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Scoliosis

Changes in lung function associated with idiopathic thoracic scoliosis

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The contention that operative correction of thoracic scoliosis leads to restoration of the lung function, in particular the vital capacity, is controversial. In an effort to obtain further information on this question, spirometric lung function tests were performed immediately before and 2 years after the operation in 46 adolescents with progressive idiopathic thoracic scoliosis of the late-onset type. All were treated by Harrington's distraction spondylodesis performed in an identical way. According to the protocol, each patient was ambulated 2 weeks after the operation, the trunk being protected throughout the next 9 months by means of a plaster corset. The mean curvature was 61° before and 36° two years after the operation. No postoperative complications developed.

Lung function test results are presented in two different ways: (1) as absolute values expressed in millimeters; (2) as percentages of the corresponding reference values. Only in this way can preoperative and postoperative findings be reliably compared.

Results: 1. Preoperative findings corroborated the view that idiopathic thoracic scoliosis results in a so-called restrictive lung function, that is, diminution of total lung capacity (TLC); relative diminution of vital capacity (VC); relative increase of residual volume (RV). In addition, it was found that the functional reserve capacity (FRC), which consists of residual volume and expiratory reserve volume ($FRC = RV + ERV$), was decidedly diminished. As a result, the respiratory level was "lower" than normal. This situation involves more respiratory work, an increased risk of fluctuations in arterial gas pressures, and an increased risk of airway closure (which has an unfavorable effect on arterial oxygen tension). A correlation was found between the degree of curvature and the severity of the lung function changes.

2. Changes resulting from the operation were mean increase in TLC: 6 percent ($2\alpha < 0.001$); mean increase in VC: 0 percent; and mean increase in FRC: 20 percent ($2\alpha < 0.001$).

In the most severe scolioses (20 cases with a mean preoperative curvature of 70°) a slight increase in VC by 6 percent ($2\alpha = 0.05$) was demonstrable. A much more striking finding was the considerable restoration of the FRC to virtually normal values. This ensured much more efficient respiratory work and a small risk of an unfavorable effect on arterial oxygen tension, either by airway closure or by fluctuations in arterial gas pressures.

Some biomechanical aspects of brace-treated scolioses

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An idiopathic scoliosis is a deformity of the vertebral column that is characterized by lateral deviation and axial rotation of the vertebrae. Depending on the severity of the anomaly, it may be treated by means of a brace. Forces are applied to the body via pads on the tightened brace. These forces should exert both a bending and a twisting effect that may counteract progression and perhaps cause some correction.

The Boston and the Cheneau brace were biomechanically analyzed by the finite elements method to establish the effect of the location and the size of the pads on the mechanical function of the brace and to investigate the possibility of enhancing wearing comfort without reducing function.

The bending and twisting forces applied to the body via a Boston brace are not significantly influenced by the size of the pads. With this type of brace, the twisting force amounts to 65 to 80 percent of the bending force with increasing pad size. With the Cheneau brace the twisting and bending forces ap-

plied increase, because the pads are located more to the ventral aspect of the body. An increase in pad size causes an overall increase in the forces applied to the body. The maximum bending force is exerted if the pads are located on the lateral aspect, and the maximum twisting force when the pads are located on the ventral aspect.

The flexibility (and therefore the wearing comfort) of both braces can be enhanced by using thinner material; this does not affect function in any significant way. In this case the increase in material tensions in the Cheneau brace exceeds that in the Boston brace.

Reliability of measuring the scoliosis angle according to Cobb

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Measurements of the scoliosis angle according to Cobb is of decisive importance in assessing a scoliosis. However, the reliability of this measurement is not sufficiently known. It was investigated in the context of a school screening program. In observation on the scoliosis angle, two sources of variation may be distinguished: angle measurement and radiography (with variations in the patient's position). With regard to the former variation, three investigators independently assessed the scoliosis angle of 46 radiographs. The variation in this measurement was expressed as correlation coefficient (r) and standard deviation (SD). In an attempt to estimate the importance of the second source of variation, six radiographs of each of 10 patients were used to determine the correlation between scoliosis angle and age, with a corresponding SD of the deviation from the line of regression. The variation in angle measurement proved to be small ($r = 0.97$, $SD = 0.8^\circ$). As expected, the variation due to radiography proved to be significantly greater ($r = 0.73$, $SD = 3.2^\circ$). The latter variation should be carefully considered in making decisions concerning the treatment of scoliosis.

Scoliosis or "schooliosis"? A longitudinal epidemiologic study of scoliosis in a year-of-birth cohort of Rotterdam school children

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In juvenile health care, screening for dorsal and postural ab-

normalities is a permanent feature of periodic medical examinations performed at the ages of 4.5, 7, and 11 years, and during the second secondary school year. A prospective longitudinal epidemiologic study of spinal and postural abnormalities was performed in about 5,000 Rotterdam school children of a year-of-birth cohort (1973) during the school years 1984/85 and 1986/87. The purpose was to gain some insight into (1) the efficacy of this method and frequency of screening for early detection of scoliosis and (2) the interval between early detection and specialist examination and therapy. Referrals to the family doctor were made in accordance with preset criteria (e.g., thoracic gibbus > 5 mm, any lumbar gibbus, visible scoliosis or kyphosis). The GP was asked to verify and, if necessary, to refer to an orthopedic surgeon. Of the 5,000 pupils, 113 (2.3 percent) were referred to their family doctor in view of (kypho)scoliosis in 1984/85, and 56 (1.1 percent) in 1986/87. The data following referral were collected for a follow-up: not to family doctor 8 percent, exercise therapy and/or return visits 17 percent, and further referral (to orthopedist) 75 percent. In 11 percent of these, scoliosis was not clinically or radiographically demonstrable. The remainder continued under specialist supervision: 2 percent for other anomalies (osteochondrosis), 87 percent for scoliosis (Cobb angle < 10° in 53 percent, $10-20^\circ$ in 24 percent, and > 20° in 10 percent).

The method and frequency of screening by the school physician are sufficient for early detection; specialist examination revealed < 10° scoliosis in some 50 percent. It is advisable to leave further supervision of these children to the school physician. Referral should take place again in the event of progression.

School screening for scoliosis: Possibilities and problems in the Utrecht field study

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In order to determine the useful effect of school screening for scoliosis, a screening program was carried out in the province of Utrecht during the period 1984/1985. Three-year groups, each comprising 10,000 pupils aged 10, 12, and 14 years, were screened annually for scoliosis during 3 years. After primary screening with the aid of the bending test, a second screening included gibbus measurement, measurements of external vertebral rotation, and Moiré topography. In the case of a positive screening result, the family doctor was advised to start further investigations.

Each year, a positive bending test was found in 5.6, 4.5, and 5.2 percent, respectively. At the second screening the corresponding percentages were 3.1, 3.0, and 2.3. During the first year, 306 children attended the orthopedic consulting hour: 20 proved to have a scoliosis exceeding 20° . During the final phase the dropout rate was high due to the large number of persons involved in the screening (41 school physicians,

270 family doctors, and 40 orthopedists) and the low specificity of the screening techniques used. In order to investigate requirements for an increased specificity, some methodologic parameters of the screening techniques were examined during the second screening phase: intraobserver and interobserver variation and validity. It was found that upon use of one of the techniques mentioned, normal and pathologic values could not be sharply distinguished: only a "danger zone" could be defined. Given a measured value within this zone, the measurement should be repeated by the school physician within a short time. Measurement of external vertebral rotation proved to be the best means of enhancing specificity.

Changes in proprioception in patients with idiopathic scoliosis

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Changes in proprioception may play a role in the pathogenesis of progressive idiopathic scoliosis in adolescence. To verify this, proprioception was tested in a population of 25 patients with this abnormality, 25 with nonprogressive scoliosis, and 100 normal test subjects aged 6–22 years. The Slinger and Horsley arrangement was used, the blindfolded test subject being asked to approximate with the index finger of one hand the index finger of the other hand as closely as possible several times and with the target finger in different positions behind a horizontal glass partition. The deviations measured were suitable for statistical analysis. The range of deviations found in normal test subjects was considerable. The mean value slightly diminished during the second decade. In all the cases a symmetric pattern was observed, with slightly greater precision on the dominant side. Many patients with progressive scoliosis showed a characteristically asymmetric pattern of deviation. The mean asymmetry in this group differed significantly from that in the normal group. However since this pattern was not always observed in the patients with progressive scoliosis, other factors probably also play a role in the pathogenesis of this abnormality. Therefore, the above-mentioned test cannot be regarded as reliably predictive of progression.

Idiopathic scoliosis: The prognostic value of the profile

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Although scoliosis is mostly defined as an abnormal curvature of the spine in the frontal plane, it actually involves a complex three-dimensional deformity. Perdrille maintains

that 80 percent of the abnormality in fact lies in the sagittal plane at curvatures of less than 35°. Some sagittal spine models are more likely to predispose to scoliosis than others.

The prognostic value of the sagittal model of the spine for the development of scoliosis was studied.

Patients and method: In 120 out of 138 cases of idiopathic scoliosis with a thoracic component, brace therapy proved to prevent further progression. In the remaining 18 cases, this failed, and an operation followed. In both groups the angle of each vertebra from the horizontal was measured on the lateral radiograph obtained prior to treatment.

Results: Particularly in the high thoracic segment the two groups showed differences. In progressive scoliosis the vertebrae slanted dorsally far into the high thoracic region (for T6 an average of 11°), whereas in the less progressive forms the high thoracic vertebrae slanted ventrally (for T6 an average of 2°).

Conclusions: High thoracic vertebrae show a more dorsally slanted position in progressive scolioses than in the stable forms. This is true even at the start of therapy. Not the lordosis as such, but the predominant position of the vertebrae in the sagittal plane is important. Next to sex, skeletal age, type of curvature and rotation on the anteroposterior radiograph, this is of prognostic value.

The Netherlands scoliosis electrostimulation project

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Five scoliosis centers accepted 44 patients with progressive idiopathic scoliosis for nocturnal transcutaneous electrostimulation. There were 12 male and 38 female patients with 20° and 40° scoliosis shown to be progressive, expecting at least 2 year's further growth, and with a Risser sign of maximally 3. In 20 cases there was a double primary curve that was treated by dual-channel electrostimulation.

Results: At follow-up the treatment of 16 patients had been successfully completed after skeletal maturation without progression in excess of 5°. In 9 other patients, treatment is still being continued with a stable curve and a mean duration of treatment of 3 years. Ten patients had shown significant progression of the scoliosis. Nine patients had had to discontinue treatment due to insufficient motivation, pain, or skin irritation.

Conclusion: So far, electrostimulation has yielded satisfactory results in idiopathic scoliosis. Other studies show that it is uncertain whether electrostimulation causes a significant improvement in the natural course. Electrostimulation seems suitable for flexible thoracic and thoracolumbar curves. Patients are generally not inconvenienced by this therapy, but it is time-consuming in scoliosis centers.

Results of brace treatment of progressive idiopathic scoliosis

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Since the introduction of the Boston brace in 1978, our indications for brace treatment of idiopathic scoliosis have remained unchanged: it is used for scolioses between 25° and 45° in growing children before or during the puberal growth spurt. If untreated, virtually all of these scolioses show some degree of progression. The efficacy of brace treatment was studied, taking skeletal age and degree of curvature into account.

Patients: Since 1978, 131 patients with a thoracic (T) or thoracolumbar (TL) scoliosis have been treated until completion of growth and with a follow-up of at least 1 year. They were divided into three groups: Group I: 33 males and 2 females, skeletal age up to 12 years, scoliosis angle in excess of 30°, mean initial angle 35°, T in 32 and TL in 3 cases. Group II: 31 males and 1 female, skeletal age up to 12 years, scoliosis angle 25–30°, initial angle 26°, T in 27 and TL in 5 cases. Group III: 58 males and 6 females, skeletal age over 12 years, scoliosis angle in excess of 30°, initial angle 35°, T in 50 and TL in 14 cases.

Results: Group I: favorable (< 45°) in 21, failure (> 45°, therefore operated on) in 10, premature discontinuation in 3 cases. Group II: favorable in 28, failure in 2, and premature discontinuation in 2 cases. Group III: favorable in 49, failure in 8, and premature discontinuation in 7 cases.

Conclusion: The efficacy of brace treatment in Group I (patients with T/TL scoliosis in excess of 30° and a skeletal age up to 12 years) was significantly less than that in Groups II and III.

Is the natural course of idiopathic scoliosis influenced by a brace?

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Of 301 patients with idiopathic scoliosis who started with brace treatment at the St Maarten Hospital in Nijmegen during the period 1970–1982, 209 patients were evaluated. Only growing patients with an initial Cobb angle of 20°–50° were treated. The mean age was 13.4 years and the mean Cobb angle was 32°; mean Perdriolle angle (rotation of apical vertebra) 17°; mean gibbus 16 mm. An increase in the Cobb angle (> 5°), Perdriolle angle (> 5°), and gibbus (> 5°) was found in 27, 29, and 27 percent of the patients, respectively; a decrease in these values was found in 23, 8, and 17 percent, respectively. The course of the scoliosis (Cobb angle, Perdriolle angle,

gibbus, spine balance) before, during, and after brace treatment was correlated with some 20 variables (e.g., skeletal age, Risser sign, sex, possibility of correction by traction, bending or brace, progressiveness, apex location, type of scoliosis) and compared with the natural course of scolioses in patients with corresponding variables (mentioned in the literature) who were left untreated.

Conclusion: The natural course of idiopathic scoliosis is favorably influenced by brace treatment; all the differences were significant regardless of the published report on the natural course.

Managemental evaluation of brace treatment in idiopathic scoliosis

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In three peripheral and two university hospitals, a study was started in 1986 to evaluate brace treatment of idiopathic scolioses in terms of management. Interventions to which the patients were submitted and the means used for them were studied. The data were translated into money with the aid of the COTG tariffs for sick-fund patients. The basic model was an imaginary 12-year-old patient who was treated for 5 years and given aftercare for 2 years. All the cost elements for outpatient visits, radiographs, instrument maker, material and repairs, admission to hospital, lung function tests, and physiotherapy were qualified and summed for the treatment strategies of the five participating hospitals. The differences in therapeutic methods between the five hospitals are also reflected in the total cost of therapy.

Striking differences were (1) differences in total cost: 29 percent between the minimum (f 17,600.-) and the maximum (f 22,800.-); (2) three hospitals admitted patients for fitting the brace and becoming accustomed to it; (3) the difference between the largest and the smallest number of radiographs was factor 2; (4) only in one hospital were lung function tests performed; the difference between the highest and the lowest frequency of physiotherapy was factor 1.4 (physiotherapy is the principal cost element in the total cost of therapy); (5) cost of materials and repairs: for comparison the number of braces was standardized at 3 during the 5 years; there was a factor 2 difference between maximum and minimum cost.

The comparative cost analysis may be a reason to introduce more stringent protocols for brace treatment.

Symptomatic unbalancing lumbar kyphosis following Harrington distraction spondylosis down to and including the sacrum for idiopathic scoliosis: Results of osteotomies in 8 patients

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During the period from 1971 through 1981, 23 patients with idiopathic scoliosis were treated by Harrington distraction spondylosis down to and including the sacrum. The mean follow-up was 12 (7–17) years. For a study of long-term results in this group, static changes in the sagittal plane were measured clinically and radiographically. The static changes were correlated with the complaints and the degree of disability. In 8 cases, complaints and static changes were such as to necessitate a corrective osteotomy. A single osteotomy was sufficient in 6 cases, whereas 2 required three osteotomies. Statics improved in all the cases, but complete lasting equilibration in the sagittal and the frontal plane was achieved in only 4. Complaints of pain and fatigue disappeared in 7 cases. All the osteotomies were stabilized with thick compression rods and healed primarily. No neurologic complications developed.

Treatment of a so-called flat back after distraction spondylosis for scoliosis is difficult, and complete restoration of balance in the sagittal and the frontal plane cannot be readily predicted. The main concern should be prevention of the so-called flat back syndrome: Harrington distraction spondylosis down to and including the sacrum for idiopathic scoliosis is contraindicated.

Ventral spondylosis in thoracolumbar scoliosis: Results and complications

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During the period 1978–1987, ventral spondylosis was performed on 33 patients with severe thoracolumbar scoliosis (21 with an idiopathic and 12 with a paralytic scoliosis); the Dwyer instrumentation was used in 5 and the Zielke in 28 cases. All the patients were evaluated clinically and radiographically. The mean follow-up period was 3 (1–8) years.

The mean correction of the scoliosis angle was 36° (50 percent) and in the paralytic cases 46° (48 percent); the torsion was reduced by 50 percent. In the idiopathic group the nonstabilized proximal angle was reduced by an average of 11° (23 percent). Over the operation distance averaging 6 (4–8) levels, kyphosis from 3° lordosis before to an average of 12° kyphosis after the operation was observed. Pain was significantly alleviated in 7 out of 8 patients.

Complications: Neurologic problems in 2 cases, screw in disc in 1 case, skewness of screws in 5 cases, overcorrection in 1 case, spondylosis at the wrong level in 1 case, decubitus in 3 cases, superficial wound infection in 1 case, intercostal neuralgia in 1 case, pseudarthrosis in 1 case, broken rod in 3 cases.

In view of the good results, the advantages of a shorter spondylosis distance, and the possibility of derotation, ventral spondylosis with the Zielke instrumentation is now fully accepted in our department for cases of severe thoracolumbar scoliosis.

Preliminary experience with the Cotrel-Dubousset procedure in the treatment of idiopathic scoliosis

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From February 1986 until June 1987, operations for idiopathic scoliosis were performed in four hospitals on 31 patients; 23 females and 9 males, including 28 adolescents averaging 17 years of age and 3 adults. The mean preoperative scoliosis angle was 59°, versus 20° after the operation; the mean correction was 65 percent. In 15 cases no postoperative immobilization was used; 16 patients were given a corset or plaster cast. The principal complication observed was loosening of one or several hooklets in 5 cases, resulting in loss of correction; this necessitated a reoperation in 2 cases.

Treatment of neuropathic scoliosis using Luque's segmental spinal instrumentation

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Segmental spinal instrumentation (SSI) was used in the treatment of 25 patients from September 1983 through June 1987. The group included 5 patients with spina bifida, 7 with cerebral paresis, and 6 with neuromuscular diseases. The mean scoliosis angle was 70 (39–110)°. All the operations entailed a substantial loss of blood, 1,800 (650–3,800) mL. The postoperative scoliosis angle was 40 (7–92)°, correction 43 percent. The loss of correction after 6 months averaged 8°. Complications included transient loss of femoral nerve function and, in 6 cases, displacement of the material. Two patients required reoperation. In experienced hands, SSI is a re-

liable technique in the treatment of neuropathic scolioses, which enables rapid return to the preoperative level of activity. It is advisable to use the original Luque rods and, if possible, to immobilize the patient for a few months with the aid of a removable corset.

Spine

Fiber typing of the low back muscles

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Recent EMG studies of the intrinsic low back muscles have yielded indications that a functional difference exists between three different columns of muscles. Medially, static forces in the sagittal plane are important; dynamic forces in the frontal plane play a role laterally; and the intermediate part is functionally in between these two. Such a functional differentiation should correspond with a morphologic one: slow-twitch type I fibers to be mostly expected medially and fast-twitch type II fibers laterally. In order to verify this, biopsy specimens were taken from 30 postmortem specimens (22 from males and 8 from females) in such a way that a comparison with EMG studies was possible. The data on fiber-type distribution led to the following conclusions.

1. On an average, 13 percent more slow-twitch fibers were found medially than laterally (this supports the functional difference postulated).

2. Medially, there was a significant left/right difference; laterally the number of slow-twitch fibers on the left averaged 4.4 percent higher than that on the right. This difference merits further investigation in relation to the pathogenesis of scoliosis.

3. No correlation seemed to exist between age and fiber type distribution, although the material studied had a high median age. An investigation in a younger population seems advisable.

Automated CT measurement in a lumbar vertebral body

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In calculations of surface areas and densities of osseous tissue, as used in measuring osteoporosis in lumbar vertebrae, precise delineation of cancellous bone from cortical bone is a necessity. This is usually made by hand and visual estimate, but in large groups of patients this method is too cumbersome

and not sufficiently accurate. A work-up in a consecutive series (batch mode) is therefore essential.

In the first step the vertebral body is localized within the CT image with the aid of variable threshold values and by applying some morphologic transformations. Next, a Region Of Interest (ROI) within the cancellous bone is determined with the aid of a texture classification. A reference histogram is used to delineate the cancellous from the cortical bone.

This technique makes use of binomial distributions and the Mahalanobis distances between them, and may be an alternative to current measuring methods using median roentgen absorption values.

Surgical treatment of posttraumatic kyphosis

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During the period 1978–1986, operations were performed on 82 patients with posttraumatic kyphoses. The minimum interval between accident and operation was 6 months. The indication for operation was pain in 84 percent of the cases, progression of the kyphosis in 9 percent, and progression of neurologic dysfunction in 7 percent. Five patients were treated solely by a laminectomy.

Treatment consisted of dorsal spondylodesis with instrumentation of 11 patients, ventral spondylodesis with instrumentation in 20, and combined dorsal and ventral spondylodesis with internal fixation in 41. The kyphosis correction immediately after the operation amounted to 50 percent. Half of the patients no longer complained of pain; improvement in neurologic dysfunction was observed in 13 cases. After a follow-up of at least 2 years, 9 of the 11 patients treated by dorsal and 11 of the 20 treated by ventral spondylodesis showed a loss of correction of more than 10° versus the immediate postoperative result. Of the 41 patients treated by combined dorsal and ventral spondylodesis, only 3 showed some loss of correction. In view of the better results, combined dorsal and ventral spondylodesis seems preferable in the treatment of posttraumatic kyphosis.

Direct repair of the defect in spondylolysis

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Between 1982 and 1986, direct repair of the defect in spondylolysis according to Buck was performed in 20 patients aver-

aging 29 years of age. All of them had first been conservatively treated for severe backache for at least 1 year. Criteria for the operation were a normal subjacent disc at discography, absence of degenerative lesions in the lumbar spine, and a maximum spondylolisthesis of 4 mm. The follow-up averaged 4 years. Complete consolidation was achieved in 14 cases and unilateral consolidation in 3; in 3 other cases, there was no consolidation.

Clinical results were good in 13 patients and fair in 4; 3 patients showed no improvement.

Conclusion: Direct repair of the defect in spondylolysis with a limited spondylolisthesis is a good alternative to spondylosis.

Complications in the surgical treatment of grades III and IV spondylolistheses

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In ventral intercorporeal spondylosis, correction of the olithetic kyphosis is of primary importance because it ensures that the fusion is subject more to compression than to a vertical shearing force. Twenty-four patients were treated by operation; in 3 cases dorsal spondylosis with instrumentation was also performed. One female patient developed a severe caudal lesion as a result of compression of the dural sac due to overcorrection of the lumbosacral kyphosis; a laminectomy finally led to this patient's recovery. Unmistakable shortening of the hamstrings persisted after the operation in 1 case; laminectomy of the loose arch led to complete disappearance of this symptom. Chronic foot drop resulted after the operation in 1 case, while in another case a transient foot drop was seen. Two patients developed pseudarthroses that consolidated after reoperation. Ventral intercorporeal reposition and stabilizing spondylosis of a severe spondylolisthesis is a technically difficult procedure with a risk of neurologic complications. It should be established in advance whether decompressive laminectomy of the loose or elongated arch is first required.

Tuberculosis of the vertebral column: Early and late problems of diagnosis and therapy

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Vertebral tuberculosis is an uncommon disease in The Netherlands. In 1986, there were 26 hospital admissions, at an incidence of 1,236 (9 per 100,000). Beside the fact that its diagnosis is difficult, this is probably the cause of the usually long diagnostic delay. Nevertheless, imported tuberculosis is to be taken into account in view of the increasing incidence in non-western countries. Another problem is that of confrontation with late (healed) tuberculosis of the spine that, as progressive neurologic dysfunction indicates, has not reached a stable terminal stage. The diagnostic possibilities of magnetic resonance imaging (MRI) are discussed with reference to 4 patients recently treated. As the literature indicates, its sensitivity is significantly higher than that of conventional radiography. However, tomography remains valuable with regard to therapeutic decisions. Surgical treatment (ventral resection and dorsal stabilization with segmental techniques) significantly reduces the period of rehabilitation, and late complications such as kyphosis and paraparesis can be prevented. Apart from their use in acute tuberculosis, segmental techniques also offer possibilities in the treatment of late sequelae such as severe kyphosis and progressive paraparesis. Their treatment consists of a two-stage operation: vertebral decompression and homologous bone graft, and dorsal sublaminar segmental fixation.

Peroperative spinal monitoring with the aid of evoked potentials

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One of the most dreaded complications during surgical correction of lesions of the spine is paraplegia. Ischemia of the spinal cord due to a spasm of the anterior spinal artery probably plays a prominent role in this respect. Early detection of potential cord lesions is very important. Two methods of spinal monitoring have been described in the literature. The first is the so-called wake-up test. The second is spinal monitoring with the aid of evoked potentials, i.e., potentials that develop in the nervous system following stimulation of a sensory nerve. Cortical evoked potentials were measured during 150 operations on the spine performed from October 1983 to April 1988. None of the patients had any preoperative neurologic abnormality. In 157 patients, nonpersistent disturbances in somatosensory-evoked potentials (SSEP) measured were observed; these patients showed no postoperative neurologic changes. Severe disturbances of the SSEP occurred in 3 patients (1.8 percent) treated for severe scoliosis by Harrington's spondylosis; the distraction was immediately diminished. Two patients did show postoperative neurologic dysfunction (1.3 percent). In 1 (female), the signs of dysfunction had not disappeared entirely 1 year after the operation (0.6 percent).

Orthopedic treatment of patients with sacral and lumbosacral agenesis

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Of 5 patients with partial or total agenesis of the lumbosacral spine, 2 showed a normal level of ambulation, 2 were wheelchair-bound, and 1 was too young to be able to walk. Two of these patients were treated by proximal femoral osteotomies and tenotomies of the hip, which led to improved mobility in 1. Seven patients showed partial or total agenesis of the sacrum; in all of these cases the level of ambulation was normal and no orthopedic operations were performed. The most common accompanying orthopedic abnormalities were scoliosis and foot deformities. The level of ambulation in the total group depended on the level of neuromotor dysfunction, which usually corresponded to the severity of the agenesis. Orthopedic operations may be of value in some cases of lumbosacral agenesis in order to correct contractures of hips and knees. In sacral agenesis, operations are rarely indicated.

Restoration of continuity in a case of total lumbosacral agenesis

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The patient was a boy with agenesis extending from the 11th thoracic vertebra down through the sacrum. This discontinuity had caused severe thoracopelvic instability with complete paraplegia, as well as urogenital and intestinal dysgenesis.

After conservative treatment in a cardan suspension brace, the patient at age 6 was treated by surgical reconstruction between the thoracic spine and the pelvis, using a Harrington distraction system, autologous tibial chips, and vascularized rib chips. A second operation was performed for orthopedic/cosmetic correction of a Buddha position of the legs with marked popliteal webbing. Careful multidisciplinary management led to an excellent result some 3 years after the operation.

Varia

Muscle course and muscle force in a model of a neonatal hip

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The ultimate purpose of studying a model of a neonatal hip is improvement of the treatment of congenital hip dysplasia. We assume not only that a wrong direction of the force applied to the femoral head can lead to dysplasia, but also that correction is possible by exerting a force in an appropriate direction. The force on the femoral head is usually exerted by muscle forces. Because measurement of these muscle forces or calculation from external forces is not feasible, the muscles were described in a model.

For this purpose the following parameters were measured from a specimen: (1) five positions of femur and tibia in relation to the pelvis (fetal, neonatal, anatomic, adduction, and Lorenz position); (2) some morphologic characteristics of femur and pelvis; (3) origins and insertions of the hip muscles; (4) muscle locations; (5) muscle volumes; (6) muscle fiber lengths.

Muscles were modeled as lines, which may be straight, kinked, or curved around the femoral head, around the femoral neck, around the greater trochanter, or combinations of these.

Descriptions of the muscle course were given in relation to the five positions and femoral neck directions to be simulated. The magnitude of the muscle force at maximum activation was deduced from volume, fiber length, muscle length, and muscle length at rest with the aid of a flat bipenniform muscle model and a normed force/length diagram for sarcomeres. Muscle activations were used to simulate spina bifida and spasticity. They were also optimized to approximate a desired direction of force on the femoral head. For this purpose, they were first set at 50 percent and then separately increased or decreased by 1 percent, depending on whether the desired force direction was approximated better or less well. A marked mean deviation from the original 50 percent meant that the desired force direction was not readily approximated, and therefore in reality it was probable.

Some conclusions based on the hip model were (1) neonatal hip muscles often should not be approached as straight lines; (2) the residual lengths of the muscles in the model exert considerable influence on the force direction; (3) the mean resultant force on the femoral head after birth is probably steeper and directed more anteriorly than before birth.

Adaptive bone remodeling around prostheses

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Bone resorption around implants can play a prominent role in the clinical failure of implants. It has often been postulated that this adaptive bone remodeling is influenced by the load on the bone. Internal loads and deformations of the bone can be determined using the finite elements method (FEM). By integrating this FEM with a computer simulation program in which the bone remodeling process is described analytically,

the degree of bone resorption can be predicted. A quantitative bone remodeling hypothesis is required for this. This study discusses the application of one such hypothesis and shows what it implies for the remodeling around a fully coated, uncemented femoral component of a total hip replacement.

Method: A two-dimensional FE model of the proximal femur served as a basis for the analyses. The medial and the lateral cortex were linked up by means of a posterior plate to give the model three-dimensional aspects. The bone remodeling hypothesis can be defined as an effort to ensure that the local elastic energy density in each fragment of osseous tissue is constant. This effort is reflected by the equation $U/p = C$, in which U represents the mean elastic energy density of an area, p the apparent density, and C a constant. Because U is related to load, a relationship between density (porosity) and load is thus obtained. To begin with, computer simulation was used to establish what the density distribution of a proximal femur is when the hypothesis is fully met, given a load in accordance with average daily activity. The normal homeostatic density distribution thus obtained was taken as a basis for a femur with implant under the same load conditions. Because the elastic energy density distribution in the bone changes as a result of the implantation (stress shielding), the bone will remodel and seek a new equilibrium to meet the requirement $U/p = C$.

Results and discussion: In both analyses the density distribution converged to a stable end configuration, always fulfilling the criterion set. The calculated normal homeostatic density distribution showed adequate similarities to the structure of a proximal femur. After implantation of the uncemented stem, a large portion of the proximal bone around the stem resorbed. This phenomenon—clinically known as stress shielding effect—seemed more prominent in the simulation than it was clinically observed, although instances of very marked proximal bone resorption have been described in animal experiments.

The results support the clinical experience that prudence is advisable when using relatively stiff, uncemented implants coated over their entire length. It may be possible to ensure a more favorable pattern of bone remodeling around uncemented implants by adjusting various design parameters of the implant such as stiffness, geometry, and area coated.

Mechanical behavior of the patellar tendon after removal of a graft for the anterior cruciate ligament

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The most widely used technique of reconstructing the anterior cruciate ligament makes use of a portion of the patellar tendon, most often the central one third.

An *in vitro* study was performed to establish whether the possible disadvantages of suturing the (donor) defect, e.g., patella baja and increased tension in the retinacula, is compensated by an enhanced ability to cope with mechanical stress immediately after the operation.

For this purpose the biomechanical parameters rigidity (in N/mm), (maximum) strength (in N), and site of collapse (as a measure of failure) were determined in 14 porcine knee-joints. The specimens used consisted of the proximal tibia, the patellar tendon, and the patella. The 14 specimens were divided at random into three groups: 1) a control group A ($n = 5$) with an intact tendon; 2) an "unsutured group" B ($n = 4$) with a central donor defect; 3) a "sutured group" C ($n = 5$) with a closed defect.

The experiments were performed using an Instron-TTCM traction bench (Instron, High Wycombe, U.K.).

Results: The mean rigidity was 285 ± 53 N/mm in group A, 126 ± 30 N/mm in group B, and 124 ± 45 N/mm in group C. The mean maximum strength was $2,157 \pm 675$ N in group A, $1,004 \pm 305$ N in group B, and 975 ± 448 N in group C. Thus, there was no difference either in rigidity or in (maximum) strength between group B and group C. The decrease in rigidity was 56 percent in both groups, and the decrease in strength was 53 percent and 55 percent, respectively. Three specimens in group A collapsed within the ligament, while two collapsed at the boundary between patellar tendon and patella. The corresponding numbers in group B were three and one. Each of the five specimens in group C showed intra-ligamentous collapse. A striking finding was that both rigidity and maximum strength showed a higher (individual) standard deviation in group C.

The findings warrant the conclusion that suturing of the donor defect *in vitro* had no demonstrable favorable short-term effect on mechanical behavior. No statements can be made about *in vivo* or long-term effects.

Effect of gentamicin on articular cartilage

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Septic arthritis is an inflammation of one or several joints as a result of bacterial infection. The hip and knee joints are the sites of predilection. One of the principal consequences is irreversible damage to the cartilage, which in 30 percent of patients leads to permanent restriction of the function of the affected joint. Systemic antibiotic medication usually involves a broad-spectrum antibiotic given intravenously in large doses. This medication entails stress on the system. Local application of the antibiotics might be better and safer. The question is, however, whether local application of high concentrations of an antibiotic may have a negative effect on the cartilage of the joint(s) affected. The effect of gentamicin

on normal articular cartilage was studied in two different ways: (1) By means of a patellar culture using the $^{35}\text{SO}_4$ method to determine the metabolism of the cartilage exposed to different antibiotic concentrations. (2) By histologic examination of patellae exposed to gentamicin for several days.

Patellae of rats (Lewis, aged 12–14 weeks) were removed under aseptic precautions and placed in a culture dish with medium. Next, the antibiotic was added to 12 patellae with end concentrations of 2, 7, 16, 30, and 50 $\mu\text{g}/\text{L}$. A group not given gentamicin was used as a control group. On days 1 and 3, $^{35}\text{SO}_4$ incorporation was determined by measuring the radioactivity.

In order to study changes in histologic features, patellae were cultured under similar conditions for 2 and 4 days. They were fixated, embedded in paraffin and stained with HE, AB-PAS, and safranin-O.

No significant differences were found between the control group and the groups with the various gentamicin concentrations. Nor was there any difference between the groups of day 2 and day 4. Moreover, no demonstrable histologic differences had developed between the various groups.

The findings indicate that high concentrations of antibiotics have no demonstrable negative effect on articular cartilage.

Vascularized rib graft: Technique and results in 7 patients

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A vascularized rib graft can be used to bridge vertebral defects or kyphotic spine segments, either for stabilization or after correction of the kyphosis. Because the rib segment remains vascularized, it rapidly consolidates with the vertebral body, thus preventing possible stress fracture and loss of correction. This technique was used in 9 cases. In 2 cases the rib was found insufficiently vascularized during the operation; in 1 case this was due to the thoracic and vertebral injury as such, and in the other case the 11th rib proved to be too hypoplastic for this technique. In 7 cases (5 posttraumatic cases and 1 following resection of vertebral metastases) with a follow-up of 0.5–4 year, this technique ensured uneventful consolidation without stress fractures and with only limited loss of correction. In the last-treated patient a bone scan demonstrated the intact circulation in the rib.

The technique seems especially suitable for larger defects on the ventral side of the spine, for patients who cannot be readily immobilized for longer periods, and when bone chips are to be used in an irradiated region where poor bone remodeling is to be expected.

An external pin fixation system for performance of a glenohumeral arthrodesis

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In order to permit experimental determination of the optimal individual fixation position prior to glenohumeral arthrodesis, an adjustable external pin fixation system was developed. This system is used to fix the bone fragments; and in subsequent visits to the outpatient clinic, the position can be varied until the optimal fixation position is found. During the arthrodesis, performed 1 or 2 weeks later, part of the fixation system can be removed without affecting the position set. After the operation the system can be used to exert compression in the plane of fusion to ensure optimal contact between the head of the humerus and the glenoid cavity. During the period of consolidation (12 to 14 weeks) the patient can function reasonably well with the fixation system in place. The results obtained with this system in the first 4 cases have been encouraging.