Brain (1994), **117**, 325–335

Epidemiology of cervical radiculopathy
A population-based study from Rochester, Minnesota, 1976 through 1990

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Summary

An epidemiological survey of cervical radiculopathy in Rochester, Minnesota, 1976–90, through the records-linkage system of the Mayo Clinic ascertained 561 patients (332 males and 229 females). Ages ranged from 13 to 91 years; the mean age ± SD was 47.6 ± 13.1 years for males and 48.2 ± 13.8 years for females. A history of physical exertion or trauma preceding the onset of symptoms occurred in only 14.8% of cases. A past history of lumbar radiculopathy was present in 41%. The median duration of symptoms prior to diagnosis was 15 days. A monoradiculopathy involving C7 nerve root was the most frequent, followed by C6. A confirmed disc protrusion was responsible for cervical radiculopathy in 21.9% of patients; 68.4% were related to spondylosis, disc or both. During the median duration of follow-up of 4.9 years, recurrence of the condition occurred in 31.7%, and 26% underwent surgery for cervical radiculopathy. A combination of radicular pain and sensory deficit, and objective muscle weakness were predictors of a decision to operate. At last follow-up 90% of our population-based patients were asymptomatic or only mildly incapacitated due to cervical radiculopathy. The average annual age-adjusted incidence rates per 100 000 population for cervical radiculopathy in Rochester were 83.2 for the total, 107.3 for males and 63.5 for females. The age-specific annual incidence rate per 100 000 population reached a peak of 202.9 for the age group 50–54 years.

Key words: cervical; radiculopathy; spondylosis; disc prolapse; epidemiology

Introduction

Cervical radiculopathy describes the group of symptoms and signs related to dysfunction of cervical spinal nerve root(s) (Adams, 1976; Yu *et al.*, 1987). Characteristically, there is pain in the neck and in a radicular distribution in one or both upper extremities occurring in episodes often lasting a few weeks, frequently accompanied by varying degrees of other sensory, motor and reflex changes. Neck movement is often restricted, but in more chronic cases it may be free.

Parkinson (1817) is credited with the first clinical description of a case of cervical radiculopathy, although he ascribed it to a 'rheumatic affection of the deltoid muscle'. Dejerine (1914) formulated the concept of radiculitis and described the intensification of the pain by sneezing. In 1926 Elliott described how radicular symptoms might arise through narrowing of intervertebral foramina secondary to arthritic changes of the cervical spine. Turner and Oppenheimer (1936) elaborated on this further, describing intervertebral foraminal narrowing secondary to thinning of the disc. Brain *et al.* (1948) re-emphasized the distinction between spondylosis and intervertebral disc protrusion, which was initially suggested by Key (1838). The clinical picture of cervical spondylitic radiculopathy and myelopathy was well delineated four decades ago (Frykholm, 1951; Brain *et al.*, 1952; Yoss *et al.*, 1957). Lees and Turner (1963) analysed the natural history of cervical radiculopathy and concluded that it rarely progressed to a myelopathy and that these entities are separate.

Neck pain that radiates to varying degrees in an upper extremity simulating cervical radiculopathy can occur in peripheral entrapment neuropathies, myofascial syndromes, reflex sympathetic dystrophies, thoracic outlet syndrome and in diseases of the heart, chest and shoulder joint (Fager, 1963; Dillin *et al.*, 1986; Kutz, 1992). Electrophysiological and radiographical examinations are often used to establish further the diagnosis of cervical radiculopathy and to determine the

location and extent of the abnormalities (Eisen and Hoirch, 1983; Jahnke and Hart, 1991).

Cervical nerve root pathology may occur in many diseases (Kelsy, 1978). By far the most common causes of cervical radiculopathy are cervical spondylosis and intervertebral disc prolapse resulting in nerve root impingement. Other causes include vertebral fracture dislocation, vertebral collapse, spondylolisthesis and trauma to cervical roots with avulsion or radiation injury. Infiltrative, neoplastic, infectious, para-infectious and metabolic conditions may also result in radiculopathy (Kelsy, 1978). There are, however, instances of cervical radiculopathy as determined by subjective symptoms and objective signs that cannot be attributed to a definite cause. It has been speculated that the pain in these cases derives from a root irritation from inflammation produced by degradation of discal proteoglycans (Lipson and Muir, 1981; Rosomoff *et al.*, 1992).

Cervical radiculopathy is a common condition which affects both sexes after middle age (Kelsy, 1978). Most studies of cervical radiculopathy or of individual conditions which produce cervical radiculopathy are based on referral-practice or hospital-based populations (Yoss *et al.*, 1957; Honet and Puri, 1976; Kelsy *et al.*, 1984). There have been several reports of the surgical treatment of patients with cervical radiculopathy describing and comparing different surgical approaches (Jacobs *et al.*, 1970; Murphey *et al.*, 1973; Gregorius *et al.*, 1976; Henderson *et al.*, 1983), and on conservative management (Martin and Corbin, 1954; British Association of Physical Medicine, 1966; Honet and Puri, 1976; Rosomoff *et al.*, 1992).

In spite of the vast amount of information available on the various aspects of cervical radiculopathy, there is a paucity of population-based descriptive statistics on this condition. In the population survey of spinal degenerative disorders from northern England (Lawrence, 1969), the diagnosis of cervical radiculopathy was based on antecedent information, and other causes of neck and upper limb pain were not excluded. The epidemiological study of Kondo *et al.* (1981) represented only patients with a specific form of cervical radiculopathy related to disc prolapse, who underwent surgical intervention and, hence, comprised only a small fraction of all the cases of cervical radiculopathy.

The requirements for an ideal descriptive epidemiological study are (i) a precise diagnosis, (ii) a well-defined population denominator, (iii) a long period of observation, (iv) a nearly complete ascertainment of all symptomatic patients. None of these requirements can be easily accomplished in the disorder of cervical radiculopathy. First, there are no well-defined diagnostic criteria for cervical radiculopathy, making a differential diagnosis from numerous other causes of neck and upper limb pain difficult. Since the clinical spectrum of this condition is quite varied and patients with cervical radiculopathy are treated by rheumatologists, neurologists, neurosurgeons, orthopaedic surgeons, physical medicine specialists and chiropractors, this condition is difficult to ascertain in a uniform way from the population.

Predicting the outcome of diseases affecting the musculoskeletal system is difficult. Most of the studies in which the prognosis of cervical radiculopathy has been evaluated have used a tertiary referral centre sample and are biased in favour of an advanced or complicated disease process. The cost of cervical radiculopathy to the individual and to society, in terms of work days lost, medically related expenses and medicolegal claims, is thought to be substantial. However, the impression that cervical radiculopathy causes significant morbidity in the general population has not been substantiated by population-based studies of the condition.

With the above considerations, the present investigation was undertaken in Rochester, Minnesota, to define (i) a population-based cohort of patients with cervical radiculopathy, (ii) descriptive statistics on the characteristics of the patients in this cohort, (iii) the natural history of cervical radiculopathy in a population-based sample, (iv) possible prognostic factors by comparing certain attributes of patients with cervical radiculopathy who were treated conservatively and surgically.

Patients and methods

Area of investigation and medical organization

The population of Rochester, Minnesota ($\sim$70 000 in 1990), provides an excellent resource for this epidemiologic study, since medical care of the residents of Rochester is provided almost entirely by the Mayo Clinic, its two affiliated hospitals and the Olmsted Medical Group, with its affiliated hospital. Diagnoses from these health-care facilities (outpatient, inpatient, emergency department and even house calls) have been indexed for computer retrieval, which allows access to the original medical records for review. The case ascertainment and follow-up afforded by this comprehensive computerized medical records-linkage system offers unique opportunities for studying diseases in a circumscribed population over a long period. The organization and potential of this data resource have been described elsewhere (Kurland and Molgaard, 1981).

In any given year, nearly 70% of the Rochester population medically attends at a Mayo facility or an Olmsted Medical Group facility. Among the people 65 years and older, >90% are seen at least once annually. In a 3 year period, almost all local residents will have at least one medical encounter. In a recent survey, every Rochester resident identified by random digit dialling had a medical record at the Mayo Clinic or Olmsted Medical Group (Phillips *et al.*, 1990). Consequently, the records-linkage system provides what is essentially an enumeration of the population of Rochester.

Case ascertainment

For this retrospective study, the indexes were searched for all Rochester residents for whom the following diagnoses were made during the period 1976–90: cervical radiculopathy, cervical neuralgia, cervical neuropathy, spinal neuropathy, cervical spondylitis, cervical disc diseases, disc space infection and inflammation, cervical pain and stiffness, myalgia of upper

extremity, cervical vertebral fracture and its late effects, dislocation of cervical spine, injury to neck and its after-effects, cervical laminectomy, disc removal, foraminotomy and cervical bone graft. Inclusion in the study was based on the diagnostic criteria for cervical radiculopathy as described below. To be considered a case, onset of symptoms had to have occurred during the time period of the study, 1976–90, and residency had to be established in Rochester at least 1 year prior to the date of onset. In order to study as homogenous a group as possible, we excluded patients with concomitant involvement of the spinal cord as indicated by increased tone, exaggerated deep tendon reflexes, sensory abnormalities in the lower limbs and Babinski sign (*see* Appendix). The only exception was a patient with hereditary spastic paraplegia. Patients with a past history of cervical radiculopathy were included only if their recent onset of symptoms during the study period was preceded by an asymptomatic period of >6 months.

Data acquisition

Data were abstracted from the medical records of the cases identified, using a precoded abstracting form (available on request) in a computer format with the following information: demographic data, antecedent events, onset, symptoms and signs of cervical radiculopathy, investigative data, treatment and follow-up. The onset of cervical radiculopathy was classified as acute (peak of symptoms from onset ≤7 days), subacute (peak of symptoms >7 days, <21 days), and chronic (progression of symptoms >21 days).

Electromyographic localization of the cervical root involvement was based upon the findings of acute denervation (fibrillation potentials) in the cervical paraspinal muscles and/or in a myotomal distribution (Eisen and Hoirch, 1983). The presence of large polyphasic motor unit potentials without evidence of acute denervation was considered insufficient for the diagnosis. The results of the motor and sensory nerve conduction studies were utilized to differentiate the electromyographic abnormalities from concomitant peripheral entrapment neuropathies. Plain radiological findings in the form of proliferative changes in the posterolateral margins of the cervical vertebral bodies and the narrowing of intervertebral spaces and intervertebral foramina were considered significant. Patients with a disc protrusion observed at surgery, computer-assisted myelography or MRI were designated as having cervical radiculopathy due to 'disc prolapse'. The cause of radiculopathy was classified as 'spondylosis, disc or both' if it occurred along with bony ridges, osteophytes, narrow intervertebral disc space or foramen, or occlusion, distortion or displacement of the root pouches and sleeves observed at myelography.

Follow-up data regarding recurrences and current functional status were available through medical records for almost all patients. Recurrence was defined as the reappearance of symptoms of cervical radiculopathy during the period of the study, after a symptom-free interval of not less than 6 months. Functional status at last follow-up was arbitrarily categorized as normal (asymptomatic), or mildly (symptoms producing slight incapacity but not preventing ordinary everyday activities), moderately (incapacity affecting performance of everyday tasks) or markedly (hardly any useful function of the affected upper limb) incapacitated.

Diagnostic classification

The neurological symptoms and signs, the radiological and electromyographic data and the operative findings were utilized to diagnose cervical radiculopathy and to localize the nerve root(s) involved accurately. None of these parameters, taken alone, was considered sufficiently specific to provide an unequivocal diagnosis of cervical radiculopathy. We have, therefore, categorized patients with symptoms suggestive of cervical radiculopathy into definite, probable and possible cases, based on combinations of the above features (*see* Appendix).

Statistical analysis

Statistical analyses were performed using the SAS computer package (SAS Institute, 1990). We used standard deviation to define the dispersion. Statistical significance between the conservatively and surgically treated groups was assessed by t test, χ^2 test, or Fisher's exact test, as appropriate. The Cox proportional hazards model was used to assess which variables were associated with the rate at which surgical intervention was employed following the diagnosis.

Age- and sex-specific incidence rates were calculated by dividing the number of incident cases by the proper denominator, estimated from decennial census data as described elsewhere (Bergstralh *et al.*, 1992). Incidence rates were adjusted to the total 1980 US population using the direct method, and 95% confidence limits for the adjusted rates were estimated, assuming a Poisson distribution for observed cases.

Results

The incidence cohort and incidence rates

During the study period, 1976–90, 561 cases (332 men and 229 women) with cervical radiculopathy were identified among the residents of Rochester, Minnesota. The mean age at diagnosis was 47.9 ± 13.4 years (range 13–91 years); 47.6 ± 13.1 years for males and 48.2 ± 13.8 years for females.

Average annual incidence rates per 100 000 persons for cervical radiculopathy by age and sex are shown in Table 1. The annual age-adjusted rates per 100 000 were 83.2 for total, 107.3 for males and 63.5 for females. The male to female ratio of the adjusted rates was 1.7. The age-specific incidence rates for cervical radiculopathy reached a peak of 202.9 for the 50–54 year age group. After the age of 60 years, there was a decline in the incidence of cervical radiculopathy in both sexes, this phenomenon was more dramatic in the females.

Table 1 *Average annual incidence rates of cervical radiculopathies per 100 000 population in Rochester, Minnesota, 1976–90, according to age and sex*

Age group (years)	Females		Males		Both sexes	
	n	Rate	*n*	Rate	*n*	Rate
15–29	18	12.9	23	20.2	41	16.2
30–34	19	42.7	33	79.2	52	60.3
35–39	29	86.2	39	121.2	68	103.3
40–44	30	107.1	54	209.7	84	156.3
45–49	35	154.9	51	237.1	86	195.0
50–54	34	164.5	46	245.1	80	202.9
55–59	20	106.1	39	230.5	59	164.9
60–64	18	104.5	17	121.6	35	112.1
65–69	7	43.8	11	98.5	18	65.8
70–79	12	41.7	11	72.5	23	52.3
80+	6	28.0	8	115.0	14	49.3
All ages*	228	58.3	332	104.3	560	79.0
Age adjusted†		63.5		107.3		83.2
95% confidence limits		55.1–71.8		95.4–119.2		77.0–91.1

*One female patient aged 13 years not included; †Adjusted to the 1980 US population.

Clinical features

Antecedent events

A history of physical exertion or trauma immediately preceding the onset occurred in 83 patients (14.8%). The most frequently encountered types of physical exertion which precipitated radicular symptoms were shovelling snow in winter and playing golf in summer. Cervical radiculopathy due to a spinal fracture or root avulsion resulting from a motor vehicle accident occurred in 17 patients (3.1%); however, no patient had a disc prolapse precipitated by an automobile accident. An antecedent history of cervical radiculopathy was obtained in 31% of cases and lumbar radiculopathy in 41% of cases (Table 2).

Onset

Duration of symptoms prior to diagnosis varied from 1 day to 60 months, with a mean of 40.6 days (median, 15 days). The onset was acute in 281 (50.1%), subacute in 135 (24.1%) and insidious in 145 cases (25.8%).

Symptoms and signs

The frequency of symptoms and signs at initial examination are shown in Table 3. Cervico-brachial pain at onset occurred in all but 14 patients (97.5%), which was radicular in distribution in 65.6% of them. While paraesthesia in a root distribution was a frequent symptom, subjective weakness was present in only 86 cases (15.3%). The symptom at onset was unilateral in 98% of the patients. The most frequent neurological sign was diminished deep tendon reflexes, followed by weakness and dermatomal sensory changes. Alteration of triceps reflex occurred most frequently (54.5%); biceps and brachioradialis reflexes were involved in one-third of the patients. Pain on neck movement and paraspinal muscle spasm occurred in nearly 90% of cases.

Table 2 *Antecedent history among patients with cervical radiculopathy*

Condition	No. of patients (n = 561)	Percentage frequency
Physical exertion/trauma	83	14.8
Cervical radiculopathy	174	31.0
Lumbar radiculopathy	230	41.0
Spinal surgery	20	3.6
Contrast study	15	2.7

Table 3 *Symptoms and signs at presentation among patients with cervical radiculopathy*

	No. of patients (n = 561)	Percentage frequency
Symptoms		
Pain	547	97.5
Radicular pain distribution (n = 547)	359	65.6
Paraesthesia	503	89.7
Weakness	86	15.3
Signs		
Paraspinal muscle spasm	493	87.9
Painful neck movements	547	97.5
Sensory changes	185	33.0
Weakness	360	64.2
Atrophy	8	1.4
Fasciculations	2	0.4
Diminished tendon reflex	472	84.1
Laterality of symptoms and signs		
Unilateral		
Right	266	47.4
Left	267	47.6
Bilateral		
Asymmetric	26	4.6
Symmetric	2	0.4

Table 4 *Frequency, age and population distribution of patients with cervical radiculopathy in Rochester, Minnesota, by diagnostic category, root(s) involved and aetiology*

	No.	Percentage of total	Age (mean ± SD)	Age/sex-adjusted* incidence/100 000	
				Rate	95% confidence limits
Diagnostic category (n = 561)					
Definite	256	45.6	47.8 ± 12.9	38.4	33.6–43.2
Probable	160	28.5	47.8 ± 14.5	23.7	19.9–27.4
Possible	145	25.8	48.1 ± 13.0	22.0	18.3–25.7
Root(s) involved† (n = 561)					
C5	37	6.6	50.6 ± 17.6	5.4	3.7–7.2
C6	99	17.6	45.5 ± 12.8	14.2	11.3–17.1
C7	260	46.3	46.8 ± 12.2	38.8	34.0–43.6
C8	35	6.2	53.0 ± 16.0	5.4	3.6–7.3
C5, C6	58	10.3	52.2 ± 14.3	9.2	6.8–11.6
C6, C7	47	8.4	45.6 ± 12.0	6.9	4.9–9.0
Aetiology† (n = 561)					
Disc protrusion	123	21.9	46.5 ± 10.6	18.6	15.2–22.0
Spondylosis, disc or both	384	68.4	49.9 ± 12.9	58.5	52.5–64.4
Spinal fracture/root avulsion	17	3.1	32.7 ± 19.0	2.3	1.2–3.5
Obscure	32	5.7	34.0 ± 7.5	3.9	2.5–5.3

*Adjusted to 1980 US population; †see text for infrequent occurrences.

Investigations

Plain radiographs of the cervical spine revealed an abnormality in 86.6% of patients. Electromyography was performed in 175 (31.2%) of cases; it showed evidence of acute denervation in 130 patients (74.3%). Electromyography helped to ascertain 39 additional root involvements. One hundred and fifty-three patients (27.3%) underwent myelography, 26 patients MRI, and 14 patients computer-assisted myelography.

Treatment and follow-up

During follow-up, 146 patients (26%) underwent surgery for cervical radiculopathy, whereas the remainder were treated only conservatively. The most common surgical procedures performed were hemilaminectomy with discectomy and foraminotomy. Ninety-four percent of these operations were performed within 3 months of the diagnosis, but 3.4% of them were performed >1 year subsequently. The conservative measures used included combinations of immobilization with cervical collar, medication with analgesic and muscle relaxant drugs, physical therapy, intermittent cervical traction and isometric exercises when the pain had diminished.

All except five patients were seen on follow-up; mean duration of follow-up was 5.9 years, median 4.9 years. A recurrence of cervical radiculopathy occurred in 178 (31.7%) of cases; many of them had only an isolated recurrence. At last follow-up a majority (90.5%) of the patients in this population-based sample were normal or only mildly incapacitated due to cervical radiculopathy. Moderate to severe disability secondary to cervical radiculopathy occurred in only 53 cases (9.5%).

Diagnostic category and frequency of the root involvement

According to our diagnostic criteria, 45.6% of patients were classified as definite, 28.5% as probable and 25.8% as possible cervical radiculopathy. Their age distribution did not differ (Table 4). The frequency of recurrence (χ^2 = 5.855, P = 0.210) and the disability status (χ^2 = 3.614, P = 0.461) did not differ between the three diagnostic categories. However, inability to detect a difference may be related to the small number of patients with disability. The symptoms and signs, if present, remained unilateral in the majority (95.6%).

The distribution of patients according to the cervical root(s)

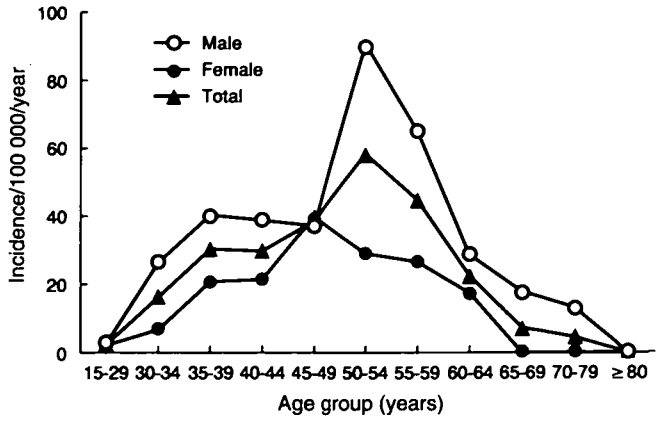

Fig 1 Age- and sex-specific incidence rates of cervical radiculopathy in Rochester, Minnesota, due to confirmed disc protrusion.

Table 5 *Comparison of the characteristics of patients with cervical radiculopathy treated conservatively alone and surgically in Rochester, Minnesota*

Variable	Treatment groups		Statistical significance
	Conservative alone (n = 415)	Surgical (n = 146)	
			Two-tail probability
Age at diagnosis	48.2 ± 13.9	46.9 ± 11.8	0.4950
Number of roots involved	1.2 ± 0.4	1.2 ± 0.5	0.9294
			χ^2 probability
Gender: Male	238	94	0.137
Female	177	52	
History of cervical radiculopathy	127	47	0.759
Antecedent physical exertion/trauma	55	28	0.081
Onset: Acute	217	64	0.134
Subacute	99	36	
Insidious	99	46	
Radicular distribution of pain	254	105	0.022
Sensory deficit	115	70	<0.001
Objective muscle weakness	231	131	<0.001
Diminished deep tendon reflexes			
Biceps	144	39	0.077
Triceps	214	92	0.017
Supinator	145	44	0.291
Roots involved clinically			
C5	77	18	0.121*
C6	154	45	0.199
C7	229	91	0.157
C8	30	18	0.084*
C5, C6	42	12	0.625*
C6, C7	23	8	1.000*
Laterality of signs			
Right	194	72	0.103
Left	201	66	
Bilateral	20	8	
Abnormal electromyography	71	32	0.197

*Fisher's exact test.

affected clinically, electrophysiologically, radiologically, at surgery or by a combination of these parameters is cited in Table 4; 701 cervical roots were involved among 561 patients. Involvement of the C7 root in isolation was the most frequent, followed by C6 and a combination of C5 and C6. Involvement of C7 and C8 (15 patients), C5, C6 and C7 (six patients), and C6, C7 and C8 (four patients) were infrequent. A C8 radiculopathy occurred in a significantly older population ($P \leq 0.007$). The frequency, age and population distribution of patients with cervical radiculopathy according to diagnostic category and root(s) affected are illustrated in Table 4.

Aetiology

The frequency distribution of the major causes of cervical radiculopathy is shown in Table 4. A disc protrusion delineated by radiology or at surgery was associated with cervical radiculopathy in 123 (21.9%) patients; spondylosis, disc or both was the most frequent (68.4%). Radiculopathy without myelopathy as a direct result of spinal trauma occurred in 17 patients (3.1%). In addition, there were two patients with spinal metastases and single cases related to Klippel–Feil anomaly, rheumatoid spondylitis and herpes zoster. In 32 patients, the cause of cervical radiculopathy was uncertain. The population distribution of cervical radiculopathy according to aetiology is shown in Table 4; however, since the differential diagnosis between disc prolapse and spondylosis remained uncertain in the majority, these rates are arbitrary.

The age- and sex-specific annual incidence rates of cervical disc prolapse resulting in radiculopathy are shown in Fig. 1. Age-specific incidence reached a peak of 58.3 per 100 000 per year in the 50–54 year age group and rapidly declined after the age of 60 years. Age-adjusted annual incidence rates (and their 95% confidence limits) for confirmed disc prolapse

Table 6 *Cox proportional hazards model to examine the predictors of a decision favouring surgical intervention among patients with cervical radiculopathy*

	Parameter estimate	*P*	Hazard ratio	95% confidence limits for hazard ratio
Univariate models				
Radicular pain	0.4265	0.024	1.53	1.06–2.22
C8 radiculopathy	0.5510	0.025	1.74	1.07–2.81
Sensory loss	0.7397	<0.001	2.10	1.51–2.90
Objective weakness	1.7418	<0.001	5.71	3.34–9.74
Multivariate model				
Radicular pain plus sensory loss	1.0624	<0.001	2.89	1.81–4.64
Objective weakness	0.7890	<0.001	5.98	3.37–10.62
Radicular pain plus sensory loss plus objective weakness	2.8501	<0.001	17.29	8.26–36.16

per 100 000 population were 18.6 (15.2–22) for the total, 25.9 (20.1–31.7) for males and 11.9 (8.2–15.5) for females.

The patients in the four aetiological groups cited in Table 4 had significantly different mean ages ($P < 0.001$; ANOVA). The patients in the group with an unclear aetiology and spinal fracture were younger, whereas those with disc protrusion and/or spondylosis were older.

Prognostic factors

The distribution of variables among the groups of patients treated non-surgically and surgically are shown in Table 5. Univariate analysis revealed an association with surgery for radicular distribution of pain ($P = 0.02$), sensory deficit ($P < 0.001$), muscle weakness ($P < 0.001$) and diminished triceps reflex ($P < 0.02$). Eighth cervical root involvement appeared to favour surgery; however, this variable did not reach statistical significance ($P = 0.084$).

The significant predictors of a decision to operate, assessed in a Cox proportional hazards model, are detailed in Table 6. Among many variables examined, radicular pain, sensory deficit, weakness and C8 root involvement were significant univariate models. In a multivariate proportional hazards model, presence of objective muscle weakness strongly predicted a decision for surgical intervention (hazard ratio, 6). Although neither radicular pain nor dermatomal sensory deficit in the absence of the other favoured surgery, their combination was significantly associated with surgery (hazard ratio, 2.9). A combination of radicular pain, sensory loss and muscle weakness had a hazard ratio of 17.3.

Discussion

Merits of the study

We believe our study provides the most comprehensive descriptive epidemiological data on cervical radiculopathy reported to date. To the best of our knowledge, ours is the first study which utilized a population-based sample of patients with cervical radiculopathy attributable to different causes. Other investigators have ascertained patients through hospital or referral practices with special interests in neurosurgery (Henderson *et al.*, 1983; Kelsy *et al.*, 1984), orthopaedics (Kelsy *et al.*, 1984; Gore *et al.*, 1987) and physical medicine (Martin and Corbin, 1954; Honet and Puri, 1976); used unspecified criteria in defining cervical radiculopathy (Lees and Turner, 1963; Lawrence, 1969; Rosomoff *et al.*, 1992) or included only selected cases of cervical radiculopathy, such as due to intervertebral disc prolapse (Yoss *et al.*, 1957; Murphey *et al.*, 1973; Kondo *et al.*, 1981). A direct comparison of the results of this survey with other studies on cervical radiculopathy is therefore difficult.

Although the present study is not a door-to-door survey, due to the reasons mentioned in the Patients and methods section, it is our impression that we achieved a virtually complete ascertainment of symptomatic patients with cervical radiculopathy. A study like the current one with diagnostic precision, a long study period and a well-defined population denominator is largely free from biases caused by different referral patterns.

Deficiencies of the study

Admittedly, our study has limitations. Patients with mild symptoms of brief duration due to cervical radiculopathy might never have sought medical attention. In order to achieve diagnostic precision, we did not include patients who failed to meet our diagnostic criteria; this might have resulted in some minimally symptomatic patients with cervical radiculopathy being excluded from this survey. Hence, the incidence rates for cervical radiculopathy described in our study should be considered as conservative. Although we evaluated the different electrodiagnostic and neuroimaging techniques and utilized the data for diagnosis and classification, we did not attempt to compare the relative merits of different methods, since only

a small proportion of patients in this retrospective study underwent these investigations.

Clinical aspects of cervical radiculopathy

Cervical radiculopathy requires highly specific diagnostic criteria in order to distinguish it from numerous other disease processes that may mimic radicular symptomatology (Fager, 1963; Dillin *et al.*, 1986). The diagnosis of cervical radiculopathy is largely clinical, and neuroradiology and electromyography can only confirm the clinical impression. The well-known clinico-radiological dissociation in cervical degenerative disease was recently re-evaluated by MRI in a group of asymptomatic subjects; disc protrusion was seen in 20% of those in the 40–55 year age group and in 57% of those aged over 64 years (Teresi *et al.*, 1987). Because the muscles are innervated by multiple roots and denervation activity does not appear for several weeks in the peripheral muscles of an upper limb, the positive yield of electromyography is influenced by the number of muscles sampled and the duration of the radiculopathy (Eisen and Hoirch, 1983; Partanen *et al.*, 1991). Accurate history and reliable neurological examination alone have been shown to predict the correct roots involved from C5 to C8 preoperatively in 80–90% of cases (Yoss *et al.*, 1957; Fager, 1963; Henderson *et al.*, 1983). Reliable diagnoses of C3 and C4 radiculopathies are difficult, but fortunately, they are rare.

In our study, cervical radiculopathy was more common in males compared with females (sex ratio, 1.4) and occurred in a wide age distribution (mean 47.9 ± 13.4 years), which are in agreement with the general impression in the literature (Yoss *et al.*, 1957; Henderson *et al.*, 1983; Kelsy *et al.*, 1984). The mean duration of symptoms prior to diagnosis was 40.6 days for our cases and the symptoms were acute or subacute at onset in the majority. By contrast, in surgical series the mean length of time-significant symptoms that were present preoperatively was considerably more, 49.5 weeks in the series of Henderson *et al.* (1983), and the pattern of onset was slow and progressive in most of the cases (Gregorius *et al.*, 1976; Herkowitz, 1989). A majority (95%) of our patients had unilateral involvement and the right and left upper limbs were affected equally. By contrast, 36% of the patients in a referral sample had bilateral radicular involvement (Kelsy *et al.*, 1984). The dominance of left side over right side was seen by some researchers (Yoss *et al.*, 1957; Kondo *et al.*, 1981); however, the frequency is almost equal in other studies (Henderson *et al.*, 1983; Kelsy *et al.*, 1984). The C7 root in isolation was the most commonly involved, followed by the C6 root in our study, which is in agreement with the pattern observed by others (Yoss *et al.*, 1957; Murphey *et al.*, 1973; Honet and Puri, 1976; Kondo *et al.*, 1981; Henderson *et al.*, 1983).

An antecedent history of trauma preceding the onset of cervical radiculopathy was rare in our series (14.8%). It is important to emphasize, in the present-day litigious environment that, although cervical radiculopathy due to fracture of the spine and root avulsion were associated with automobile accidents, there was no case of intervertebral disc extrusion in our study which could be ascribed to a flexion-extension injury related to a rear-end automobile collision. In contrast, among the patients from a referral centre-based study of cervical disc prolapse, 23% of cases attributed the onset to an automobile accident (Kelsy *et al.*, 1984). Our data corroborate those of Murphey *et al.* (1973), who in their extensive experience had seen only a single instance of hyperextension injury resulting in a cervical disc protrusion.

Forty-one percent of our patients had an antecedent history of lumbar radiculopathy. Among a group of 736 patients operated on for cervical disc protrusion, 33.4% had a history of surgically treated lumbar disc disease (Henderson *et al.*, 1983). A strong relationship of cervical to lumbar disc degeneration in both sexes, suggesting a constitutional predisposition, has also been observed by Lawrence (1969) in a population survey from northern England.

Aetiology of cervical radiculopathy

The major cause of cervical radiculopathy is degenerative disease of the spine. The pathoanatomical features contributing to radicular compression at the intervertebral foramina are often multifactorial—namely, disc herniation and other changes, collectively termed spondylosis, such as osteophytes from uncovertebral and superior facet joints, narrowing of the foramen due to decreased disc height and spondylolisthesis (Brain *et al.*, 1952; Lestini and Wiesel, 1989; Heller, 1992). In their study, Wilkinson *et al.* (1969) found that 97% of patients with radiculopathy had radiographical evidence of foraminal stenosis. Differentiation between the two common mechanisms of radicular impingement, disc herniation (soft disc) and osteophyte (hard disc) is difficult clinically, radiologically and even at surgery (Jahnke and Hart, 1991; Heller, 1992). Conventional myelography cannot distinguish between the two (Jahnke and Hart, 1991) and surgical series are strongly biased in favour of disc prolapse (Murphey *et al.*, 1973; Partanen *et al.*, 1991; Wilson *et al.*, 1991). Recent studies with computer-assisted and intravenously contrast-enhanced myelography and with gradient-echo MRI have shown that neural foraminal stenosis caused by uncal osteophytes are much more common than disc herniation as the cause of cervical radiculopathy (Jahnke and Hart, 1991).

In our study, disc herniation was responsible for cervical radiculopathy in 22% of patients; however, cervical radiculopathy of uncertain pathogenesis associated with degenerative disease (designated as 'spondylosis, disc or both') was more frequent (68%). Among 32 of our patients with a mean age of 34 ± 7.5 years, with a rapid resolution of symptoms and a normal cervical radiograph, the cause of radiculopathy remained obscure, although covert degenerative disease and disc prolapse still remain as the major aetiological possibilities.

Natural history of cervical radiculopathy

The natural history of lumbar radiculopathy is well recognized, with 80–90% of patients recovering within 3 months (Weber,

1983). In contrast, the outcome of patients with cervical radiculopathy is unknown. Referral centre-based studies have shown that cervical radiculopathy can cause persistent pain and incapacity in two-thirds of patients treated conservatively (Lees and Turner, 1963; Dillin *et al.*, 1986). In a group of 255 patients treated non-surgically, only 29% obtained complete relief (DePalma and Subin, 1965). Gore *et al.* (1987) followed 205 patients with non-operatively treated neck and referred pain for an average period of 15 years. At the end of the study period, one-third had moderate to severe pain that interfered with their lifestyle. Rothman and Rashbaum (1978) observed a similar group of patients for 5 years; 23% remained partially or totally disabled.

On the other hand, Martin and Corbin (1954) followed 61 patients treated with cervical traction for a mean period of 2 years, 77% of them demonstrated definite improvement. Ninety percent of 84 patients reported by Rubin (1960) responded well to a conservative therapy. A multicentre trial of the effect of physiotherapy for neck and arm pain sponsored by the British Association of Physical Medicine (1966) revealed relief of symptoms in 92% of 493 patients receiving cervical traction. Of 59 patients, seen in a rehabilitation medicine practice at a community hospital, who met strict diagnostic criteria for cervical radiculopathy and were followed for 2 years, 71% had a good outcome (Honet and Puri, 1976).

The difference in the results of these studies is largely attributable to the source of cases, i.e. surgical (DePalma and Subin, 1965; Rothman and Rashbaum, 1978) versus physiotherapy centres (Martin and Corbin, 1954; Honet and Puri, 1976), and the inclusion of heterogenous entities in the category of cervicobrachial pain (Gore *et al.*, 1987).

One-fifth of our patients, the majority with a disc prolapse, underwent surgery for cervical radiculopathy. It is interesting to note that in our study, with a mean duration of follow-up of 5.9 years, the majority of the cases were asymptomatic or only mildly incapacitated. This contradicts the impression based on referral centre studies that cervical radiculopathy is a recurring and disabling disorder.

Population incidence of cervical radiculopathy

The average annual age- and sex-adjusted incidence of cervical radiculopathy in Rochester, Minnesota, of 83.2 per 100 000 reported in our study shows that it is a common condition. In the age group 50–54 years, cervical radiculopathy occurred at a rate of 202.9 per 100 000. In both sexes, the incidence rates declined after the age of 60 years, more consistently in females. In a population survey from northern England, the incidence of neck–shoulder–brachial pain rose until the age of 60 years (Lawrence, 1969); the cause of the pain, however, was not defined.

Disc prolapse resulting in cervical radiculopathy occurred among the Rochester population at an annual rate of 18.6 per 100 000. The difference in sex-specific incidence for disc prolapse was more explicitly in favour of males than in general for cervical radiculopathy (ratios of adjusted rates, 2.2 versus 1.7). The age-specific incidence of disc prolapse causing radiculopathy declined precipitously after the age of 60 years.

It appears from our study that, although spinal degenerative disease progresses with age, cervical radiculopathy complicating it peaks at middle age and then declines. An under-ascertainment of radiculopathy in the elderly cannot be excluded as an explanation for this phenomenon. However, epidemiological studies from Rochester, Minnesota, utilizing the same data source, have demonstrated a progressive increase in the incidence rate by age of diseases, such as amyotrophic lateral sclerosis (Yoshida *et al.*, 1986) and brain tumours (Annegers *et al.*, 1981), when compared with a peak at late middle age and a rapid decline afterward in studies elsewhere. This is due to the much better case ascertainment from the very elderly population. Moreover, as explained in the Patients and methods section, for the Rochester population, an elderly person's chance of being seen frequently in a Mayo Clinic facility is much more than the young or middle aged.

Predictors of the prognosis of cervical radiculopathy

It is well established that in patients with predominant neck pain without discrete radicular symptoms and signs, the results of surgery do not significantly change the natural course of the disease (Dillin *et al.*, 1986). The best results of cervical disc surgery are associated with radicular pain (Adams, 1976; Yu *et al.*, 1987). Failure of conservative treatment to relieve the pain and persistent or progressive muscle weakness are considered indications for surgery (Adams, 1976; Dillin *et al.*, 1986; Garvey and Eismont, 1991).

To our knowledge, the literature provides very little information about the parameters in the initial evaluation of a patient with cervical radiculopathy that allows prediction of the prognosis. Among a group of 59 patients with cervical radiculopathy, eight of whom required laminectomy, Honet and Puri (1976) found no single or combination of clinical, radiological and electrophysiological findings predicted the outcome of initial conservative treatment. The absence of associations may be due to small sample size and inadequate power to detect the difference.

We addressed this issue on a larger sample of population-based patients with a long follow-up by comparing the attributes of subjects with surgical and non-surgical outcomes. The following variables in isolation were associated with surgical intervention: radicular distribution of pain, sensory deficit; objective muscle weakness, diminished triceps reflex. The type of onset of symptoms, antecedent history of cervical radiculopathy, the root(s) involved and abnormal electromyography did not help in the evaluation of prognosis. In a multivariate proportional hazards analysis, radicular pain associated with sensory loss (hazard ratio, 2.9; 95% confidence limits, 1.8–4.6) and muscle weakness (hazard ratio, 6; 95% confidence limits, 3.4–10.6) correlated significantly with a decision to operate and the duration of time until surgery. Although the decision regarding surgery will be dictated by the

response to initial conservative therapy on an individual basis, it appears that a subject with radicular pain, dermatomal sensory loss and motor deficit (hazard ratio, 17.3; 95% confidence limits, 8.3–36.2) is at least eight times more likely than patients without any of these factors to undergo surgical intervention.

The benign nature of cervical radiculopathy observed in our retrospective community-based study raises some question about the decision for surgery or conservative management in those who present with persistent radicular pain plus sensory loss but without motor deficit. There may be sufficient justification for a prospective randomized trial, but such a trial may not be appropriate in those patients with the additional finding of progressive muscle weakness. Additional data derived from a prospective cohort study would be helpful in reaching a decision regarding the design of a randomized controlled trial of surgery versus conservative therapy.

Acknowledgements

We wish to thank James R. Wentz for data collection, Jeffrey T. Eickholt for computer programming and statistical analysis and Laura B. Long for secretarial and editorial assistance. This research was supported in part by research grants NS17750 and AR30582 from the National Institutes of Health, Public Health Service, Bethesda, Maryland, USA.

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Received August 4, 1993. Revised December 16, 1993. Accepted December 12, 1993

Appendix
Diagnostic criteria for cervical radiculopathy

(i) *Symptoms*

Onset during study period; reappearance after a symptom-free interval ≥6 months in the case of recurrence.

(*a*) Neck pain, arm pain or combined neck and arm pain.
(*b*) Paraesthesia, hyperaesthesia, or dysaesthesia in a nerve root distribution.
(*c*) Muscle weakness.

(ii) *Signs*

(*a*) Sensory changes in a dermatomal distribution.
(*b*) Weakness, atrophy or fasciculation, in a myotomal distribution.
(*c*) Unilateral diminished deep tendon reflexes.

(iii) Diagnostic tests/surgical verification

(*a*) Electromyographic evidence of acute denervation in cervical paraspinal muscles and/or in a myotome.
(*b*) Demonstrable abnormality on myelography, computer-assisted myelography, or MRI correlating with cervical radiculopathy.
(*c*) Identification of an affected cervical root at surgery.

The above parameters are used as follows to define the criteria for definite, possible and probable cervical radiculopathy.

Definite cervical radiculopathy. (iiic), or (iii*a*), or (ii*a*) and (ii*b*) and (iic), or (iii*b*) with (i*a*) and (i*b*) or (i*c*).

Probable cervical radiculopathy. More than one of (i) is present with any one of (ii), or any one of (i) is present with (iii*b*), or (i*a*) with any two of (ii).

Possible cervical radiculopathy. More than one of (i) is present.

Cervical radiculopathy deemed not present. Only one of (i) is present, or an abnormal imaging test without evidence of a recent radiculopathy, or chronic electromyographic changes without evidence of a recent cervical radiculopathy.

Diagnostic criteria for concomitant myelopathy. Neurological signs not related to an alternate diagnosis in the lower extremity, bilateral, symmetric or asymmetric, or unilateral, such as (i) Babinski sign, (ii) ankle clonus, and (iii) hypertonia, hyperreflexia and sensory deficit. Patients with (i) or (ii) or any two of (iii) were excluded.