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Paralytic scoliosis

von Werner Lack

General aspects

The treatment of neurogenic scoliosis differs principally from therapy of idiopathic scoliosis. Progression of deformity in paralytic curves is generally worse; brace treatment has no real importance; indication and time of operation are based on the probability of progression and depend on the neurogenic disease . Because of the similar symptoms of long thoracolumbar curves mostly including the pelvis, there are some principles for the majority of paralytic deformities.
Indicating operation of neuromuscular scoliosis on the one hand lung function, on the other hand walking capacity, pelvic obliquity and sitting balance play an important role. As lung function problems mostly are combinations from a paralytic and a deformity component, it should be avoided to perform operation too late. Only in case of still remaining walking capacity it has to be hold in mind, that fusion may avoid Trendellenburg-walking and therefore can make walking more difficult or impossible.
In severe pelvic obliquity fusion always should include the sacrum, otherwise it is not possible to create sitting balance; because of sensibility loss decubital ulcera at the ischial tuber and the sacrum can follow. Cranially long paralytic curves optimally are fused to the 2.thoracic vertebra, in case of using claws T2 has strong lateral processes (*Asher et al. 1990).* In case of paraplegic patients with strong upper extremities it is preferable to stop cranially at T5 to keep the mobility of the arms. Posterior fusion and instrumentation alone has in contrary to idiopathic scoliosis a high rate of pseudarthrosis and is indicated only in slight and mobile curves; in severe scoliosis a combined anterior-posterior fusion is indicated.

Historic development

A successful operative treatment of paralytic scoliosis became possible by Harrington-instrumentation 1962. Harrington implants remained for a quarter of the century the „gold standard" of posterior scoliosis correction. 1969 *Dwyer* described the first anterior scoliosis instrumentation, mainly for thoracolumbar and lumbar curves and for posterior defects in meningocele. By convexsided approach correction is performed after disc removement from end-vertebra to end-vertebra using screws connected and compressed by a titanium-cable; this technique allows a very good correction, but has a kyphosting effect in the thoracolumbar and lumbar region. *K.Zielke* described 1976 a further development of this technique using a threaded rod instead of the titanium cable and a derotaror (VDS-ventral derotation system).

An important next step in posterior instrumentation especially in paralytic scoliosis was the SSI (segmental spinal instrumentation, *Luque 1976*). Fixation is done by sublaminar wires on both sides, at the cranial and caudal end bending the rods in L-form. With this technique for he first time a brace-free treatment was possible, very important for paralytic curves. The principle of sublaminar wires was also used in other implant systemc (Harrington-Luque, Isola…).

1984 a new posterior frame system was introduced by *Cotrel and Dubousset.* It allows a stepless distraction and compression using hooks and pedicle screws, also using two transverse stabilisators. This instrumentation allows a bracefree aftertreatment too.

The further development demonstrates a lot of new implant systems with the principle of posterior frame construction amd segmental fixation, mainly using only pedicle screws with mobile screw heads (Nuvasive, Exspidium…).

Neurogenic deformities according to Scoliosis Research Society *(Bradford und Hu 1995, Winter 1994)*

1.neuropathic
A. Upper motor neuron
    1.cerebral palsy
    2.spinocerebellar degeneration
        a.Friedreich-ataxia
        b.Charcot-Marie-Tooth-disease
        c.Roussy-Levy-disease

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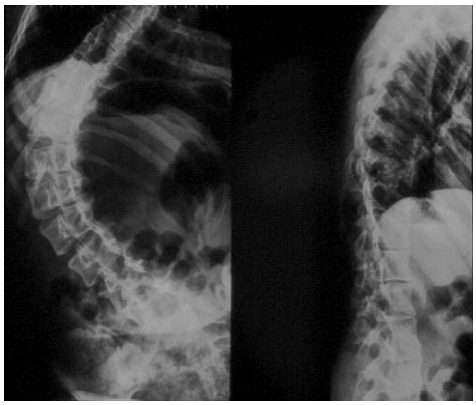
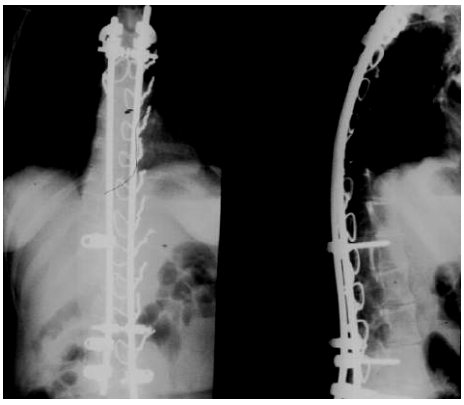
3.syringomyelia
4.medullary tumour
5.medullary trauma
B.Lower motor neuron
1.poliomyelitis
2.other forms of viral myelitis
3.trauma
4.spinal muscular atrophy
a.Werdnig-Hoffmann
b.Kugelberg-Welander
5.dysatonoma (Riley-Day-syndrome)
2.myopathic
A.arthrogryposis
B.muscular dystrophy
1.Duchenne (malign form of pelvic girdle)
2. Becker-Kiener (benign form of pekvic girdle)
3. Erb (facio-scapulo-humeral type)
C. dysproportional type
D.congenital hypotonia
E.dystrophia myotonica (Curshman-Steiner)

Scoliosis in infantile cerebral palsy

According to *Rosenthal et al. 1974* there is a 38% scoliosis incidence in ICP. The most severe curves are thoracolumbar with pelvic obliquity and luxation of hip joint *(Samilson and Bechard 1973).* Prognosis of scoliosis depends on grade of development of the system of balance-reflexes. The higher the grade of deficit of motoric development the higher is the incidence of scoliosis (*Robson 1968*). Even after end of growth we can see significant progression in curves>50°*(Thometz and Simon 1988*). Scoliosis is either long and C-shaped as „collapsing spine“ or with two curves ; especially the C-shaped curves are often associated with pelvic obliquity *(Madigan and Wallace 1981).*
Bonnet et al. concluded after 13 cases with Harrigton-spondylodesis that severe curves in cerebral palsy would need a combined anterior-posterior instrumentation. They had stable corrections in 60% using Dwyer and Harrington. Majority of authors performs combined anterior-posterior fusion especially in severe curves and in all patients with athetoid component (*Bonnet et al*|. *1976, Moe 1972, Leatherman and Dickson)*. *Suk et al. 1993* had 43° correction using CD alone and 58° with ventral derotation spondylodesis and CD. *Lonstein and Akbarnia 1983* found a complication rate of 81% (pressure sore, superficial infection, implant problems, loss of correction, 17% pseudarthroses, 5% deep infection, 0,9% paraplegia and death in 2,7%). As patients with cerebral palsy often need antiepileptic drugs, it is important to state, that especially valproin acid elongates bleeding time, therefore antiepileptic medication should be regarded in preoperative planning; if a change is not possible, thrombocyte concentrates should be prepared.

It was disappointing, that the authors could find a functional improvement in only 24 of 107 patients. *Lonstein und Akbarnia* see the main indication for operation in the danger of loss of sitting capacity.
These literature citations demonstrate, that indication for scoliosis operation in cerebral palsy should be done very cautiously.





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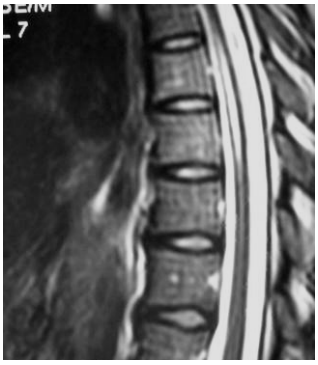
Syringomyelia

Scoliosis incidence in syringomyelia lies between 64% *(Huebert and McKinnon 1969*) and 82%. Scoliosis form is similar as idiopathic scoliosis, but progression is worse. Curves are mostly thoracic *(Vanden Brink und Edmonson 1980).* In case of suspected idiopathic scoliosis with severe progression syringomyelia should be included in differential diagnosis *(Zielke 1985*) and excluded by MRI.



Scoliosis after poliomyelitis

There exist two possible types of scoliosis: curves caused by asymmetrical palsy (Paresis of convexsided muscles) and long C-shaped curves ("collapsing spine"). caused by severe total paresis of the spine muscles *(Leong et al. 1981).* Scoliosis incidence is up to 30*% (Colonna 1941, James 1956),* depending on the kind of muscular involvement by polio-including body and upper extremities up to 80%, involvement of only leg muscles appr. 20% *(Colonna 1941).* Lumbar curves remain mobile for a longer period as thoracic. high thoracic curves have the worst prognosis *(James 1956).*

In asymmetric curves a brace therapy can be indicated beginning at 20°; curves>40° and "Collapsing spine-curves" should be fused *(Leong et al. 1981).*

After posterior instrumentation and fusion alone there is a danger of pseudarthrosis in more than 25% (*Bonnett et a1.1975).* Therefore also in these deformities a dorso-ventral fusion is recommended. *O'Brien et al.1975* saw a a correction of 77° using Dwyer-instrumentation with spontaneous correction of second curvature of 60°; after a posterior Harrington-fusion correction of secondary curve was improved to 78%.

Meningocele

Scoliosis incidence, depending on level of paresis and the last intact lamina lies between 50 and 70% *(Banta and Becker l986*, *Shurtleff et al. 1976*). In 15-18% we see a kyphosis, often with severe progression already in infantile age *(Banta und Hamada 1976).* Both scoliosis and kyphosis can be congenital (short and rigid) and paralytic. Especially in scoliosis, but also in scoliosis missing laminae, hypoplastic joints and lateral orientation of pedicles are characteristic, but also a hypoplastic pelvis and insufficient soft tissue closure above the apex of the curve *(Banta 1990).*

According to these complex problems operative treatment is difficult.
Rate of pseudarthrosis in posterior fusion and instrumentation is up to 42% *(Sriram et aL. 1972).* According to the often missing posterior elements meningocele is a domain of anterior fusion. In additional posterior instrumentation besides pedicle screws pedicle wires can be used too *(Banta 1990*).

Patients with myelodysplasia can develop an allergy against latex up to an anaphylactic shock; the risk increases with the number of operations *(Halm 1886*).

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Scoliosis in spinal muscular atrophy

While infantile Werdnig-Hoffmann-type has a very early mortality, the juvenile type Kugelberg-Welander has a better prognosis. Scoliosis incidence is about 60% *(Phillips et a1.1990*).

Brace-treatment in general cannot prevent progression *(Hormozan et al.1982),* eventually operation can be retarded until the end of growth. *Evans et al. 1981* recommend operation at a curve of 60°. Later literature notes vote for an early operation, to avoid the decrease of lung function, in this indication a combined fusion too *(Leatherman and Dickson).*

Besides rather often ocurring pulmonal complications (pneumonia, atelectasis) *(Hormozan et al.1982)* a postoperative problem is also the loss of head-position-control. *(Shapiro und Bresnan 1982).* Brace-treatment makes no sense.

Fusion is indicated in curves >40° *(Bradford und Hu 1995).* A disadvantage is the long lever arm, not good enough controlled by the weakened muscles. A rigid, but stable spine improves the use of upper extremities *(Furumasu et al. 1989*). Nevertheless patients even after 5 years do not reach the preoperative functional status *(Brown et al. 1988).*

Scoliosis in Friedreich-ataxia (spinocerebellar degeneration)

The disease starts in the age between 6 and 20 years and has a scoliosis incidence of 75% *(Shapiro und Bresnan 1982)*. There are cerebellar (dysarthria, ataxia, nystagmus) and spinal components (reduced sense of position and vibration, pes supinatus). Nearly always there is a cardiomyopathia. In most cases patients die below the age of 30 years.

Scoliosis is in >60% combined with increased kyphosis *(Labelle et al. 1986).* There are mainly right thoracic/left lumbar double major curves rarely C-shaped paralytic curves with pelvic oliquity. Probably not the muscle weakness, but the ataxia with disturbance of the balance-system is responsible for onset of scoliosis. In case of early beginning progression of deformity is significantly worse, onset before puberty always leads to a severe progressive scoliosis. Curves>40° after early onset should be operated *(Labelle et al. 1986).*

With a low incidence scoliosis can be seen in peripherous neuropathies; in peroneal muscular atrophy Charcot-Marir-Tooth the incidence is described in 10%, higher in hypertrophe polyneuritis Dejerine-Sotta with an atactic component *(Shapiro und Bresnan 1982)*.

Paralytic scoliosis after trauma of medulla during growth

After trauma with paraplegia in childhood majority of patients develop progressive long paralytic scoliosis; prognosis depends mainly on age of trauma. At an age below ten years a severe scoliosis must be expected. Level of lesion plays no important role; in sagittal plane we se very often a long thoracolumbar kyphosis; brace treatment cannot stop the progression in general *(Lancourt et a1.1981.)*

Scoliosis in arthrogyposis

Scoliosis incidence in arthrogryposis is 20% *(Herron et a1.1978);* most curves are long thoracolumbar with lumbar hyperlordosis, including the pelvis. Main problems are hip flexion contractures, the early beginning rigidity of the scoliotic curve and severe and fast progression. In some cases structural thoracic curves can be caused by congenital anomalies; the treatment in these cases must be according the principles of congenital deformities, eventually by anterior resection (*Leatherman und Dickson 1979).* To treat rigid curves the long thoracolumbar scoliosis also should be operated from anterior and posterior. There are very often pulmonal problems in arthrogryposis.

Scoliosis in Duchenne muscular dystrophy

Spinal deformitis are rare in the time of walking capacity, but begin very often at the end of this disease period, first as mobile lumbar hyperlordosis by weakness of gluteal max. muscle. As long as the patient can still walk, a brace is contraproductive *(Shapiro und Bresnan 1982).*

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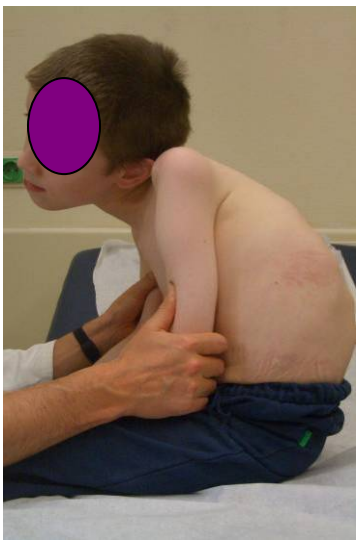
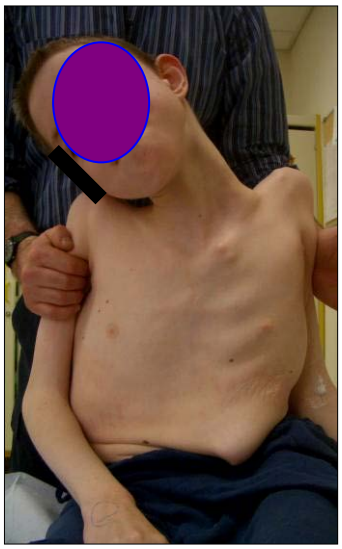


Death is caused by breath insuffency by the musle weakness, but also by concomitant cardiomyopathy and progressive scoliosis. In the wheelchair-period >90% develop a progressive scoliosis *(Galasko and Dettaney 1995).* Although progression can be decreased by brace or special sitting chairs *(Readet al|. 1983*), an early operative fusion at the beginning of the wheelchair-period is indicated to avoid a fast decrease of lung function; a comparative study of fused and not operated patients demonstrates a high significantly decreased lung function without fusion and a much higher rate of early died patients in this group after 5 years (79% versus 44%, *Galasko und Delenay 1995).*

In early operation posterior fusion and instrumentation is sufficient . With a vital capacity<30% operation is contraindicated *(Gibson et aL. 1978).* Preoperatively exact lung function analysis including arterial blood gases, a clotting status and an exact cardial analysis because of the possible cardiomyopathia are essential. According to contractile dysfunction and unsufficient closure of intramuscular vessels contributed to the weakness and fibrosation of muscles blood loss can be seriously increased! Concomitant osteoporosis also can cause intraoperative problems.

Patients with Duchenne-muscular dystrophy may develop a malign hyperthermia with fatal end! A triggerfree technique of anaesthesia should therefore be obligatory, at the first signs of malign hyperthermia Dantrolene is the therapeutic antidot can *(Forst et al. 1991).*

In less severe forms of muscular dystrophy (Becker, extremity type) one should be aware, that in patients with a certain grade of of hyperlordosis and trendellenburg-limping fusion may decrease the walking capability. In uncertain cases a temporarily worn brace can imitate fusion.

Rett-syndrome

Children learn to walk, but not to speak. Scoliosis in Rett-syndrome can be seen as neurogenic curve. Deformity starts earlier and shows more progression than idiopathic scoliosis and the majority of other neurogenic deformities. Early hypotonia, weakness muscular insufficience are the signs of bad prognosis *(Lidström et al. 1993).*

Conservative treatment

In general paralytic deformity is no good indication for conservative therapy, because of disturbed muscular function, the severe tendency of progression and partially also because of loss of sensibility and higher danger of pressure sore.

In englishspeaking countries sometimes the Milwaukee-brace is used, *(Bradford und Hu 1995),* in Europe more often the Cheneau-brace *(Cheneau und Gaubert 1986).* Especially in higher-graded curves the Bending-brace *(Lukeschitsch and Meznik)* has a rather good effect *(Huber 1994)*.

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It must be hold in mind, that in paralytic deformity a brace-therapy can only show a passive effect; the most important indication for bracing is therefore a later and better time for fusion to perform a spondylodesis appr. at the age of 12 years *(Bunch 1975, Nash 1980).*

In severe cases a special sitting device can lead to „closure" of the facets with decreasing the danger of progression *(Murri)*.

Operative treatment

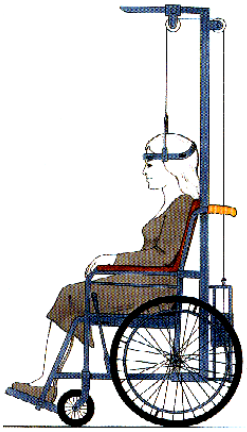
The following techniques, in neurogenic deformity often in combination) are used:
anterior techniques
- discektomy-open or by thoracoscopy
- mobilising anterior osteotomy
- anterior instrumented spondylodesis
- vascularised rib-graft (Bradford)
- fibular strut gruft

posterior techniques
- mobilising posterior osteotomy
- instrumented posterior fusion

combined techniques
- total vertebrectomy (Bradford)

techniques for pelvic fixation or for lumbosacral fixation
- Galveston (Allen and Ferguson)
- Dunn
- Iliac screws
- AxiaLIF

Principles of operative treatment of paralytic scoliosis
Preoperative correction
Pre-extension has lost some importance in the last decade, but still has its place in very severe and/or rigid curves. The effect doesn`t lie as much in improvement of end correction, but in a rather slow and less dangerous correction minimizing neurologic risk and especially improving the preoperative lung function, which makes in some cases operation possible!



Extension is performed in all cases by a Haloring, being fixed appr. 1cm above eye-brows and top of the ears, below the largest circumference of the skull, using four pins. The anterior pins are fixed at the lateral 2/3 of the eye-brows, laterally of the supraorbital nerve and medial of the temporal artery, the posterior pins 1cm above and behind of the ears. Distance of ring to head should be 1-2cm.
Today mostly Halo-wheelchair extension is used with an extension force up to 20 kilopond ; during night the head-part of the bed is raised and extension reduced for one third *(Scheier and Grob 1990).*

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A neurologic control must be done daily (eye movements, facial nerve by showing teeth and closing eyes, hypoglossic nerve by showing the tongue, mobility of arms and legs).
Halo-Pelvic traction *(O´Brien et al. 1973)* can have severe complications (infections of pelvic region, severe degenerative changes in cervical spine) and has lost importance.

Plan of treatment

preparations
1) essential x-rays
   total spine C7-sacrum including hip joints pa (reduction of dosage for mamma) and lateral)
   (in paralytic curves often in sitting position))
   extension-x-rays pa and lateral
   bending-films to convexity and concavity.
2) preparing investigations
   lung function
   cardiologic investigation (muscular dystrophy, Friedreich)
   preoperative treatment with bronchial dilatators, bronchial toilette *(Winter 1994*)
   preoperative mask breathing (muscular dystrophy-*Bradford und Hu*)
   preoperative hyperalimentation in katabolic nutrition status
4) preextension with Halo
5) reduction of intra-und postoperative blood transfusions by patients blood
   isovolaemic acute hemodilution
   correcte positioning with free abdomen (scoliosis frame)
   controled hypotension
   autotransfusion by Cellsaver
   Erythropoietin
   evtl. change of antiepileptic drugs (valproin acid)
6) evoked potentials
7) double-tube intubation can lead to collaps of one lung and make the transthoracic approach easier
8) planning operation

In rather light and mobile curves without inclusion of pelvis poster instrumentation and fusion is sufficient. According to the rule of Harrington upper and lower end vertebra of fusion shall be within the „stable zone“ , that is the zone between the vertical lines between the joints L5/S1*(Harrington 1962).* With the modern segmental implant systems fusion and instrumentation can be shorter (end vertebra or one vertebra caudal). Using segmental stabilisation aftertreatment can be without brace.

If an early operation some years before the end of the growth period is necessary, it must be hold in mind, that also in neuromuscular scoliosis a posterior fusion mass can grow again into deformity including more rotation because the growth potential of the vertebral bodies (Crankshaft-phenomenon, *Jackson et al. 1993).* Should therefore a fusion be necessary at Risser 0 or 1, an additional anterior fusion with destruction of ring apophyses must be performed before posterior instrumentation. In rigid long curves the first step should be a discectomy with anterior bony fusion by anterior approach (thoracophrenolumbotomia). A possible alternative to open discectomy is the videoscopic assisted discectomy with 4 small incisions and the possibility to remove up to 8 discs. The less morbidity of this operation makes the posterior instrumentation easier if performed as single operation. In patients with good pulmonal and cardial state a posterior fusion can also be performed after open discectomy on one day *(Powell et al. 1994).*

As an alternative after discectomy an anterior correction and instrumentation can be added by compression, in most cases from end-to-end vertebra. Advantage is a good correction and derotation, disadvantage the impossibility to instrument down to the sacrum and to higher stress of the to the caudal segments. Using a rather non-rigid anterior instrumentation (ventral derotation spondylodesis, Zielke) we could show, that after posterior instrumentation one week later 10% of additional correction was possible *(Lack et al. 1993).*

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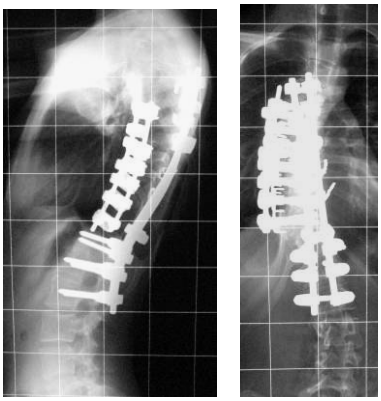

In anterior instrumentation structural grafts should be given into the thoracolumbar disc-spaces to avoid kyphosation.

An important indication for anterior instrumentation and fusion is myelodysplasia with missing posterior elements.

In cases of bony fusions, secondary fused facets or ribs may prevent a sufficient correction; this is only possible after osteotomy at disc level or between the pedicles. In severe cases an osteotomy in several levels is necessary. If it is not possible to get a sufficient correction in spite of the osteotomies, an intercurrent Halo extension can be done before the definite spondylodesis.

In extremely rigid curves discectomy or osteotomy cannot correct in a sufficient way. In those cases complete vertebrectomy (Bradford) can be the solution. In a first step vertebral bodies of the apex are prepared; with a chisel from 2-3 vertebral bodies a part consisting of cortical bone, periost and annulus fibrosus is lifted, cancellous bone is removed, the pedicles are resected; cancellous removed bone particles are filled on the posterior longitudinal ligament and the cortical bone and periost closed again. 2 weeks later the corresponding posterior parts including the dorsal rib parts are removed and a posterior instrumentation and fusion is added.

In case of remaining kyphosis after a fusion an anterior strut graft must be performed. An ideal technique is the vascularized rib (Bradford). By leaving the vascular bundle at the prepared rib graft osseous integration is possible within 2 months. Approach is transthoracic at the concave side, the rib is prepared keeping the vascular bundle and the adjacent intercostal muscles; the rib is parted at the costal angle sparing cautiously the vessels, which are prepared to the foramen. Now the rib can be put into the vertebral bodies to make an anterior-concavsided strut-graft.

Alternatively and for longer strut grafts fibula can be used; without vascularisation osseous integration takes much longer, in some cases after appr. 10 months a fracture of the graft can occur.

In conclusion *Bradford und Hu* see the following indications for a previous anterior approach:

1. contract pelvic obliquity
2. structural kyphosis> 70°
3. rigid scoliosis> 80° with flexibility<50%
4. inacceptable high risk of pseudarthrosis (adult scoliosis with fusion down to the sacrum
5. risk of Crankshaft-phenomenon

Principles of instrumentation

In dorsal instrumentation fixation between rods and spine can be done by hooks, wires and pedicle screws.

hooks

lamina hooks
pedicle hooks
transverse process hooks
Hooks can be closed (at the end of instrumentation) or open.

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By combination of two hooks in the same or in adjacent segment (claw) a very tight anchor to the spine can be built, for instance lamino-transversal claw; claws are specially used at the upper end of instrumentations with closed hooks.

pedicle screws

Pedicle screws are the most important implants in scoliosis surgery, especially in the lumbar region, but more and more also as thoracic screws. In the apex region with severe rotation the implantation can be difficult and, if the position is not really correct, in correction maneuvers neurologically dangerous. Pedicle screws can resist distraction, compression and derotational forces, but less against extrusion; in kyphotic curves additional safety can be reached by combination with sublaminar wires or additional laminar hooks

wires

sublaminar wires
subpars-wires (drawn from sublaminar position laterally under the joint process)
spinous process wires (drawn through the base of spinous process)
titanium cables *(Songer et al. 1991*).

In paralytic scoliosis there are very often high pull-out forces, therefore strong implants (double wires or titanium cables) are advisable. Concavesided wires are perfect for scoliosis-correction by translation and kyphosis correction, as the rod can be drawn to the segmentally implanted wires. They make no sense at the end of the instrumentation. Sublaminar wires cannot derotate, subpars-wires make a slight derotation.

In general long and flexible curves are better corrected by translation, short angular deformities by distraction.

The rods should be connected by 2 transverse connectors to make a stable frame correction.

Pelvic fixation

Galveston technique
Dunn technique
Iliac screws
AxiaLIF
(sacral screws)

Biomechanic investigations show the implantation of additional sacral 2 to S1 screws as the weakest possibility *(Camp et aL. 1990).* Gold standard for pelvic fixation is the Galveston technique; rods are bent, so that they can be inserted 6-8cm into the pelvis from the posterior spine between outer and inner cortical bone. Exact entry point is at the lower edge of posterior iliac spine at the level of S2. Bending of rods is rather difficult, a certain blood loss from the pelvis may not be underestimated. Alternatively iliac screws can be used.

A new technique of additional lumbosacral fixation of long distance fusions is AxiaLIF (axial intercorporal lumbosacral fusion). In this percutaneous technique a screw is implanted from the anterior sacrum into the fifth lumbar vertebra with removing the disc by special instruments and filled

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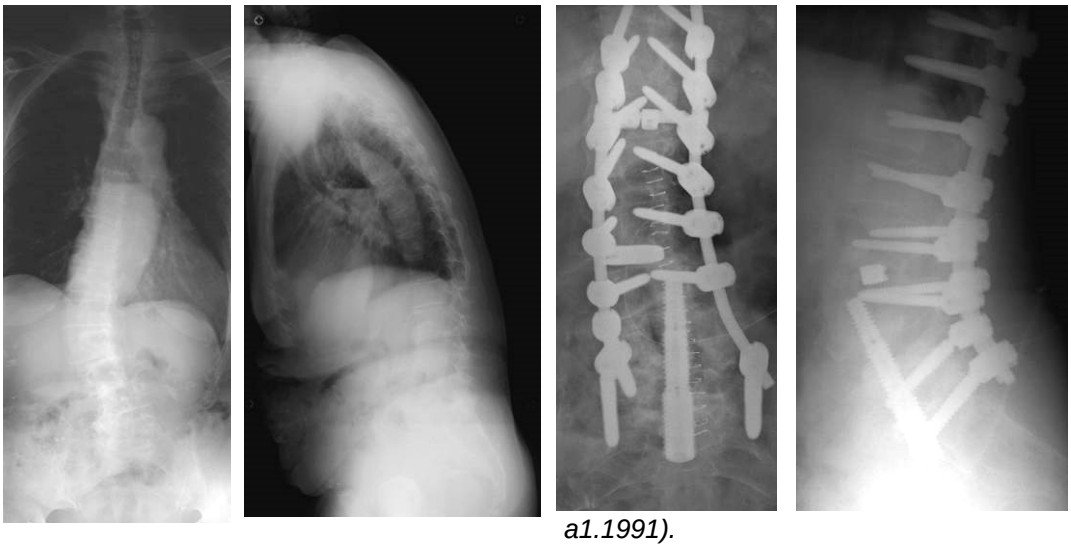
with bone material to get an osseous intercorporal fusion. This technique gives a very good additional stability of the lumbosacral segment in long distance fusions (*Lack et al. 2010).*

Fixation technique of Dunn uses bent rods at the anterior sacrum in correction and fusion of lumbar kyphosis in myelodysplasia *(Bauer et a1.1991).*

Sagittal bending of rods should follow physiology: there is a straight part of the spine between Th11 and L1, kyphosis cranially is increasing as lordosis caudally. The most posterior level is Th5/6, the most anterior level L3/4 *(Asher et a1.1991).*



Treatment of pelvic obliquity in paralytic scoliosis

Pelvic obliquity can be caused by leg length difference, ab-or adduction contracture of hip joint or structural scoliosis. In paralytic scoliosis all of these causes can play a role. Causes must be evaluated and treated carefully, contractures by release of tractus iliotibialis or adductors; pelvic obliquity by scoliosis fusion down to the pelvis; contractures should be released before spinal fusion.

According to *Winter und Pinto* a spondylodesis down to L4 or L5 in case of pelvic obliquity has never a real success.
In case of hip (sub)luxation scoliosis should be treated first *(Winter und Pinto 1986).*

Results

Authors report with posterior spondylodesis an average scoliosis correction of 50% (*Luque 1989*-5o%, *Swank et al*. with SSI 53%, *Metz and Zielke 1982* with SSI 47%, *Hopf et al*. with CD 51%, *Halm et al*. *1995* with CD 50%). In combined anterior-posterior fusion average correction is 60% (*Brown et al. 1982* with Dwyer and Harrington 60%, *Liljenquist et al*. 1996 with VDS and Munster posterior double rod system 64%).

Operations at the growing skeleton

In severe and/or progressive deformities during growth danger of Crankshaft-phenomenon (progression of curve in spite of bony fusion) exists. At end of growth combined anterior-posterior fusion can prevent Crankshaft; the modern segmental posterior instrumentation can „overpower“ the Crankshaft.

In severe curves up to the age of 10 years definitive fusion is not indicated; some techniques were developed to allow correction without fusion. “Growing rods”, to be distracted after appr.6 months, try to allow correction without fusion till the end of growth (“Zielke-Ascani”, “Luque-trolley”). There are some disadvantages of these techniques: increasing rigidity of curves, early fusion, especially at the end of the curves, missing correction of sagittal deformity, danger of implant luxation, increased infection rate by instability.

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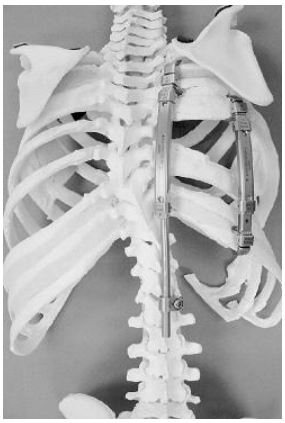
A new principle is VEPTR-technique (vertical expandable vertebral prosthetic rib), with distraction between concavesided ribs or between ribs and iliac crest. Distraction after 6 months is necessary as in the techniques of growing rods. Advantages are improvement of thoracic chest deformity with possible improvement of lung function, correction of pelvic obliquity and lower grade of rigidity. Unfortunately in this technique the rate of complications is rather high too: pressure sores, luxations, infections, junctional kyphosis cranially.



Complications

Correction of paralytic scoliosis has a relatively high complication rate caused by reduced lung function, duration of operations and special morbidities (cardiomyopathy in Duchenne, Friedreich..). In severe reduced lung function preoperative breathing therapy, Halo-extension and evtl. preoperative tracheostoma may be necessary *(Scheier und Grob 1990*).

Percentage of letal complications in scoliosis surgery is small (0,43% in a study of the“groupe d`etude de la scoliose, *Du Peloux et al. 1970),* but can increase in severe scoliosis and higher age (5,6% , *Stagnara et al.*
1970).

Best prophylaxis of severe and letal complications is an early operation

The most severe complication besides of death in scoliosis surgery is irreversible paraplegia, in most cases caused by reduced vascularisation of the medulla (distraction, but extremely rare by direct trauma of the medulla). Using sublaminar wires distraction should be avoided before translation correction!

Percentage of severe neurologic complications (incomplete or complete paraplegia) is given with 0,73% in scoliosis correction using Harrington device in a study of Scoliosis Research Society *(MacEwen et al, 1975*). The authors believe in a higher incidence. Risk is increased by pre-existing neurologic damage, kyphosis and severe scoliosis.

As important prophylaxis of neurologic damage the "Wake-up-Test" (Stagnara) is still valuable *(Vauzelle et al.1973).* The wake-up test has the disadvantage of being performed at the end of instrumentation, so that traumas of the medulla in previous parts of the operation may not be recognized. It is important to make this test at least 10 minutes after the end of correction, otherwise false positive results could be seen *(Zielke and Pellin 1975).*

There are different techniques of „Spinal Cord Monitoring". Spinal Cord Monitoring can be performed either as somato-sensoric evoked potentials (SSEP), motoric evoked potentials (MEP) or neurogenic motor evoked potentials (NMEP) *(Krismer and Bauer 1991).*

Hematothorax and/or hematopneumothorax can follow transthoracic operations and posterior operations with rib resection or osteotomy. A thoracal drainage is necessary.

The so-called "Cast-Syndrom" (Spinal Traction Syndrome) is a less known complication of scoliosis surgery. Symptoms are vomiting, nausea and (sub) ileus. As a cause on the one hand mechanic compression of the duodenum by the superior mesenteric artery, on the other hand functional

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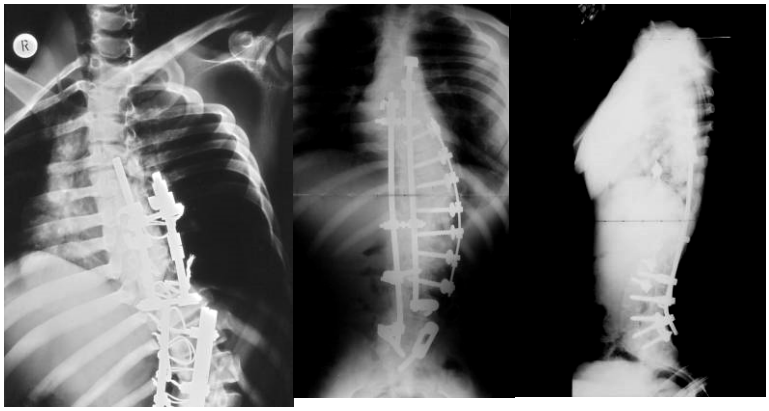
disturbance of intestine motility by distraction of splanchnical nerves are discussed. Prophylaxis can be 3-days of parenteral nutrition after spondylodesis and avoiding of intestine-motility reducing drugs as opiates *(Meznik et al. 1978*). A conservative treatment with correction of electrolytes, fluids and the medication with parasympathicomimetics is recommended.

Risk of infection in operation of neurogenic deformities is relatively high according long duration of operation and the often reduced internal status. In deep wound infection an early revision with debridement and suction drainage is indicated, leaving the implants in situ, as stability seems to have a positive influence to infection. In some cases repeated debridements may be necessary.

The percentage of implant failure and pseudarthrosis is higher in neurogenic deformity than in other forms of scoliosis, caused by less muscular stabilisation, worse vascularisation of bone because of paretic muscles, the poor osseous quality of the pelvis as place of transplanted bone material and the high mechanical force on the spondylodesis *(Scheier und Grob 1990*). Posterior spondylodesis alone in Polio has a risk of pseudarthrosis of 30% *(Bonnet et al. 1975).* Fractures of the rods need not necessarily demonstrate pseudarthrosis, especially kyphoscoliosis can cause fatigue fractures of the rods even after fusion.

A definite pseudarthrosis requires revision with refreshment of fusion mass and reinstrumentation, eventually with additional anterior fusion.



In revision-cases the complete fusion mass must be prepared cautiously and investigated for mobile pseudarthrosis. According our own experiences in suspicion of pseudarthrosis the operative revision is the only method to make diagnosis certain, as scintigraphy and functional x-rays are not really valuable; the best radiologic technique is thin-sliced CT, but has a high radiation dosage for the patient. If a severe loss of correction takes place, an osteotomy may be necessary.

In anterior operations in a group of 1223 patients a direct complication rate of 11.5% is described *(Faciszewski et al. 1995).* Severe complications seem to be very rare *(Zielke 1983*-death 0,3%, paraplegia 0,2%, deep wound infection 0,6%*)*. As an approach-specific problem lung atelectasis, hemo-and/or hemato-pneumothorax and very rarely chylothorax by lesion of ductus thoracicus in left-sided thoracotomy can occur. *Nakai and Zielke 1986* recommend in case of chylothorax at least 3 weeks conservative treatment with drainage. Especially preparation in lumbar levels may cause a lesion of the sympathetic chain with hyperthermia of the leg; interestingly most patients complain of cold feeling in the “healthy” leg!
Very rare are abdominal herniations, lesions of big vessels, of the lumbar nerve plexus or of the ureter.

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