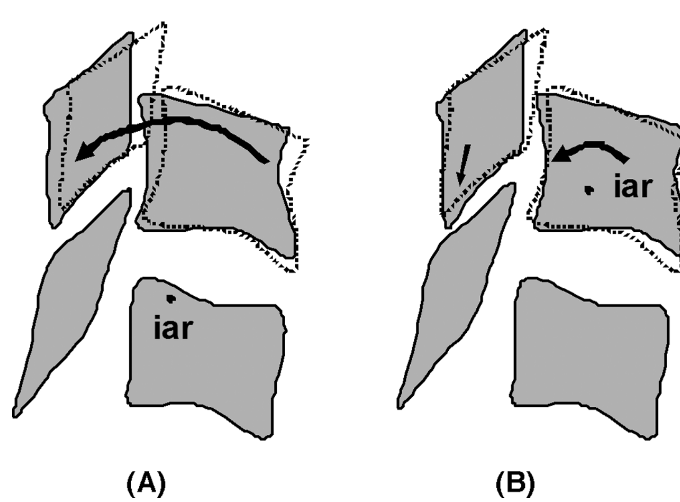

Figure 3. The motion of lower cervical spine segments about their instantaneous axis of rotation (iar). **A,** Under normal conditions the axis lies in the lower vertebra, and the zygapophysial joints glide backwards tangential to the superior articular process. **B,** In whiplash, the axis lies in the moving vertebra, around a shorter radius, so that the inferior articular process chisels into the superior articular process.

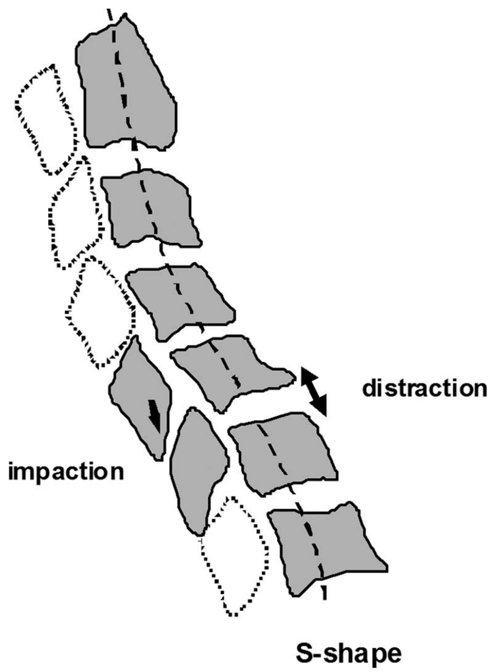

Figure 4. A sketch of the radiographic appearance of the cervical spine at about 110 ms after impact, based on Kaneoka *et al*.[5] The sigmoid deformation of the cervical spine causes abnormal rotation of the lower cervical segments, during which the anterior elements are distracted whereas the posterior elements are impacted.

cadavers tested.[19] Of the 12 lesions found on cryomicrotomy, only two were evident or suggested on plain radiography, and three on computed tomography.[19]

Collectively, these various biomechanics studies, in normal volunteers and in cadavers, predict or produce the same spectrum of lesions as that identified in postmortem studies. In particular, they indicate that the zygapophysial joints can be injured.

Animal Studies

When laboratory animals are subjected to simulated whiplash (adjusted for size), the capsules of their zygapophysial joints are stretched.[20] This stretch evokes sustained nociceptive activity from the affected joint.[21–24] As well, in the central nervous system, downstream changes are produced that are markers of nociceptive activity[23,25–30]; and this activity correlates with behaviors that indicate nociception, such as allodynia.[23,25–27,30–32] Collectively, these studies demonstrate the physiological processes that link biomechanical injury to pain from an injured zygapophysial joint.

Medial Branch Blocks

Cervical medial branch blocks are a diagnostic test for pain stemming from a cervical zygapophysial joint.[33] They involve anaesthetizing each of the one or two nerve that innervate a given joint, with a tiny volume (0.3 mL) of local anaesthetic. To control for possible false-positive responses in patients with chronic pain, the blocks can be controlled using comparative local anesthetic blocks[33–35] or placebo-controlled, triple blocks.[33,36–38] A positive response is complete relief of pain when the offending joint or joints are anaesthetized.

Studies from multiple centers, in different settings, have yielded similar results. In patients with chronic neck pain after whiplash, or in patients with neck pain with or without a history of whiplash, the prevalence of pain stemming from a zygapophysial joint is about 50%[39–41] (Figure 5). Similar or lesser prevalence rates have been reported in studies of patients with nonspecific neck pain, in which the incidence of whiplash as a precipitating event was not specified[42–45] (Figure 5). One study that reported a relatively low prevalence[42] included a large proportion of patients who, for various reasons, did not complete investigations and so, its prevalence (36%) constitutes an underestimate of the typical prevalence. The joints most commonly affected are C2–3 or C5–6 alone, followed by C5–6 and C2–3 in combination, and less often C5–6 and C6–7 in combination.

The results of these clinical studies are fully concordant with the results of postmortem and biomechanics studies. The latter point to the possibility that zygapophysial joints could be injured and, therefore, could be a source of pain. The clinical studies show that they are, indeed, a source of pain—and are commonly so. The zygapophysial joints are the single, most common source of pain in patients with chronic neck pain after whiplash.[39,40,41] No other diagnostic procedure or technique has been tested and validated as extensively as cervical medial branch blocks.[34–38] No study has produced data on any other source of pain to rival the prevalence of zygapophysial joint pain.

Radiofrequency Neurotomy

Cervical zygapophysial joint pain can be treated with cervical medial branch radiofrequency neurotomy. This is a neurosurgical procedure in which percutaneous electrodes are used

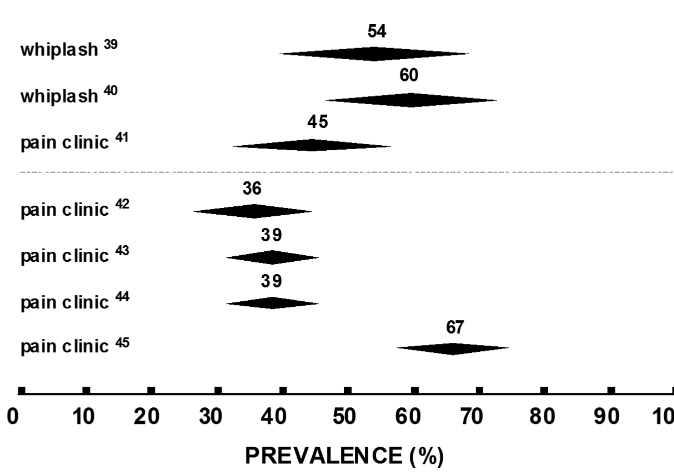

Figure 5. A graphic summary of the prevalence of cervical zygapophysial joint pain in various studies using different samples of patients. The source samples are listed on the left. The diamonds indicate the reported prevalence and its 95% confidence intervals. Studies above the dotted line enrolled patients with whiplash or stipulated the proportion of patients with whiplash or post-traumatic neck pain. Studies below the line did not stipulate the number of patients expressly with whiplash.

to coagulate the medial branches that innervate the painful zygapophysial joint or joints.[46] Denervation of the joint provides complete relief of pain stemming from the joint.

An early study showed that previous reports were flawed by incorrect selection of patients, and by inaccurate surgical technique; but if patients were selected using controlled diagnostic blocks, and if accurate surgical technique was used complete relief of pain could be achieved in a substantial proportion of patients, sufficient to justify a placebo-controlled trial.[47] That trial was subsequently conducted.

The controlled trial showed conclusively that active treatment achieved successful outcomes in a greater proportion of patients for a substantially longer duration than did sham surgical treatment.[48] The definition of success was complete elimination of pain, with full restoration of activities of daily living, and no need for any other health care. A successful outcome was achieved in 70%, and in those patients relief lasted for a median duration of 400 days.[48] Such outcomes are unparalleled by any other treatment for neck pain, surgical or conservative. When independently reviewed, this controlled trial was assessed as a benchmark for the standard of research into the treatment of neck pain.[49]

Later studies reported the long-term outcomes of radiofrequency neurotomy. They showed that if pain recurred, relief could be reinstated by repeat neurotomy.[50,51] By repeating neurotomy, relief could be maintained for several years.

Others later corroborated these outcomes, for patients with neck pain[52] and for patients with cervicogenic headache.[52,53] They showed that repeat neurotomy can be used to maintain the relief of pain.[53,54] Outcomes in patients pursuing litigation are not significantly inferior statistically than in patients not involved in litigation.[51–54]

The most recent corroboration study has been conducted in conventional practice, not in an academic setting.[56] It showed that in two, separate practices, the success rate of cervical radiofrequency neurotomy for chronic neck pain was essentially 70%, with success being defined as complete relief of pain, restoration of activities of daily living, no need for other health care, and return to work. Using single or repeat treatments, success was maintained for a median duration of 29 months in one practice and 26 months in the other, with 60% of patients still having ongoing relief at the time of follow-up. The median duration of relief after an initial or repeat neurotomy was 15 months per procedure.

DISCUSSION

The concept of cervical zygapophysial joint pain is underwritten by an extensive base of evidence. For no other explanation of the pain of whiplash has such a comprehensive evidence-base been assembled. Potential lesions have been demonstrated in postmortem studies. The mechanism of injury has been demonstrated in normal volunteers and in cadavers. Lesions have been produced in cadavers, and in experimental animals. The induced lesions produce nociception in experimental animals. Pain from putatively affected joints in patients can be diagnosed using validated, controlled, diagnostic blocks. Once so diagnosed that pain can be abolished, and patients restored to normal activity. The accumulated evidence satisfies the criteria for convergent validity: multiple, independent lines of evidence point to the same conclusion.

Zygapophysial joint pain is neither a singular nor universal explanation for whiplash. It does not account for every case. The epidemiologic data indicate that it accounts for only a modest 50% of the chronic population. The field remains open for other models to account for the majority of acute cases and the remainder of the chronic cases. However, 50% is not a negligible proportion. If controlled diagnostic blocks are correctly applied, 50% of patients with chronic neck pain can have a legitimate diagnosis established. An explanation of why and how they have developed pain can be provided, based not on conjecture but on established laboratory evidence. If radiofrequency neurotomy is correctly performed, according to prescribed guidelines, some 70% of these patients can have their pain completely relieved. No other treatment for neck pain has been shown to offer that prospect in such a proportion of cases.

Perplexing to some is why this evidence has not captured the imagination of those who comment on whiplash and its management, or who undertake that management. It is not as if the evidence is new; it has been available for over a decade, during which period it has been publicized widely.[57–72]

Among the explanations are that medial branch blocks and radiofrequency neurotomy cannot be performed other than by specially trained, medical practitioners. This means that many health professionals, who might care to be involved in whiplash, are disenfranchised. Legally denied the option of adopting these procedures, they are not able themselves to embrace this solution for their patients. They would prefer that there be a solution that they can embrace.

Nor is referring patients, to someone who can perform medial branch blocks or radiofrequency neurotomy, a dependable option. Few practitioners around the world are skilled in these procedures; and among those who purport to be skilled, there is no guarantee that they perform the procedures properly. Although practice guidelines have been published,[33,46] there is no system of accreditation and, therefore, no guarantee that practitioners abide by those guidelines. The available evidence indicates that good outcomes can only be expected if those guidelines are followed. There is no evidence that any other version, of performing diagnostic blocks or performing radiofrequency neurotomy, achieves the same outcomes as when guidelines are strictly followed.

The lack of uptake of cervical medial branch blocks and radiofrequency neurotomy, therefore, is not for lack of evidence; it is a psychosocial problem—not on the part of patients, but—on the part of health practitioners. Some practitioners overlook, avoid, or abjure the evidence for cervical zygapophysial joint pain, for it does not suit their personal paradigm. Others embrace it, but irresponsibly if not fraudulently. One solution, therefore, to the problem of reducing the transition from acute to chronic whiplash is to resolve these psychosocial problems among healthcare practitioners.

➢ Key Points

- ❑ Biomechanics studies implicate injury to the zygapophysial joints in whiplash.
- ❑ Animal studies show that zygapophysial joints can be rendered painful.
- ❑ Clinical studies show that zygapophysial joint is common.
- ❑ Zygapophysial joint pain can be stopped by radiofrequency neurotomy.

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