Surgical treatment of cervical cord compression in rheumatoid arthritis

H A CROCKARD,1 W K ESSIGMAN,2 J M STEVENS,1 J L POZO,1 A O RANSFORD,1 B E KENDALL1

From 1the National Hospitals for Nervous Diseases and University College Hospital, London WC1; and the 2Lister Hospital, Stevenage, Herts

SUMMARY Cervical myelopathy is a rare but potentially dangerous complication of rheumatoid arthritis and presents considerable therapeutic problems. A conservative approach carries high mortality and surgical intervention is not without serious risks. Reduction of subluxation and posterior fusion is widely practised but may require prolonged bed rest and continuous skull traction, sometimes for many weeks. When anterior decompression has been attempted prolonged immobilisation and external fixation have created problems. In this series 23 rheumatoid patients with cervical myelopathy were investigated over a four-year period. Seventeen underwent anterior decompression of the cervical cord, of whom 14 had a transoral removal of the odontoid peg and pannus and posterior occipitocervical fusion during the same anaesthetic without mortality or serious postoperative complications; all but one have improved. The authors believe that early mobilisation after a combined cord decompression and internal fixation has reduced the mortality and morbidity. Management of cervical myelopathy in rheumatoid arthritis and indications for operation are discussed.

Key words: atlantoaxial subluxation, rheumatoid pannus, cervical myelopathy, transoral surgery, surgery – rheumatoid arthritis.

The involvement of the cervical spine in rheumatoid arthritis has become recognised increasingly over the last decade. In a recent prospective study of patients with rheumatoid arthritis Windfield et al.1 have shown that cervical subluxation may develop in association with peripheral erosive disease within two years of its onset, though remaining asymptomatic. In those with longstanding disease 25–36% have significant radiological changes and 2–5% of these develop myelopathy.2 3 About half of those developing this complication progress rapidly and succumb within a year despite conservative measures.4 A review of the literature5 indicates that in the cervical spine it is the atlantoaxial joint which is involved most commonly, with the joints below C3 being affected evenly to account for the remainder. Atlantoaxial subluxation was recognised as a dangerous complication of trauma (1824) and syphilitic ulceration of the pharynx (1830) by Sir Charles Bell,3 but it was not until 1951 that Davis and Markley6 drew attention to it as a cause of medullary compression in rheumatoid arthritis. The subluxation backwards of the odontoid peg resulting in the compression of the craniovertebral junction of the cord is considered to be the usual cause of neurological abnormalities in this condition.

The transverse ligament which has such a crucial role in maintaining stability at the atlantoaxial joint may be damaged by riding over the eroded surface of the odontoid peg or be directly affected by the inflammatory changes. The role of pannus formed at any or all of the synovial joints surrounding the odontoid peg, however, has been less emphasised, and the soft tissue mass produced by the inflammatory process at the craniovertebral junction, though demonstrated at autopsy, has been implicated rarely in pathophysiology of the neurological changes in such patients.
Neurological assessment of a patient with rheumatoid arthritis may be difficult. Increasing difficulty in walking, stiffness of the limbs, clumsiness of the hands, muscle weakness, may all be the result of active synovitis, progression of the disease, or involvement of either the peripheral or central nervous system, and it may not be easy to assess tendon reflexes in the presence of painful or ankylosed joints. As the outcome of conservative treatment of progressive cervical myelopathy has been uniformly fatal,7 surgical intervention alone may offer hope to these patients. The accurate localisation and knowledge of the character of the compressive lesion are essential for successful surgical planning; conventional radiology and myelography have not always been sufficient for this purpose. With the advent of the modern computerised tomography with three dimensional reformatting and the new non-ionic contrast media assessment of such patients has been greatly simplified and can even be carried out on a day patient basis.

The surgical treatment of cervical cord compression described in the literature includes anterior fusion8 with or without decompression9 and posterior fusion as separate operations.10 All require pre- and postoperative skull traction and prolonged immobilisation in bed or in a ‘halo body’ jacket. The recognised complications of such treatment and the authors’ own experience led to the decision to perform a one stage procedure in which decompression of the cervical cord and internal metal fixation were carried out (unpublished data). Early mobilisation has reduced the incidence of postoperative complications. This paper describes the investigation and management of 23 patients over a four year period.

Patients and methods

Patients
Since 1979 we have evaluated 23 patients (14 female, nine male) with either classical or definite rheumatoid arthritis who presented a clinical picture suggesting the involvement of cervical spine in the rheumatoid process. Three patients were less than 31 years of age, one was 45 years, and the remainder were over 50 years (range 22–77 years). Seventeen were seropositive, four seronegative, and in two the serology was not known. All had a longstanding disease, the shortest being five years, the longest 50 years (average 16±9 years), and all of them at some stage of their illness had been treated with steroids or remission inducing agents, or both. Only one of the 20 patients with atlantoaxial subluxation had not been treated with steroids. Approximately half of the patients reported here had already had orthopaedic operations on one or more of their limb joints.

Symptoms and signs
Neck pain, paraesthesiae, and limb weakness to a varying degree were the presenting complaints in the 23 patients in this series (Table 1).

Nineteen patients had neck pain made worse by neck movement and in four it was associated with occipital neuralgia. Although the systemic disease was long standing, the neck pain was of relatively recent onset (average 10 months) in all but one patient who had suffered thus for 18 years. It preceded paraesthesia or weakness in nine patients and occurred at the same time in six patients. The latter group had the most rapid clinical course.

Sensory symptoms were common and extremely varied (Table 1). There was no obvious correlation with any radiological abnormality. In some there was clinical evidence of a peripheral entrapment neuropathy. In two there was a patchy sensory loss. Vibration sense was usually preserved, but joint position sensation was difficult or impossible to assess at deformed or stiff joints.

Motor weakness was very difficult to evaluate in the presence of widespread arthritis, but it was usually spastic in type. The patients’ assessment of their condition in terms of reduction in performance was a more valuable indicator of neurological deterioration. For the same reasons reflex changes and plantar responses were difficult to assess. In most cases reflexes were increased, and in all but one plantar responses were either doubtful or

<table>
<thead>
<tr>
<th>Symptoms and signs</th>
<th>No</th>
<th>Average duration (months)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck pain</td>
<td>19</td>
<td>10*</td>
</tr>
<tr>
<td>Occipital pain</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Numbness and paraesthesia</td>
<td></td>
<td></td>
</tr>
<tr>
<td>one arm</td>
<td>16</td>
<td>6-6</td>
</tr>
<tr>
<td>two arms</td>
<td></td>
<td></td>
</tr>
<tr>
<td>legs</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>‘glove and stocking’</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Lhermitte’s sign</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Weakness</td>
<td>18</td>
<td>4-1</td>
</tr>
<tr>
<td>one arm</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>two arms</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>one arm and leg</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>two legs</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>all limbs</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Sphincter disturbance</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Brain stem signs</td>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

*Excluding one patient with 18-year history of neck pain.

Note the rapid progression of the myelopathy despite the long-standing history of arthritis.
extensor. Three patients were quadriplegic at the
time of presentation. Two had lost all sphincter
control and one had alteration in her voice and
suffered nasal regurgitation of fluids.

One of the youngest patients presented with a
right sided hemiparesis, loss of gag reflex, and
vertical nystagmus. He reported florid nightmares
and a terror of going to sleep for the two weeks
before his admission (Ondine's curse) — indicating
profound depression of the respiratory centre.

CERVICAL RADIOGRAPHS

All patients had lateral cervical radiographs in
maximum flexion and extension. In two whose
presenting symptom was neck pain alone, only
minimal radiological changes were found and no
further investigations performed (Tables 2 and 3).

The commonest site of abnormality was at the
atlantoaxial level (19 patients) and was the main site
in 13. In six others there was evidence of involve-
ment at other levels. In the 13 patients the maximum
atlanto-odontoid movement was 5–14 mm. In those
with disease at other sites it was less than 4 mm (six
patients).

In addition to movement in the sagittal plane
there was upward movement of the peg (upward
translocation of the dens) through the foramen
magnum in three patients who had the most ad-
vanced neurological signs.

Subluxation below the level of the axis was noted
in nine cases and was the only site in three. Two
showed a 'staircase' phenomenon with sequential
subluxation at all levels.

COMPUTED MYELOTOMOGRAPHY

Twenty-one of the 23 patients had contrast studies,
the first by conventional myelography alone. With
the installation of a high resolution computed
tomographic (CT) scan (GE 8800) 20 patients had
an intrathecal injection of water soluble contrast
medium and sequential high resolution axial sec-
ctions 1.5 mm in thickness over the affected area.
In the last six patients the studies were repeated with
flexion and extension of the cervical spine. Three
dimensional reformattting allowed further visualisa-
tion of the brain stem and cervical cord, the
cerebrospinal fluid spaces, and the bony and soft
tissue deformations (Fig. 1).

Details of the technique are given elsewhere. The
distribution of the pathology is given in Table 3.
There was definite deformity of the medulla caused
by odontoid peg and/or soft tissue pannus in three
and definite distortion at the craniocervical junc-
tion in seven cases (Fig. 2). In half of the 10 (three
severe, seven moderate) it was the soft tissue which
was responsible for the spinal cord compression. In six
others with little evidence of bony movement, four
had associated soft tissue distorting the dural sac in
the region. There were five in whom the main site
of compression was below the axis. No cord com-
pression was noted in four patients.

SURGICAL TECHNIQUE

Details of surgical technique are given elsewhere; a
broad outline is provided here.

Transoral craniocervical decompression is carried
out through a vertical posterior pharyngeal incision
over C1 and C2. The anterior arch of C1 and the
odontoid peg are removed, together with any soft
tissue pannus in the region, and the anterior aspect
of the dura is decompressed. Exposure has been a
major problem. Initially, an elective tracheostomy
was performed and the soft palate split, but with
technical improvements an armoured nasotracheal
airway and retraction of the soft palate has been
enough. Sometimes the temporomandibular joint
has involved in the arthritic process, and in one
case a midline mandibular split was required to
effect exposure.

Posterior occipitoatlantoaxial fusion is performed

Table 2 Summary of radiological investigations

<table>
<thead>
<tr>
<th>Investigation</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral cervical spine (flexion and extension)</td>
<td>23</td>
</tr>
<tr>
<td>Computed myelotomography ± myelogram</td>
<td>20</td>
</tr>
<tr>
<td>Conventional myelogram alone</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3 Findings on computed myelotomography

(a) Bone deformity†

Atlantoaxial

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>19</td>
</tr>
<tr>
<td>Alone</td>
<td>13</td>
</tr>
<tr>
<td>Subaxial</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
</tr>
<tr>
<td>Alone</td>
<td>3</td>
</tr>
<tr>
<td>No gross bone problem</td>
<td>2</td>
</tr>
</tbody>
</table>

(b) Medullary or cord compression, or both

Medullary (infraolivary) | 3 |

Cord 'craniocervical junction' | 16 |

<table>
<thead>
<tr>
<th>Degree</th>
<th>Due to pannus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe</td>
<td>3</td>
</tr>
<tr>
<td>Moderate</td>
<td>7</td>
</tr>
<tr>
<td>Mild</td>
<td>6</td>
</tr>
</tbody>
</table>

Cord 'subaxial' | 5 |

No compression    | 4 |

*These are divided into (a) the bony abnormalities and (b) the CT
evidence of brain stem and cervical cord compression. Note that in
nine out of 16 patients a significant proportion of the cord
compression was not due to bony subluxation but to pannus.
†In five patients multiple levels were seen on computed
myelotomography.
after the anterior decompression by carefully turning the patient to the prone position. Fixation is effected by interlaminar wiring. Fusion by cancellous bone chips.

The patients are provided with a moulded collar and allowed out of bed on the third to fifth postoperative day.

Anterior decompression at lower cervical levels is along conventional neurosurgical lines and has been combined with suitable posterior fusion to prevent angulation at the site of decompression.

**Operative Complications**

No patient has died after the transoral procedure. The most serious complication has been bleeding from a displaced vertebral artery during odontoid removal. In this patient C1 was rotated as well as subluxed and the vertebral artery 'presented' in the midline anteriorly. Haemostasis was required, but the decompression had to be abandoned, and she has continued to deteriorate. The soft palate has required resuturing in two patients early in the series. Modification of technique has removed the necessity to split the palate. There have been no complications with the posterior pharyngeal wound.

Skull traction pre- and postoperatively was used in the first three patients and in all three there were problems associated with prolonged immobilisation; pulmonary emboli in two, and pneumonia in all. No embolic phenomena have been detected since external splintage has been abandoned.

**Histology**

At operation the soft tissue mass varied in consistency. On several occasions colourless oily fluid emanated from an incision of the anterior longitudinal ligament before bone removal. With this, was associated florid soft pink tissue.

In two patients the pannus formation was so widespread that the C1 lamina was completely eroded and the muscles in the area infiltrated with the tissue which contained small white 'melon seeds'. More usually the tissue was firm grey pink and showed end-stage chromic inflammation of synovial tissue. There were synovial palisades and patchy inflammatory cell infiltration but no lymphoid follicles. There was hyperplasia and prolifera-
Surgical treatment of cervical cord compression in rheumatoid arthritis

Case studies

Our management policy is illustrated by the following three case histories.

Case 1
A female aged 35 had been suffering from classical seropositive rheumatoid arthritis since the age of 16 and had intermittent pain in the neck for several years. Her treatment included steroids and remission inducing drugs. For five months the neck pain had become more severe and neck flexion produced pain and paraesthesiae down both arms. Examination showed brisk but equal reflexes and an equivocal extensor plantar response on the left. Cervical spine radiography showed atlantoaxial subluxation. Her symptoms settled down after four months, with no change in the neurological state. No further investigations have been carried out but careful follow up has been arranged.

Case 2
A 21 year old female developed chronic seronegative juvenile rheumatoid arthritis of rheumatoid type at the age of six and required treatment with steroids and remission inducing agents. When 20 years old she underwent synovectomy of the right knee and in her 21st year of life bilateral hip replacement. Routine x-ray of the cervical spine before the second operation showed atlantoaxial subluxation (5 mm). Four months later she developed pain at the back of the neck radiating to the right shoulder and made worse by movements of the neck. On examination all reflexes were brisk but equal, with equivocal plantar responses but no sensory changes. A computed myelogram showed erosions of the odontoid process, indentation of the dura but no evidence of medullary or spinal compression. She was provided with a collar and carefully followed up. Nine months later she developed mild weakness of the lower limbs and repeated CT myelography showed the presence of atlantoaxial subluxation with pannus formation around the odontoid peg, compressing the cord. She underwent transoral excision of odontoid and posterior occipitocervical fusion in one procedure without any problems.

Case 3
A male aged 54 with classical seropositive rheumatoid arthritis for 24 years had never been treated with steroids or remission inducing agents. Poliomyelitis in his youth left him with weakness of the left leg and some trunk muscles, and recently he developed a peptic ulcer. In August 1983 movements of the neck became limited and painful, and an x-ray of the cervical spine showed marked atlantoaxial subluxation and forward slip of C4 on C5. Three months later he began complaining of pain in the neck associated with transient weakness of the left arm on leaning forward. The weakness gradually increased, he developed tingling and numbness, and became clumsy with his fingers. Computed myelography showed erosions on the odontoid peg and pannus formation above it. In addition there was flattening of the cord at the C4–C5 level. Transoral removal of the odontoid peg with its associated pannus, anterior decompression at the C4–C5 level, and posterior occipitocervical fusion were carried out in one surgical procedure. The patient was out of bed in five days and allowed home three weeks after the operation. He lost all neck pain and regained full function of the arm.

Results

A summary of the management and outcome of the 23 patients is given in Table 4. Two patients with minimal neck pain and paraesthesia were carefully followed up as outpatients and showed no signs for 14 months until there were signs of progressive myelopathy in one case (case 2), for which she had surgery. One patient was unfit for surgery and two refused despite progressive deterioration. Seventeen patients were offered surgery and, apart from our first case on whom we performed a conventional posterior fusion alone, no patient has died in the perioperative period; she died of progressive respiratory failure. Two have deteriorated since surgery, one at three years due to subsequent C6–C7 subluxation, the other within weeks of surgery. In this latter case profuse bleeding from a displaced

<table>
<thead>
<tr>
<th>Management</th>
<th>No</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation only</td>
<td>2</td>
<td>2. No change</td>
</tr>
<tr>
<td>Unfit for surgery</td>
<td>1</td>
<td>1. No change</td>
</tr>
<tr>
<td>Refused surgery</td>
<td>2</td>
<td>1. Died</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Deteriorated</td>
</tr>
<tr>
<td>Posterior fusion alone</td>
<td>1</td>
<td>1. Died</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0. Died</td>
</tr>
<tr>
<td>Transoral + posterior fusion</td>
<td>14</td>
<td>2. Deteriorated*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12. Improved†</td>
</tr>
<tr>
<td>Anterior subaxial ± posterior fusion</td>
<td>3</td>
<td>0. Died</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Improved</td>
</tr>
</tbody>
</table>

*One patient suffered profuse bleeding and the operation was abandoned; one patient had subsequent subluxation at C6–C7.
†One patient died of myocardial infarction at 8/12; one patient died of carcinomatosis at 2/12.
vertebral artery during a transoral procedure forced us to abandon the decompression; neurologically she continued to deteriorate and is now quadriplegic.

All the other patients who had transoral surgery or anterior subaxial surgery reported cessation of their neck pain, and 15 out of the 17 patients improved. The quadriplegic patients walked out of hospital with recovered sphincter function. Those with paraesthesia noted an improvement, and the Lhermitte’s sign disappeared in all cases in which it was present before the operation.

There were no perioperative deaths in those subjected to transoral surgery, but as might be expected in this age group some succumbed for other reasons. Two of the patients aged 68 and 72 died eight months and 22 months after surgery of myocardial infarction and carcinomatosis respectively.

Discussion

The neurological assessment of a patient with rheumatoid arthritis, particularly in its more severe form, may be difficult. Failure to establish an early diagnosis of cervical myelopathy, therefore, is not unusual and there are reports of a six months’ delay in appreciating the neurological deterioration, which in some patients may lead to, or coincide with, a fatal outcome. In Marks and Sharp’s series\(^1\) 19 of 31 patients died due to a myelopathy, 15 of them within six months of onset, and Meijers et al.\(^13\) reported recently that of nine patients with cervical myelopathy who were not operated upon, four died within a year.

Cord compression in rheumatoid arthritis was first described by Garrett in 1890,\(^3\) and a recent estimation of the incidence of this complication in a longstanding disease is between 2 and 5\%.\(^5\) There is a small proportion of patients who improve spontaneously, whereas in others myelopathy is static for years. However, any progression of an established myelopathy and deterioration in the neurological status should be taken as evidence of an unfavourable outcome if left untreated.

The clinical picture of cervical myelopathy has already been well described, and our patients were similar to those of other series. There was no obvious correlation with sensory symptoms and the distribution of radiological abnormalities. There was some relationship between motor signs and CT evidence of cord compression. We have found the following particularly useful in alerting the clinician to the possibility of myelopathy: (a) neck pain or occipital neuralgia of recent onset in a rheumatoid patient; (b) paraesthesiae or numbness in the trunk or limbs or ‘electric shocks’ produced by movements of the neck, such as reading, lifting the head off the pillow, or leaning forward (Lhermitte’s sign); and (c) the patient’s own account of his diminished motor ability or a documented change since the last outpatient visit.

Any synovial joint in the cervical spine may be involved in rheumatoid arthritis, but in a review of 325 cases assembled from the literature Boyle found an incidence of 47% involvement at the C1–C2 level.\(^5\) The role of atlantoaxial subluxation was emphasised by Davis and Markley in 1951\(^6\) and led to an increased awareness of the condition. Stevens et al.\(^*\) reported that 36% of the patients in their series had this complication and estimated that two thirds of such patients eventually developed cervical myelopathy. They also recorded that 16% of their cases with no gross bony subluxation had cervical myelopathy and emphasised that the bony subluxation in itself may not necessarily be the whole problem.

The role of the rheumatoid pannus in the production of cervical myelopathy has not been given its due importance, though its description has been found in pathology texts. More severe grades of compression may be shown with conventional myelography, but the advent of computed myelography with facility to reformat in any plane has allowed the more precise evaluation of the relative roles played by the bony element and soft tissue, and the detection of milder grades of compression of the cervical cord. Some advocate computed tomography without intrathecal contrast for these patients,\(^14\) but in our opinion cord compression may not be apparent in some cases.

The results of different forms of treatment have been evaluated by Marks and Sharp,\(^3\) though there was considerable difficulty in establishing comparable groups. In their untreated group there was a 100% mortality, while 50% of patients treated with a cervical collar also died. All subjected to skull traction alone died. In a recent communication Meijers et al.\(^13\) reported that in their series ‘nine patients with cervical myelopathy who were not operated upon all died within a year, four of them due to consequence of cord compression’. Reduction and fixation by posterior fusion was the most successful procedure, though two out of eight in Boyle’s series\(^3\) died in the immediate postoperative period from respiratory failure. A recent report has again shown the respiratory hazards of this approach.\(^15\) These procedures have aimed at the correction of subluxation and have not taken into account the compressive effect of pannus, which
may increase when the bones have been realigned. All the published accounts describe immediate respiratory failure or further cord compression in a proportion of their operated cases. One has gone as far as saying that sudden death was an unfortunate but inevitable consequence in some cases. It is our opinion that attention to the compressive element anteriorly before posterior fixation is an essential part of the treatment for patients with pannus.

Meijers et al. treated their 25 patients with cervical myelopathy by posterior fusion, preceded for three days to 10 weeks (mean three weeks), and followed for a period of 2.5–3 months by continuous skull traction and nursing on a circoeleptic bed. Three of their patients died from the complications of immobilisation, e.g., pulmonary embolism. There have been other reports of a two stage procedure with transoral decompression initially and occipitocervical fusion at a later date, but the patients required continuous skull traction between the two operations. None of the authors digress from purely technical and academic assessment of their results to describe their experience in terms of human suffering of the patients exposed to a prolonged bed rest on continuous skull traction. Because of this and the increased incidence of complications associated with immobilisation for a long period of time, we decided to perform anterior decompression and posterior fusion as a one stage surgical procedure. We have been surprised to discover how well the patients have tolerated surgery of this magnitude. They have been out of bed within five days, starting on an active mobilisation programme, and discharged from the hospital after a fortnight to be followed up from both the neurosurgical and rheumatological outpatient departments. Their only inconvenience was a stiff collar, which they have had to wear for about three months.

Obviously the cord may be compressed subaxially and the usual finding is a forward displacement of the upper on the lower vertebral body. In six of our patients with an atlantoaxial problem there was evidence of subaxial involvement. The surgical decision in such patients was to approach the site of maximum compression as judged on computed myelotomography and follow up the patient carefully postoperatively. For subaxial compression we have been disappointed with a conventional anterior decompression and fusion (Cloward procedure), because of angulation at the operative site within a few months. The approach which we have adopted is a simultaneous anterior decompression and posterior interlaminar fixation to an O ring. This produces good decompression with complete stabil-
Surgical treatment of cervical cord compression in rheumatoid arthritis.

H A Crockard, W K Essigman, J M Stevens, J L Pozo, A O Ransford and B E Kendall

*Ann Rheum Dis* 1985 44: 809-816
doi: 10.1136/ard.44.12.809

Updated information and services can be found at:

[http://ard.bmj.com/content/44/12/809](http://ard.bmj.com/content/44/12/809)

**Email alerting service**

Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

**Notes**

To request permissions go to:
[http://group.bmj.com/group/rights-licensing/permissions](http://group.bmj.com/group/rights-licensing/permissions)

To order reprints go to:
[http://journals.bmj.com/cgi/reprintform](http://journals.bmj.com/cgi/reprintform)

To subscribe to BMJ go to:
[http://group.bmj.com/subscribe/](http://group.bmj.com/subscribe/)