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Artificial intervertebral components for adolescent idiopathic scoliosis and physiotherapeutic approach

Master thesis

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I dedicate this thesis to my parents, my brother and sister and to all the family members which have been supportive to me throughout my studies. I also thank my friends and my supervisor prof. Stanislav Otahal.
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DECLARATION

This master thesis has been written by myself with the use of the list of literature which is attached.

SIGNATURE

Michalis Playbell

SUMMARY

The aim of this thesis was to discuss new surgical approaches of spinal artificial intervetebral components used for AIS and give some ideas for further research on physiotherapeutical approaches to this. The method used was a critical review and I have used many journals, through the Charles University access to medical journals. I have found around a hundred and twenty articles related to this problem directly or indirectly. By comparing contents of these articles I conclude that new technologies bring to the problem new aspects and these aspects are connected with updating the physiotherapeutic approach. I can conclude that it's possible to use a traditional physiotherapeutic approach for now, until further research has been done with specific treatment methods on patients.

CONTENTS

KEY WORDS: Scoloisis; trunk deformation, spine shape, implants, operation techniques, exercise, physiotherapy, examination

CHAPTER 1

1.1 Definition of problem:

The problem is each implant, technology leads to typical changes in the dynamics of the spine, so it needs special Physiotherapy or Rehabilitation approach. There exists such a special approach to this. There are two questions risen. Is there such an approach to rehabilitation practice and second is this physiotherapeutic practice intuitive by this work; is there a positive result of analysis biomechanically. Partial problems that come to this great problem connect with type of scoliosis, type of instrument, age of patient and all clinical complications which come to this problem i.e diabetes, pulmonary disorders.

1.2 New technology comes to clinic

Treatment choice in adolescent idiopathic scoliosis is determined by a complex equation which includes the patient's physiologic (not chronologic) maturity, curve magnitude and location and potential for progression. Thoracic curves are at higher risk for progression than thoracolumbar curves or lumbar curves. Patients whose curves are of consequential magnitude prior to onset of their adolescent growth spurt are at significant risk for curve progression. Treatment options include observation, bracing or surgery. General guidelines include re-evaluation every 4-6 months (often including a PA erect T-L spine radiograph) for patients who are skeletally immature (but still not fully skeletally mature) and have curves less than 25° . In patients who are more skeletally mature with curves less than 45° similar observation should be carried out to assess any evidence of interval change at 6 months. (Review on scoliosis AIS treatment in Spine Universe 2007)

Brace (orthotic) management of adolescent idiopathic scoliosis is used in children with spinal deformity and curve magnitudes of 25-40° who are skeletally immature and with significant growth remaining. The primary goal of brace management is to stop curve progression. Any amount of curve correction at the end of brace treatment must be considered a "bonus." (Review on scoliosis AIS treatment, in Spine Universe, 2007)

The orthoses used are usually underarm or higher reaching Milwaukee-type styles (fig.1). The type of braces and amount of time the braces are worn daily vary according to the orthopaedist's choice. (fig.2). Mileaukee is bad for physiotherapy, there is no exercise possible and no compensation for bracing. Charleston is only used during night time, there is space for whole day to apply physiotherapeutic methods. (Otahal, 2008)

Dynamic corrective spinal brace **Cerny** (DCSB Cerny fig.3) is a new original type of spinal brace, which is used for treatment of spinal deformities (scoliosis) in both of the planes frontal and sagital and had modifications possible. This brace effectively affects thorax scoliosis curves, classified according to King (with advantage King III and II, often King I and V). The correcting efficiency of this brace is fairly so high as the efficiency of the rigid braces. Moreover this type allows in a great extent the spine movements in thoracolumbal and lumbal area. There is thus achieved the highest correction of the spine curve (scoliosis) in the case of the inclination to the convexity of the curve. This is widely used with the active rehabilitation and positioning. There is possible an appropriate motion in the flexion and extension of the lumbar spine.

Advantages: The correction of the common curves is on the same level as by application of the classical spinal brace according to Cheneau. DCSB Cerny does not create any decompensation of scoliosis. With DCSB Cerny is minimised the trunk muscle hypotrophy and the spinal rigidity. DCSB Cerny is much more acceptable for the patient - it is better aired , it causes less limits for daily activities.

Requirements: Appropriate maintenance.

DCSB Cerny enables the connection of physiotherapeutical effects of daily activities with the biomechanical orthotic effects on the pathological spinal curves. It creates ideal conditions for the intensive remodelation of the whole spinal skeleton.

Dynamic corrective spinal brace **Kosteas** (DCSB Kosteas fig.4) is a new original type of spinal brace, which is used for treatment of spinal deformities (scoliosis) in frontal plane. There is possible an appropriate motion in the flexion and extension of the thoracolumbal and lumbal spine. DCSB Kosteas easier provides for daily activities sitting people with scoliosis. Orthose is in patent process.

Corrective spinal brace **Cheneau** is a classical rigid corset for treatment of scoliosis. Cheneau corset (first type) usefully substitute all types of other rigid corrective spinal braces (Boston, CBW, NYOH, Milwaukee, Cuxhaven, Stagnara, Hannover ...).

Corrective reclination spinal brace **Gschwend** (fig.5 modif. ORTOTIKA) can efficiency correct harmfull spine curves in sagital planes, as thoracic hyperkyphosis, lumbar hyperlordosis and both curves together, it is used for example by m. Scheuermann, by osteoporosis, past laminectomy ... Beside Jewett orthosis can stabilize fractures over stages of thoracic spine. It is possible to make cervical collar for safe stability of C-Th spine or cervical spine.

Lumbar plastics (fig.6) brace heartily fixes lower column of spine (Th-L and L area). Lumbar orthose with subclavian pads we could fix all of thoracic and lumbar area of spine. Subclavian part is unstrapped.

Lastly **Cervical orthoses** (fig.7) without/with thoracic piece. This modification is effective for stabilization C, C-Th and upper Th of the spine.

(Review of Spinal Braces, November 2006)

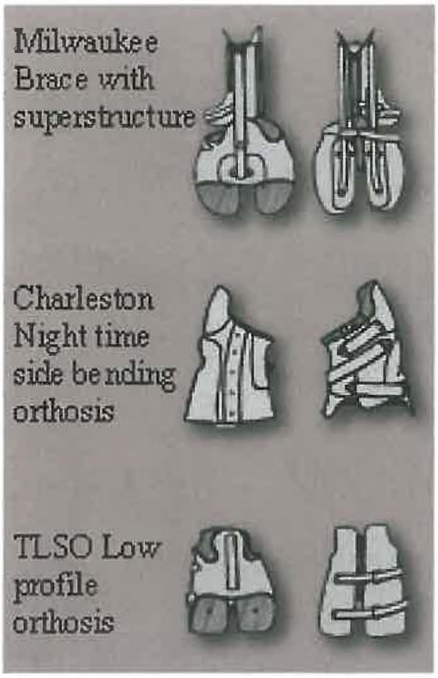


Fig.1 Brace types (http://www.spineuniverse.com/displayarticle.php/article1507.html)

Fig.2 Radiograph of a patient with AIS undergoing brace treatment
(http://www.spineuniverse.com/displayarticle.php/article1507.html)

Fig.3 Cerny (http://www.ortotika.cz/scoliosis.htm)

Fig3a (http://www.ortotika.cz/scoliosis.htm)

Cerny modification

By small and flexible lumbar curves without significant thoracic curves can be used a short modification of the brace Cerny for scoliosis. On the pictures right is one from some possible variant of this short brace (without lumbar pad), it is used for curves with culmination in Th-L area.

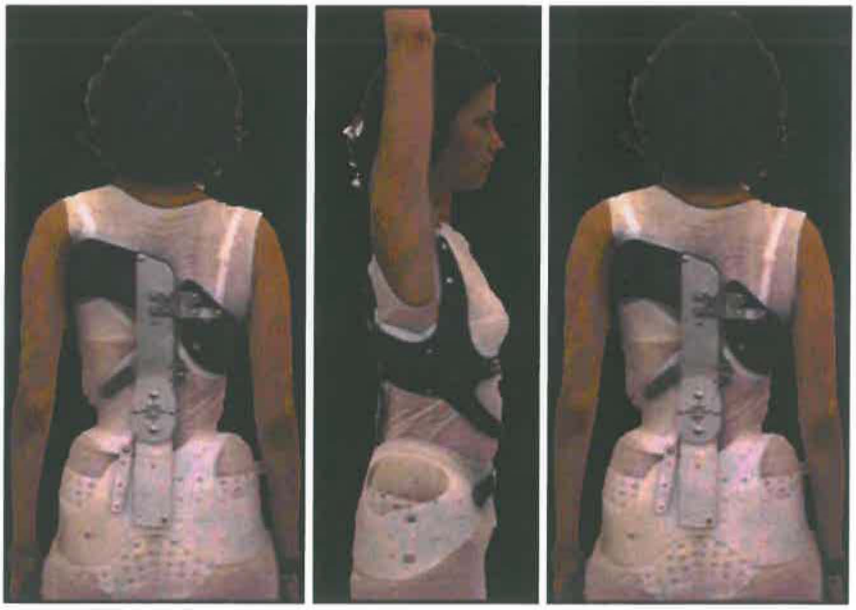


Fig3b (http://www.ortotika.cz/scoliosis.htm)

Modification of Cerny brace

Some segments are possible to make from cabon composite. The brace is lighter and harder.

Fig.4 Kosteas (http://www.ortotika.cz/scoliosis.htm)

Fig.5 Gschwend (http://www.ortotika.cz/scoliosis.htm)

Fig.6 Lumbar plastics (http://www.ortotika.cz/scoliosis.htm)

Fig.7 Cervical orthoses (http://www.ortotika.cz/scoliosis.htm)

Brace removal for participation in sports is strongly encouraged. An alternative to full-time brace wear is the use of a night time "bending" brace for management of a single curve. The termination of successful brace use is determined by the achievement of skeletal maturation, usually indicated by the patient not having further changes in height (and no curve progression) and evidence of maturity on skeletal radiographs.

Surgery for idiopathic scoliosis is suggested when curve magnitude is 50° or more in either the previously untreated patient or in one who fails brace treatment. That could be because the brace wasn't worn properly—for example, it wasn't worn tightly enough or for the right amount of time. However, in some cases, even a child who has been a good brace wearer and has followed the doctor's recommendations exactly will have a curve that progresses. This is not the child's fault.

(Review on scoliosis AIS treatment, in Spine Universe, 2007)

Surgery is undertaken with two goals in mind. The primary one is to prevent spine deformity progression and the secondary one is to diminish spinal deformity. The goal of spine surgery for scoliosis is to stop the curve from getting worse, restore the spine to a more normal alignment and appearance, and also to address any back pain or heart or lung function problems caused by the scoliosis.

With current instrumentation techniques, post-operative casting and bracing are not required in most idiopathic scoliosis cases. Patients are rapidly ambulatory and usually discharged from hospital within 5-7 days postoperatively with progressive resumption of routine daily activities, including return to school (also mentioned in the next paragraphs). (Review on scoliosis AIS treatment, in Spine Universe, 2007)

However, the older you are, the riskier the surgery is. Compared to children, adults are more at risk for post-surgical complications, such as infection and pneumonia. Adults may undergo surgery for scoliosis for different reasons, especially chronic pain. Unlike scoliosis surgery for children, correcting the curve isn't the most important goal of surgery. Instead, trying to stop the curve from getting worse later is the main goal.

To **prepare** for and plan the scoliosis surgery, the surgeon will consider:

- the number of curves
- where the curve is
- how severe the curve is
- how old you are

Your surgeon will decide which surgical approach (posterior, anterior, anterior-posterior, or minimally invasive) is best based on several factors, including the curve severity and the spinal instrumentation needed. Imaging methods will be used also (mentioned later).

As with any operation, there are risks involved with scoliosis surgery. Your surgeon will discuss potential risks with you before asking you to sign a surgical consent form. Possible complications include, but are not limited to:

- non-healing of the bony fusion (pseudoarthrosis)
- failure to improve
- instrumentation breakage/failure
- infection and/or bone graft site pain
- blood clots in the lungs
- injury to the spinal cord and/or nerves

Post-operation care

After scoliosis surgery, the child won't instantly be better and your curve won't instantly look better. He or she will most likely be out of bed within 24 hours on pain medications for 2 to 4 weeks. The incision should heal in at least 7 to 14 days, and the fusion should completely heal in at least 6 to 9 months.

In the meantime, the curve may even get slightly worse as the fusion settles in and the spine readjusts. Around six months, though, you should see improvement. As the fusion takes place, the child should avoid any heavy lifting, bending, or twisting. Exercise is all right as long as the spine is kept stable-that means no contact sports until the fusion is completely healed. After the child has healed and the surgeon says it's okay, he or she will most likely be able to play again.

(Surgery for scoliosis, in Spine Universe, 2008)

From the **physiotherapy** point of view we must be careful in flexion, extension movements and bending movements of the spine which are higher during walking. Exercises in laying position or underwater have the least stress on the spine and are more recommended. Important is to maintain rotations which are necessary for walking (Vele, 2008).

The basic principles for scoliosis surgery learned during the Harrington rod era are still valid today. Experience has confirmed the need for careful selection of the vertebrae to be instrumented, the value of anterior release for rigid curves in imparting convertibility of the deformity, and the importance of careful fusion techniques. During the last two decades, further development has occurred because of an increased knowledge of the biomechanical needs for the internally instrumented spine and a three-dimensional appreciation of the scoliotic curve. Biomechanical advances have centered on an understanding of the load-sharing properties afforded by the multiple spinal purchase sites (segmental spinal instrumentation) and the value of two-rod systems linked by couplers. These advances have provided an increased stiffness of the instrumental spine, a reduction in correction loss, improved fatigue properties of the implant, and fewer pseudarthroses. The most important advance of the last decade is an improved awareness of the three-dimensional approach to the scoliotic deformity with the need to preserve or improve sagittal contours. In particular, the importance of the loss of normal thoracic kyphosis or lumbar lordosis has been emphasized. These conceptual gains have led to the development of many new instrument systems to correct deformity. Each is associated with advantages, problems, and risks that must be understood to make intelligent choices for treatment. (Drummond DS. 1991)

The implantation techniques for treatment of idiopathic scoliosis are as follows (discussed further in detail):

1. Posterior instrumentation and spinal fusion
2. Anterior instrumentation and arthrodesis
3. Anterior spinal release
4. Thoracoplasty (not discussed here)

(Review of orthopaedic surgery, idiopathic scoliosis: surgical options, in The chidrens Hospital of Philadelphia, Jan 2008)

There is a vision of new trends, but nobody knows which stream will come to practice. Iron and titan implants are losing popularity because they are expensive, very difficult to use such elements on individual usage. Polycarbonates and polymers are also very complicated for preparation. Nanotechnology and artificial-natural tissues are yet a distant glance to the future. Engineering chondrocytes will produce new trends in physiotherapy but still it is yet early. Generally speaking, these new technologies will press engineers to prepare new elements and physiotherapy has to find new ways to work with it. (Otahal, 2008)

1.3 The problem needs for development of new approaches to physiotherapy for caring after operation

One major problem in all implantations is tensile stress or share stress, such as in cages, Prodisc (lumbosacral total disc replacement) (Jack Zigler, 2005), Charite (The worlds first artificial disc, in charitedisc.com, 2007), hydroxyapatite (Hydroxyapatite-coated screws designed for spine implants, In highbeam.com, 2008)

(coated screws that provide stabilization of spinal segments as an adjunct to fusion) and Prestige screw fixations (Prestige Cervical Disc system-P060018, In fda.gov, 2007). This type of stress produces some biological changes connected with distribution with cell combinating biofluids. If tensile stress is concentrated, we must be careful doing any sharp or sudden movements at the end range of motion (Caharite). They must be done slowly. (Otahal, 2008, Steven M. Kurtz, 2006)

In the screw fixation designs for example stress concentrates on the plate. Concentration is divided to two parts- In the end and on the screw. There is a reaction of the spongy bone to leave the space around and lose connections. We must be careful in rehabilitation wth the range of flexibility and the speed of movement.

In the ProDisc-C implant (cervical) (Prodisc C, in synthesprodisc.com, 2007) there is a mistake, that it allows movement and flexibility is great, but in extreme positions there is great stress in slippery forces. We have to work carefully with this model. Also important are the type of materials, ie. Polymers are flexible and more adaptable to forces, this pressure changes shape in extension.

Fixation loses flexibility. Every correction is nearly every time connected with loss of flexibility. For rehabilitation, the problem of losing mobility is connected extremely with growth of dangerous loading of plates. Rods are usually placed on vertebrae of thoracic and lumbar spine, loss of mobility is connected with loss of mobility of vertebral (spina) canal in this case. This is connected to cauda equina region, resulting in some dysfunctions with root nerve system. These aspects of mobility mistakes usually come to attention after surgery. (Otahal, 2008, Steven M. Kurtz, 2006)

Spinal canal contains cerebrospinal fluid important in logistics; there is only one way how to support nutrition of the spine. Also volume information which cell structure needs of central nervous system. Not all information are transmitted by synaptic way. Blood brain barrier blocks direct connection of supply of this structure. The last distributor is cerebrospinal fluid. Cerebrospinal fluid is a fluid with it's own dynamics and propulsion; three motions of CSF:

- Hard pressure
- Breathing
- Movement

In the tube formed by the spinal system, when there is movement the CSF is pressed to space. All strategy tools based on elimination of movement produced and is a secondary block of this principle. This principle is accompanied with pain, discomfort and degeneration of the spine.

In scoliosis rod system there is a rubbery rough elimination of movement. Intervertebral mobility is an expensive loss for the human body and we want to find a way in rehabilitation to compensate for this loss of mobility. Also scoliosis is connected with pelvis; L5-S1 declination of sacrum is visible. Correction between pelvis, lumbar part is needed in that case.

Between Th7-L2 transit stiffness is changed by ribs and there is stiffness of muscles and intra-abdominal pressure. Two forces are connected together, thoracal musculature and intrathoracal musulature. There is an effect of intra-abdominal pressure and intrathoracal pressure(from respiration). There is an effect of muscles in abdominal wall (transversus abdominis, external-internal obliques, diaphragm) and upper part of thoracal muscles i.e pectoral muscles, latissumus dorsi. There is also an effect of scoliosis ie.gybus on dorsal wall is mostly created in region Th7-L3 and curvature is changing from convex to concave and it is important for physiotherapy. (Otahal, 2008)

In an article about loads on an internal spinal fixation device during physical therapy some interesting facts were found. The highest implant loads were during walking, where the highest bending moments were present. Also high fixation loads were during ventral flexion and extension of the upper body during standing (if the distance between upper and lower screws was increased during surgery). Kneeling on hands and knees and performing flexion and extension of the back in this position caused decreased loads than for standing. Low loads were also in sitting position compared to standing; In sitting position is prohibited flexion and extension. The lowest loads possible are in lying position, where all the exercises would be optimal. It is important to correct rotations of the spine in scoliosis necessary for walkng and a 3d examination of scoliotic spine may be helpful.

Note: It has been noticed in some cases that after implantation breathing problems tend to occur and physiotherapy with breathing exercises to improve function of the airways must be used.

1.4 What the problem is, differentiation and relationship of efficient physiotherapeutic methods to new products and surgery

We have to find such a way of therapy which will be most suitable in the context with these new implants (artificial technology). Connection between artificial-natural brings new problem ie. Mechanical loading because stiff elements decline in time.

We know that there is prohibited rotation and flexion in sitting. Also in the beginning standing is not allowed. Under water exercises where there is dumpng of movement and loading of body is decreased are recommended, muscle strengthening especially abdominal muscles combined with breathing, soft tissue techniques for scars. The physiotherapeutic methods must not stress the spine in any way and respect the biomechanical properties as well as degradations of materials and all these interactions that I mentioned earlier.

Breathing and coughing exercises to rid the lungs of congestion must be performed shortly after the procedure and continued through the recovery process. The patient is usually able to sit up the day after the operation, and most patients can move on their own within a week. A brace may be necessary, depending on the procedure. With the anterior approach in the upper back, patients may have some trouble with activities involving the arms and hands--such as tying shoes and cutting food. In one study, however, occupational therapy using stretching and strengthening exercises allowed for full resumption of daily activities, including dressing, bathing, and grooming, within three months. Patients are often concerned that surgery will stiffen their backs, but most cases of scoliosis affect the upper back, which has only limited movement, so that patients do not notice much difference. It may take a year or more for muscle strength to return. In some cases, the operation cannot completely correct the curve, and one leg may be shorter than the other. Heel lifts may be used in this case.

(Review Report on Scoliosis-Surgery, In about.com, 2008)

CHAPTER 2

2.1 Theoretical aspects of work

2.1.1 Anatomical problem on surgical techniques and theoretical properties

Spinal Anatomy Overview

Functions of the Spine

The three main functions of the spine are to:

- Protect the spinal cord, nerve roots and several of the body's internal organs.
- Provide structural support and balance to maintain an upright posture.
- Enable flexible motion.

Regions of the Spine

Typically, the spine is divided into four main regions: cervical, thoracic, lumbar and sacral. Each region has specific characteristics and functions.

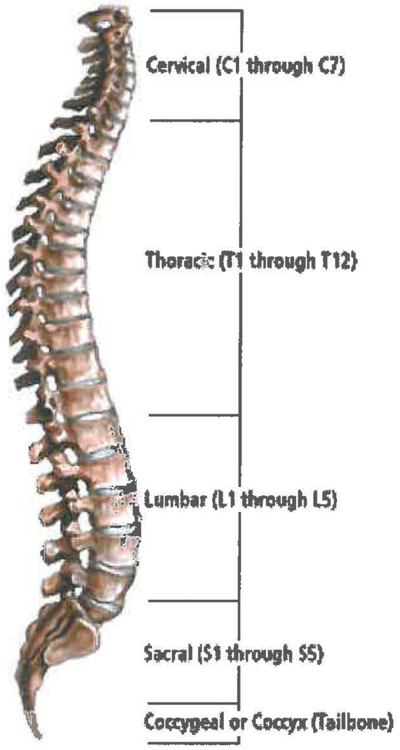


Fig. 8 (Review of Spinal Anatomy, April 2008 In: (http://www.schnipperchiro.com/Spinal_Anatomy.html)

Cervical Spine

The neck region of the spine is known as the Cervical Spine. This region consists of seven vertebrae, which are abbreviated C1 through C7 (top to bottom). These vertebrae protect the brain stem and the spinal cord, support the skull, and allow for a wide range of head movement.

The first cervical vertebra (C1) is called the Atlas. The Atlas is ring-shaped and it supports the skull. C2 is called the Axis. It is circular in shape with a blunt peg-like structure (called the Odontoid Process or "dens") that projects upward into the ring of the Atlas. Together, the Atlas and Axis enable the head to rotate and turn. The other cervical vertebrae (C3 through C7) are shaped like boxes with small spinous processes (finger-like projections) that extend from the back of the vertebrae.

Thoracic Spine

Beneath the last cervical vertebra are the 12 vertebrae of the Thoracic Spine. These are abbreviated T1 through T12 (top to bottom). T1 is the smallest and T12 is the largest thoracic vertebra. The thoracic vertebrae are larger than the cervical bones and have longer spinous processes.

In addition to longer spinous processes, rib attachments add to the thoracic spine's strength. These structures make the thoracic spine more stable than the cervical or lumbar regions. In addition, the rib cage and ligament systems limit the thoracic spine's range of motion and protect many vital organs.

Lumbar Spine

The Lumbar Spine has 5 vertebrae abbreviated L1 through L5 (largest). The size and shape of each lumbar vertebra is designed to carry most of the body's weight. Each structural element of a lumbar vertebra is bigger, wider and broader than similar components in the cervical and thoracic regions.

The lumbar spine has more range of motion than the thoracic spine, but less than the cervical spine. The lumbar facet joints allow for significant flexion and extension movement but limit rotation.

Sacral Spine

The Sacrum is located behind the pelvis. Five bones (abbreviated S1 through S5) fused into a triangular shape, form the sacrum. The sacrum fits between the two hipbones connecting the spine to the pelvis. The last lumbar vertebra (L5) articulates (moves) with the sacrum. Immediately below the sacrum are five additional bones, fused together to form the Coccyx (tailbone).

The Pelvis and the Skull

Although not typically viewed as part of the spine, the pelvis and the skull are anatomic structures that closely inter-relate with the spine, and have a significant impact on the patient's balance.

Spinal Planes

To help further understand and describe the anatomy, spine specialists often refer to specific body planes. A body plane is an imaginary flat, two-dimensional surface that is used to define a particular area of anatomy.

Term	Meaning
Frontal or Coronal Plane	Divides the front and back halves of the entire body.
Median or Sagittal Plane	Divides the left and right sides of the entire body.
Transverse or Axial Plane	Divides the body at the waist (top and bottom halves of the body).

Table 1 (Review of Spinal Anatomy, April 2008)

Spinal Curves

When viewed from the front (Coronal Plane) the healthy spine is straight. (A sideways curve in the spine is known as scoliosis.) When viewed from the side (Sagittal Plane) the mature spine has four distinct curves. These curves are described as being either kyphotic or lordotic.

A kyphotic curve is a convex curve in the spine (i.e. convexity towards the back of the spine). The curves in the thoracic and sacral spine are kyphotic.

A lordotic curve is concave (i.e. concavity towards the back of the spine), and is found in the cervical and lumbar levels of the spine.

Vertebral Structures

All vertebrae consist of the same basic elements, with the exception of the first two cervical vertebrae.

The outer shell of a vertebra is made of cortical bone. This type of bone is dense, solid and strong. Inside each vertebra is cancellous bone, which is weaker than cortical bone and consists of loosely knit structures that look somewhat like a honeycomb. Bone marrow, which forms red blood cells and some types of white blood cells, is found within the cavities of cancellous bone.

Vertebrae consist of the following common elements:

- Verterbral Body: The largest part of a vertebra. If looked at from above it generally has a somewhat oval shape. When looked at from the side, the vertebral body is shaped like an hourglass, being thicker at the ends and thinner in the middle. The body is covered with strong cortical bone, with cancellous bone within.
- Pedicles: These are two short processes, made of strong cortical bone, that protrude from the back of the vertebral body.
- Laminae: Two relatively flat plates of bone that extend from the pedicles on either side and join in the midline.
- Processes: There are three types of processes: articular, transverse and spinous. The processes serve as connection points for ligaments and tendons.

The 4 articular processes link with the articular processes of adjacent vertebrae to form the facet joints. The facet joints, combined with the intervertebral discs, allows for motion in the spine.

The spinous process extends posteriorly from the point where the two laminae join, and acts as a lever to effect motion of the vertebra.

- Endplates: The top (superior) and bottom (inferior) of each vertebral body is “coated” with an endplate. Endplates are complex structures that “blend” into the intervertebral disc and help support the disc.
- Intervertebral Foramen: The pedicles have a small notch on their upper surface and a deep notch on their bottom surface. When the vertebrae are stacked on top of each other the pedicle notches form an area called the intervertebral foramen. This area is of critical importance as the nerve roots exit from the spinal cord through this area to the rest of the body.

Facet Joints

The joints in the spinal column are located posterior to the vertebral body (on the backside). These joints help the spine to bend, twist, and extend in different directions. Although these joints enable movement, they also restrict excessive movement such as hyperextension and hyper-flexion (i.e. whiplash).

Each vertebra has two facet joints. The superior articular facet faces upward and works like a hinge with the inferior articular facet (below).

Like other joints in the body, each facet joint is surrounded by a capsule of connective tissue and produces synovial fluid to nourish and lubricate the joint. The surfaces of the joint are coated with cartilage that helps each joint to move (articulate) smoothly.

Intervertebral Discs

Between each vertebral body is a "cushion" called an intervertebral disc. Each disc absorbs the stress and shock the body incurs during movement and prevents the vertebrae from grinding against one another. The intervertebral discs are the largest structures in the body without a vascular supply. Through osmosis, each disc absorbs needed nutrients.

Each disc is made up of two parts: the annulus fibrosis and the nucleus pulposus.

Annulus Fibrosus

The annulus is a sturdy tire-like structure that encases a gel-like center, the nucleus pulposus. The annulus enhances the spine’s rotational stability and helps to resist compressive stress.

The annulus consists of water and layers of sturdy elastic collagen fibers. The fibers are oriented at different angles horizontally similar to the construction of a radial tire. Collagen gains its strength from strong fibrous bundles of protein that are linked together.

Nucleus Pulposus

The center portion of each intervertebral disc is a filled with a gel-like elastic substance. Together with the annulus fibrosus, the nucleus pulposus transmits stress and weight from vertebra to vertebra.Like the annulus fibrosus, the nucleus pulposus consists of water, collagen and proteoglycans. However, the proportion of these substances in the nucleus pulposus is different. The nucleus contains more water than the annulus.

The Spinal Cord and Nerve Roots

The spinal cord is a slender cylindrical structure about the width of the little finger. The spinal cord begins immediately below the brain stem and extends to the first lumbar vertebra (L1). Thereafter, the cord blends with the conus medullaris that becomes the cauda equina, a group of nerves resembling the tail of a horse. The spinal nerve roots are responsible for stimulating movement and feeling. The nerve roots exit the spinal canal through the intervertebral foramen, small openings between each vertebra.

The brain and the spinal cord make up the Central Nervous System (CNS). The nerve roots that exit the spinal cord/spinal canal branch out into the body to form the Peripheral Nervous System (PNS).

Between the front and back portions of the vertebra (i.e. the mid-region) is the spinal canal that houses the spinal cord and the intervertebral foramen. The foramen are small openings formed between each vertebra. These "holes" provide space for the nerve roots to exit the spinal canal and to further branch out to form the peripheral nervous system.

Type of Neural Structure	**Role/Function**
Brain Stem	Connects the spinal cord to other parts of the brain.
Spinal Cord	Carries nerve impulses between the brain and spinal nerves.
Cervical Nerves (8 pairs)	These nerves supply the head, neck, shoulders, arms, and hands.
Thoracic Nerves (12 pairs)	Connects portions of the upper abdomen and muscles in the back and chest areas.
Lumbar Nerves (5 pairs)	Feeds the lower back and legs.
Sacral Nerves (5 pairs)	Supplies the buttocks, legs, feet, anal and genital areas of the body.
Dermatomes	Areas on the skin surface supplied by nerve fibers from one spinal root.

Table 2 (Review of Spinal Anatomy, April 2008 In: http://www.schnipperchiro.com/Spinal_Anatomy.html)

Ligaments, Muscles and Tendons

Ligaments

Ligaments and tendons are fibrous bands of connective tissue that attach to bone. Ligaments connect two or more bones together and also help to stabilize joints. Tendons attach muscle to bone. They vary in size and are somewhat elastic.

The system of ligaments in the vertebral column, combined with the tendons and muscles, provides a natural type of brace to help protect the spine from injury. Ligaments keep a joint stable during rest and movement. Further, ligaments help to prevent injury from hyper- extension and flexion movements.

Ligament Name	Description
Anterior Longitudinal Ligament (ALL) A primary spine stabilizer	About one inch wide, the ALL runs the entire length of the spine from the base of the skull to the sacrum. It connects the front (anterior) of the vertebral body to the front of the annulus fibrosis.
Posterior Longitudinal Ligament (PLL) A primary spine stabilizer	About one inch wide, the PLL runs the entire length of the spine from the base of the skull to sacrum. It connects the back (posterior) of the vertebral body to the back of the annulus fibrosis.
Supraspinous Ligament	This ligament attaches the tip of each spinous process to the other.
Interspinous Ligament	This thin ligament attaches to another ligament, called the ligamentum flavum, that runs deep into the spinal column.
Ligamentum Flavum The strongest ligament	This yellow ligament is the strongest one. It runs from the base of the skull to the pelvis, in front of and behind the lamina, and protects the spinal cord and nerves. The ligamentum flavum also surrounds the facet joint capsules.

Table 3 (Review of Spinal Anatomy, April 2008 In: http://www.schnipperchiro.com/Spinal_Anatomy.html)

Muscles and Tendons

The muscular system of the spine is complex, with several different muscles playing important roles. The primary function of the muscles is to support and stabilize the spine. Specific muscles are associated with movement of parts of the anatomy. For example, the Sternocleidomastoid muscle assists with movement of the head, while the Psoas Major muscle is associated with flexion of the thigh.

Muscles, either individually or in groups, are supported by fascia. Fascia is strong connective tissue. The tendon that attaches muscle to bone is part of the fascia. The muscles in the vertebral column are called flexors, rotators, or extensors.

(Review of Spinal Anatomy, April 2008 In: http://www.schnipperchiro.com/Spinal_Anatomy.html)

Scoliosis

Scoliosis is the strutural deformity of the spine in he frontal plane. The usual vertical orientation of the spine in the frontal plane is disturbed, leading to a lateral curvature of the spine. (Goel and Weinstein 1980). Cobb's angle measures the degree of scoliosis (Martinez-Lozano 2001). Identifing the particular curve pattern and location is essential to making treatment decicions, which may include nonsurgical options such as orthoses and braces. The curve patterns of idiopathic scoliosis are called "primary" and "compensatory", each with specific meanings. "Primary curve refers to the curve that is larger in magnitude, more rigid on supine side bending (side bending in the supine posture) and generally having more cosmetic deformity. Compensatory curves are those that are smaller in magnitude and more flexible on supine side bending. The curves are always named for location of the apex of the curve being discussed. Idiopathic scoliosis assumes five classical curve patterns: right thoracic, thoracolumbar, lumbar, double primary and double thoracic primary. (Steven M. Kurtz et al, 2006)

Scoliosis causes and risk factors

Scoliosis can be caused by congenital, developmental or degenerative problems, but most cases of scoliosis actually have no known cause, and this is known as idiopathic scoliosis. While there are many forms of scoliosis, four of the most common ones include:

- **Congenital scoliosis.** This is a relatively rare form of congenital malformation of the spine. Patients with congenital scoliosis will often develop scoliotic deformities in their infancy.
- **Neuromuscular scoliosis.** This may occur when the spine curves to the side due to weakness of the spinal muscles or neurologic problems. This form of scoliosis is especially common for individuals who cannot walk due to their underlying neurolomuscular condition (such as muscular dystrophy or cerebral palsy). This may also be called *myopathic scoliosis.*
- **Degenerative scoliosis.** Scoliosis can also develop later in life, as joints in the spine degenerate and create a bend in the back. This condition is sometimes called *adult scoliosis.*
- **Idiopathic scoliosis.** By far the most common form of scoliosis is idiopathic scoliosis, which most often develops in adolescents and typically progresses during the adolescent growth spurt. Because it most often occurs during adolescence, this condition is sometimes called *adolescent scoliosis.*

Scoliosis does not come from any types of sports involvement, backpacks, sleeping positions, posture, or minor leg length differences.

Fig. 9 (P Ullrich "Scoliosis-what you need to know", in Spine Health, October 2007)

Idiopathic scoliosis

There is no known cause of idiopathic scoliosis ("idiopathic" refers to a disease or condition of unknown origin) although it does tend to occur in families.

Idiopathic scoliosis is usually categorized into three age groups:

- From birth to 3 years old - called *infantile scoliosis.*
- From 3 to 9 years old - called *juvenile scoliosis.*
- From 10 to 18 years old – called *adolescent scoliosis.*

This last category of scoliosis, which occurs from 10 to 18 years old, comprises approximately 80 percent of all cases of idiopathic scoliosis.

The risk of curvature progression is increased during puberty, when the growth rate of the body is the fastest. Scoliosis with significant curvature of the spine is much more prevalent in girls than in boys, and girls are eight times more likely to need treatment for scoliosis, because they tend to have curves that are much more likely to progress. Still, the majority of all cases of scoliosis are mild and do not require treatment.

It is important to note that idiopathic scoliosis results in spinal deformity, and is not typically a cause of back pain. Of course, people with scoliosis can develop back pain, just as most of the adult population can develop back pain. However, it has never been found that people with idiopathic scoliosis are any more likely to develop back pain than the rest of the population.

(P Ullrich, October 2007)

Types of scoliosis (from Dynamed):

- functional scoliosis - postural, compensatory, reversible curvature due to another condition e.g. limb length discrepancy, painful muscle spasm
- structural scoliosis - not postural, characterized by structural skeletal changes such as vertebral rotation and wedging and rib deformation
    - 70-80% idiopathic, a.k.a. familial scoliosis - not associated with dysmorphic features, skin lesions, bone fragility or neuromuscular disease
    - 10% congenital scoliosis - errors of formation (hemivertebra) or errors of segmentation (unilateral bar, worsens gradually), commonly associated with genitourinary anomalies, curves present at birth, up to 75% require treatment
    - 15% neuromuscular scoliosis - associated with any disease that causes weakness or spastic imbalance of paraspinal muscles in growth child, including cerebral palsy, muscular dystrophy, spinal muscular atrophy, spinal cord injury; may develop at any age in growing child but does not occur after skeletal maturity
    - 5% associated with dysmorphic syndromes - neurofibromatosis, Marfan syndrome, Ehler-Danlos syndrome, osteogenesis imperfecta, homocystinuria
- classification by age
    - infantile scoliosis - by age 3 years, more common in boys and Europeans, usually resolves spontaneously
    - juvenile scoliosis - age 4-10 years

- adolescent scoliosis - age 10 years until skeletal maturity, most significant and prevalent form, can become worse during growth spurt, chromosome 19p13.3 linked to adolescent idiopathic scoliosis (V.Chan)

International Classification of Scoliosis:

ICD-9 Codes:

- 737.30 scoliosis (and kyphoscoliosis), idiopathic
- 737.31 resolving infantile idiopathic scoliosis
- 737.32 progressive infantile idiopathic scoliosis
- 737.33 scoliosis due to radiation
- 737.34 thoracogenic scoliosis
- 737.39 other kyphoscoliosis and scoliosis
- 737.43 scoliosis associated with other conditions
- 737.8 other curvatures of spine associated with other conditions
- 737.9 unspecified curvature of spine associated with other conditions
- 754.2 congenital musculoskeletal deformities of spine
- 416.1 kyphoscoliotic heart disease

ICD-10 Codes:

- M41 scoliosis
    - M41.0 infantile idiopathic scoliosis
    - M41.1 juvenile idiopathic scoliosis
    - M41.2 other idiopathic scoliosis
    - M41.3 thoracogenic scoliosis
    - M41.4 neuromuscular scoliosis
    - M41.5 other secondary scoliosis
    - M41.8 other forms of scoliosis
    - M41.9 scoliosis, unspecified
    - optional fourth digit site codes
        - 0 multiple sites in spine
        - 1 occipito-atlanto-axial region
        - 2 cervical region
        - 3 cervicothoracic region
        - 4 thoracic region
        - 5 thoracolumbar region
        - 6 lumbar region
        - 7 lumbosacral region
        - 8 sacral and sacrococcygeal region

        - 9 site unspecified
- M96.5 postradiation scoliosis
- Q67.5 congenital deformity of spine
- Q76.3 congenital scoliosis due to congenital bony malformation
- I27.1 kyphoscoliotic heart disease

(Dynamed-EbscoHost, 2008)

Adolescent idiopathic scoliosis

The latest classification of adolescent idiopathic scoliosis:

Eponymous grading systems appear in ever increasing number in the medical press. This era is one of classification and re-classification, the aim being to refine the definition of a clinical disorder and the prediction of its natural history or treatment outcomes. Lawrence Lenke and his colleagues have now introduced a new classification of idiopathic scoliosis (Lenke LG, 2001) to replace the old King grading system. (King HA, 1983)Both these systems are designed to identify appropriate surgery. The criteria that form the basis of classification systems have not been widely considered in orthopaedic publications.(Burstein AH, 1993) Essential features include a need for the system to be comprehensive yet focused in its objectives. Intraobserver reproducibility must be tested to ensure consistency, and interobserver agreement must confirm reliability.

The basic or nominal classification of scoliosis relates to causation (eg, congenital, neuropathic, syndromic). Idiopathic scoliosis forms the largest group (about 75%). The great majority of idiopathic curves starts around puberty—ie, adolescent idiopathic scoliosis. The first classification of idiopathic scoliosis was into single-curve, double-curve, and triple-curve patterns. (Ponsetti IV, 1950)The degree of the curve is measured as the angle between the most inclined vertebral end-plates each end of the curve (the Cobb angle). Each vertebral body also rotates into the convexity about a longitudinal axis, and the internationally agreed grading system for torsion is the Nash-Moe method.(McCance SE, 1998)

In 1983 King and his colleagues from Minneapolis (King HA, 1983) reviewed 405 patients whose vertebrae had been fused with Harrington rods. They classified the patients into five groups on the basis of different patterns of curve. Each curve pattern was identified by the length of spinal fusion required. A considerable number of shortcomings are now apparent with the King classification. The system is not comprehensive and excludes single thoracolumbar or lumbar curves. The deformity is considered only two dimensionally on anteroposterior radiographs and ignores the all-important sagittal profile of the spine. Surgical recommendations based on King classification relate to the Harrington rod instrumentation, which is now obsolete. New instrumentation systems involve contoured double rods intended to correct both sagittal and torsional components of the deformity as well as the lateral curve. Insertion of these rods according to the King guidelines has left some patients with unbalanced spines. (McCance SE, 1998) Moreover, interobserver reliability and intraobserver reproducibility of the King system was recently found to be poor. (Cummings RJ, 1998).

The Lenke system1 is based on six main scoliosis types according to the level and number of curve patterns (panel). These main types are then subdivided or "modified" by two other gradings. One (A, B, or C), for the degree of a lumbar curve, is based on the deviation from the central sacral vertical line. The other is an assessment of the sagittal profile of the thoracic spine. The normal profile with a kyphotic angle of 20°–40° is cited as N. The presence of hypokyphosis or lordosis is given a minus sign. A kyphotic angle greater than 40° is given a plus sign. The kyphosis is further subdivided into proximal thoracic (PT) or thoracolumbar (TL). Therefore curve types might be recorded as 2AN or 3B+ (TL), for example. This Lenke system was first presented to the Scoliosis Research Society in 1997 and since then intraobserver and interobserver testings have validated the classification and demonstrated its superiority to the King system.(Lenke LG, 2001)

Further developments have led to the addition of a deformity score (Lenke-Harms score) to this classification. (D'Andrea LP, 2000) This deformity score is based on the Cobb angle, the kyphosis angle, and the balance of the spine. A normal spine scores 100 points, whereas a severe spinal deformity will score 50 points or less. Surgery undoubtedly improves this score. So far, however, correlation between this improvement and an outcome measure obtained by use of the Scoliosis Research Society patient's questionnaire has been poor. (D'Andrea LP, 2000). Nevertheless, the Lenke system now allows a comparison of "apples with apples" and perhaps the Lenke-Harms score identifies "apples" of different sizes. The scene is set for a more focused audit of treatment methods between different centres, between different surgical implants, and between anterior and posterior approaches to the spine.

However, the Lenke system is not the final word on the classification of idiopathic scoliosis. Already a new system has been proposed by the Montreal school; it gives greater emphasis to the torsional component of the deformity. (Poncet P, 2001) This classification is still at the hypothetical stage, so the Lenke system will be to the fore, particularly in the evaluation of surgical results, for the next decade or two.

Curve type

Type	Proximal thoracic	Main thoracic	Thoracolumbar/ lumbar	Curve type
1	Non-structural	Structural (major*)	Non-structural	Main thoracic (MT)
2	Structural	Structural (major*)	Non-structural	Double thoracic (DT)
3	Non-structural	Structural (major*)	Structural	Double major (DM)
4	Structural	Structural (major*)	Structural	Triple major (TM)
5	Non-structural	Non-structural	Structural (major*)	Thoracolumbar/ lumbar (TL/L)
6	Non-structural	Structural	Non-structural (major*)	Thoracolumbar/ lumbar-main thoracic (TL/L-MT)

*Major=largest Cobb measurement, always structural; minor=all other curves with structural criteria applied.

Curv type (1–6)+lumbar spine modifier (A, B or C)+thoracic sagittal modifier (−, N or +)

SRS=Scollosis Research Society, CSVI=centre sacral vertical fine.

Fig 9b. A new classification of adolescent idiopathic scoliosis (M. Edgar 2002)

Adolescent Idiopathic Scoliosis definition

Adolescent Idiopathic Scoliosis (AIS) is a lateral (side) curvature of the spine that can occur in children aged 10 to maturity. The spine may curve to the left or right. Sometimes AIS may start at puberty or during an adolescent growth spurt.

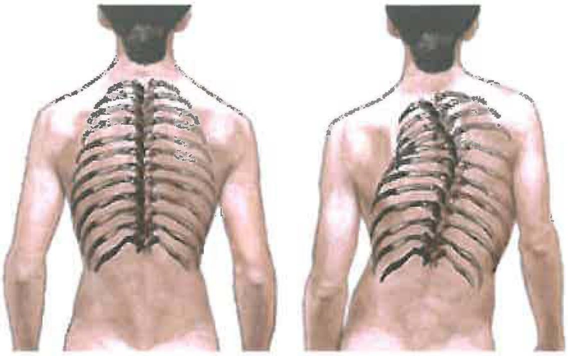


Fig. 10 (Keith H. Bridwell, 2008)

Idiopathic means the abnormal curve develops for unknown reasons. Chromosome 19p13.3 linked to adolescent idiopathic scoliosis (V.Chan)is the only explanation up to date. There is undoubtedly a genetic pre-disposition for some adolescents to develop AIS. Three to five percent of adolescents will be found to have some form of scoliosis. Most of these children will be girls, in which curves may be more progressive. Defined also as fixed (structural) lateral curvature of spine > 10 degrees in coronal plane with onset near puberty and no known cause. (Dynamed-EbscoHost, 04.03.08, Keith H. Bridwell, 2008)

Symptoms

Symptoms of scoliosis include back pain, leg length discrepancy, an abnormal gait, and uneven hips. Patients with AIS may have one shoulder higher than the other, a "prominent" shoulder blade and rib cage when bending forward, and visible curving of the spine to one side. Often the first indication of AIS is when an adolescent or parent notices that clothes no longer fit correctly (for example, the legs of pants may seem uneven).

It is important to seek treatment for AIS because progressive scoliosis, left untreated, can result in significant deformity. The deformity can cause marked psychological distress and physical disability, especially among adolescent patients. Additionally, the deformity can have serious physical consequences.

As the vertebrae (spinal bones) rotate, the rib cage is affected, which in turn can cause heart and lung compromise (i.e. shortness of breath). When progressive scoliosis affects the lumbar spine the pain can be debilitating.

Diagnosis

A spine specialist's assessment of the child's condition will include medical history, physical and neurological exam, and diagnostic tests.

Medical history may include questions about the parent's genealogy. Are there other family members with scoliosis? If so, how did the scoliosis progress and what treatment was provided? The physician will check for any underlying medical condition that might otherwise be causing the scoliosis. In addition, the patient's age, onset of puberty, and age at which a young woman has her first period, will help the physician determine the number of years that remain before the child reaches skeletal maturity. At skeletal maturity curve progression may stop as long as the curve is less than 40-45 degrees. The curve may continue to progress throughout adulthood, if the curve exceeds 40-45 degrees. During the physical and neurological examinations the physician will learn about the patient's health and general fitness.

(Keith H. Bridwell, 2008)

Organs Involved:

- spine, chest wall

Who is most affected:

- female (1.5 times), girls age 10-12 years (boys age 14-16 years)
- females tend to have more severe curves (female:male ratio 8:1 for severe deformity)

Incidence/Prevalence:

- 1-3% population, most common chest wall disease
- 0.2-0.3% > 20 degrees (10-15% scoliosis clinically significant)

Causes:

- unknown, not bad posture
- idiopathic most common, congenital anomalies, infection, paralysis (polio), cerebral palsy, syringomyelia, muscular dystrophy, amyotonia congenita, Friedreich's ataxia, neoplastic, trauma (fracture in growth plate), also see under Types above
- case report of traumatic scoliosis can be found in the Lancet (Shen FH, 2005)
- Chromosome 19p13.3 linked to adolescent idiopathic scoliosis (V.Chan, 2002)

Pathogenesis:

- gets worse during active growth
- reduced lung volume, stiff chest wall
- review of transformation of spinal curvature into spinal deformity can be found in Scoliosis 2006 Mar 31;1:3 (Martha C Hawes, 2006)

Complications and Associated Conditions

Complications:

- pulmonary hypertension
- right ventricular dysfunction
- cor pulmonale

History

Chief Concern (CC):

- usually asymptomatic, 40-80% back pain in adult

History of Present Illness (HPI):

- rarely pain (if so, look for other causes)
- recent growth?

Past Medical History (PMH):

- birth and development history
- age of menarche should be noted since skeletal growth can be predicted to be complete 18-24 months after menarche

Family History (FH):

- multifactorial genetic trait - autosomal recessive form with variable penetrance, skip generations, sex-linked dominant; increasing evidence for strong genetic basis

Review of Systems (ROS):

- exertional dyspnea, hypoventilation if severe; neurologic symptoms
- back pain suggests tumor or tethered spinal cord or unrelated musculoskeletal pain
- neurologic abnormality (bowel or bladder problems, weakness, unexplained limb pain or ataxia) suggest neurogenic scoliosis (diastematomyelia, tethered cord, syrinx, spinal tumor)

General Physical:

- alignment - base of neck should be directly above intergluteal cleft
- spinal asymmetry (shoulders, scapula, iliac crest) - if suspected secondary to leg length discrepancy, recheck in sitting position

- asymmetry of posterior thoracic cage - ribs close together on concave side of curve, widely separated on convex side
- observe gait for asymmetric pelvic rotation or drop
- forward bending test - feet together, arms hanging with palms toward body; look for rib prominence, kyphosis or lordosis
- secondary sexual characteristics

Skin:

- look for cafe au lait markings (neurofibromatosis), midline lesions over spine such as hairy patches or pigmentation (spina bifida)

Abdomen:

- vertebrae rotated with spinous processes and pedicles toward concavity

Back:

- lateral curvature does not disappear with recumbency
- increased rib or paralumbar muscle prominence occurs on convex side of curve
    - spine rotates axially within curve causing rotational asymmetry
    - not seen in functional scoliosis which tends to straighten with bending
- physical exam inaccurate, use of scoliometer may be more sensitive than physical exam of the back but also produces false-positive results

Extremities:

- leg length discrepancy
    - may be noted by different heights of iliac crests while standing
    - leg length measured from anterior superior iliac spine to medial malleolus (if unequal may cause pelvic tilt and compensatory "scoliosis")
- hips should be flexed nearly 90 degrees with patients standing in flexion
- unilateral cavus foot suggests intraspinal pathology (check MRI), bilateral cavus foot suggests Friedreich's ataxia

Note: Friedreich's ataxia is an inherited disease that causes progressive damage to the nervous system resulting in symptoms ranging from muscle weakness and speech problems to heart disease. Ataxia results from the degeneration of nerve tissue in the spinal cord and of nerves that control muscle movement in the arms and legs.

(NINDS Friedreich's Ataxia Information Page, 2008)

Neuro:

- check muscle strength - walking on toes, walking on heels, hopping on one leg
- check reflexes and sensation

Rule out:

- unequal leg length, neurofibromatosis, Marfan's syndrome, polio, cerebral palsy, myelomeningocele
- if painful NOT scoliosis - herniation of nucleus pulposis, spinal infection, discitis
- functional scoliosis if curve disappears on recumbency - correct cause (unequal leg length, muscle contracture about hip, splinting secondary to back pain)

Note: Marfan syndrome is an autosomal dominant genetic disorder of the connective tissue characterized by disproportionately long limbs, long thin fingers, a typically tall stature, and a predisposition to cardiovascular abnormalities, specifically those affecting the heart valves and aorta. (Marfan syndrome, Wikipedia, 2008)

Testing to consider:

- standing PA x-ray only
- bone scan or MRI only if suspecting other diagnosis

Blood tests:

- alveolar hypoventilation (increased PCO2) (percentage of CO2)

Imaging studies:

- Risser sign - very sensitive indicator of skeletal maturity - progress of ossification from lateral to medial direction of iliac crest (0 no ossification, 5 complete fusion)
- Cobb angle - angle of spinal curvature - define end vertebrae of curve, draw line parallel to end plate of each end vertebra, draw perpendicular to each of these lines, Cobb angle is angle formed by intersection of perpendicular lines
- CXR (chest x-ray) ribs widely spaced and rotated posteriorly on convex portion of spine creating hump; ribs on concave aspect crowded and displaced anterior

Prognosis:

- better if growth spurt completed
- prognosis depends mostly on curve size and amount of active growing remaining
- 68% of curves 20-29 degrees with Risser 0-1 will progress, but only 23% if Risser 2 or more
- most patients requiring treatment will develop trunk asymmetry by age 10
- rate of curve progression proportional to rate of growth - mild curves stabilize at skeletal maturity, severe curves continue to progress at slow rate after skeletal maturity
- if untreated
    - no increased incidence in severe back pain or hospitalization or surgery for back pain
    - pulmonary function only affected by thoracic curve > 80 degrees
    - psychosocial effects unpredictable (both from disease and treatment)
    - adult curves < 30 degrees don't progress
    - curves > 50 degrees progress 1 degree/year
    - late-onset idiopathic scoliosis (structural lateral curvature of spine arising during puberty in otherwise normal children) does not lead to disability or reduced lifespan, but may cause mild back pain and dyspnea; 117 patients with late-onset idiopathic scoliosis between 1932 and 1948 were followed up 50 years later and compared with 62 matched controls aged 54-80 years; estimated probability of survival 0.55 (95% CI 0.47-0.63) in patients and 0.57 expected for general population; 22 (22%) of 98 patients vs. 8 (15%) of 53 controls complained of dyspnea during everyday activities, increased risk with combination of Cobb angle > 80 degrees and thoracic apex, all 4 patients with chronic obstructive pulmonary disease had large curvatures; 66 (61%) of 109 patients vs. 22 (35%) of 62 controls reported chronic back pain, 70% of which was little or moderate back pain; no substantial differences in activities of daily living JAMA 2003 Feb 5;289(5):559 (Weinstein SL et al, 2003) , commentary can be found in POEMs in J Fam Pract 2003 Jun;52(6):451 (Gilmer-Scott M et al, 2003) commentary can be found in Am Fam Physician 2003 Jun 1;67(11):2391 (CAROLINE WELLBERY, 2003)
- risk factors for curve progression in adolescent idiopathic scoliosis
    - larger initial Cobb angle (odds ratio 4.6)
    - lower Risser grade (odds ratio 4.7)
    - premenarchal status (odds ratio 2.5)
    - osteopenia in femoral neck of hip on side of concavity (odds ratio 2.3)
    - younger age at diagnosis (odds ratio 2.1)
    - Reference - prospective study of 324 adolescent girls with adolescent idiopathic scoliosis (mean age 13.5 years) followed until skeletal maturity (50%) or until curve progression at least 6 degrees (50%) J Bone Joint Surg Am 2005 Dec;87(12):2709 (Hung VW et al, 2005)

Treatment overview:

- functional scoliosis does not require treatment
- observation, bracing or surgery - effectiveness of treatments for scoliosis unproven
- goal in mild curves - prevent progression, hold at moderate level to avoid surgery
- goal in severe curves - stabilize spine to prevent rapid progress (if growing) or gradual progress as adult
- TENS at night on convex side - studies inconclusive
- algorithm for management - controversial
    - for physiologically immature patients - Risser grades 0-3, premenarchal to 6 months postmenarchal
        - < 10 degrees - not scoliosis
        - 10-20 degrees - observation only, follow-up every 4-6 months with x-ray when rib asymmetry > 7 degrees by scoliometry
        - 20-30 degrees - consider treatment, especially if progression
        - 30-40 degrees - immediate bracing
        - > 40-45 degrees - consider surgery
    - for patients with little or no remaining growth - Risser grades 4-5
        - bracing ineffective
        - consider surgery for curves > 50 degrees since progression likely
- another management algorithm for idiopathic structural scoliosis
    - Cobb angle < 10 degrees - re-evaluate clinically every 6-12 months until skeletally mature
    - 11-40 degrees - determine skeletal maturity
        - mature (Risser 4-5) - stable, not treatment necessary
        - immature, 11-30 degrees - observe for progression with x-rays every 4 months until mature, brace option if progression to > 20 degrees
        - immature, 31-40 degrees - brace option
    - 41-54 degrees - surgery possibly indicated
    - > 55 degrees - surgery indicated
- for congenital scoliosis (onset 5-10)
    - < 20 degrees - observe
    - > 20 degrees - Milwaukee brace
    - maintain 40 degrees - continue brace, at 12-14 definitive fusion without rod
    - if curve > 40 degrees - short segment fusion, cast, brace until 12, definitive fusion

Surgery (overview):

- indications for surgery - controversial
    - adolescents with curve > 40-45 degrees
    - adults with curve > 50 degrees
    - thoracic curve > 50 degrees or lumbar curve > 40 degrees (may get increased risk of low back pain with age)

- general principles
    - instrumentation helps correct spinal curvature and balance
    - solid bone fusion (arthrodesis) maintains spine in corrected position, bone most often taken from iliac crest for bone graft to facilitate fusion
- Harrington distraction procedure
    - metal rods and spinal fusion, plaster of paris jacket cast for months
    - 12 hour operation, 6-9 months recovery
    - 50% improvement in curve size, < 1% neurologic injury, 10% pseudoarthrosis
- use of bone graft unncessary with posterior spinal fusion using multisegmented hook-screw and rod system based on randomized trial of 91 patients with adolescent idiopathic scoliosis and analysis of 76 patients with follow-up > 2 years (Betz RR, Petrizzo AM, Kerner PJ, Falatyn SP, Clements DH, Huss GK., 2006)
- Vertical Expandable Prosthetic Titanium Rib FDA approved for thoracic insufficiency syndrome in children, curved metal rod helps straighten spine and separate ribs (FDA Talk Paper 2004 Sep 2)
- double epidural analgesia appears more effective than intravenous morphine for postoperative analgesia
    - 30 adolescents having anterior correction for thoracic idiopathic scoliosis were randomized to epidural vs. morphine, epidural group has 2 epidural catheters placed after scoliosis correction
    - all patients given remifentanil until first postoperative morning then epidural group given continuous epidural ropivacaine 0.3% and morphine group given continuous IV morphine
    - epidural group had less pain, less rescue morphine use, improved bowel activity, higher patient satisfaction and fewer side effects
    - Reference - Spine 2006 Jul 1;31(15):1646 (Blumenthal S, Borgeat A, Nadig M, Min K., 2006)
- wait times for scoliosis surgery > 6 months associated with increased risk for additional unplanned surgery in 2 cohort studies with 317 patients with scoliosis (Clark S., 2008)

Consultation and referral:

- orthopedic surgeon if curvature > 20 degrees
- physical therapy has no accepted role in treatment of adolescent idiopathic scoliosis

Other management:

- bracing - prevents curve from progressing, does not reduce curvature permanently
    - indications:
        - curve size 20-40 degrees
        - Risser 0-2 and curve progression of 5 degrees in 1 year
        - Risser 0-2 and presenting curve 30 degrees or more
    - modern braces generally more comfortable and better tolerated, but compliance still not ideal
    - type of braces:
        - Milwaukee brace - older brace, effective but compliance difficult, cosmetically objectionable due to neck ring
        - thoracolumbar-sacral orthosis (TLSO)

        - underarm brace worn under clothing
        - indicated if apex of curve at T8 or lower
        - can retain heat, decrease pulmonary capacity
      - Boston brace
      - Charleston bending brace - reverse curve brace used nocturnally for lumbar curve
  - efficacy of braces not proven, but prospective study of 286 girls with adolescent idiopathic scoliosis concluded that bracing successful in preventing significant progression of curve (J Bone Joint Surg [Am] 1995;77:815)
  - retrospective study found that patients wore their braces 65% of the recommended time (J Pediatr Orthop 1988;8:143)
- periodic hyperinflation to increase lung compliance, PO2

Follow-up:

- repeat physical exam and PA spinal x-ray every 4 months to 1 year
- follow adolescent every 6 months if 10-15 degrees, every 3 months if 15-20 degrees; alternatively follow preadolescent child for curve progression every 6 months, every 4 months for more rapidly growing adolescent

Prevention and Screening

Screening:

- United States Preventive Services Task Force (USPSTF) recommends against routine screening of asymptomatic adolescents for idiopathic scoliosis (D recommendation) (National Guideline Clearinghouse 2004 Jul 26:5302), summary can be found in (Ned Calonge, 2005) Am Fam Physician 2005 May 15;71(10):1975
- poor evidence to recommend for or against physical exam of the back (Adams forward bending test) to detect idiopathic scoliosis in the adolescent periodic health exam (Canadian Task Force on Preventive Health Care guideline)
- Adams forward bend test does not appear adequate to rule in or rule out clinically significant scoliosis (Eugene Dinkevich, Jordan Hupert, Virginia A Moyer, 2001)
- school screening
  - visual exam with forward bending, recheck if positive, primary care referral if still positive
  - 50% school positives do not have scoliosis, one report found only 8% positive predictive value for school screening
  - school screening identifies some children who receive treatment but refers many more who do not; retrospective cohort study of children attending kindergarten or first grade in 1979-1982 followed until age 19 or leaving school district, school scoliosis screenings performed annually in grades 5 through 9; 2242 children screened, 92 (4.1%) referred for further evaluation of whom 68 (74%) had documented medical or chiropractic evaluation of scoliosis; school screening identified 5 of 9 children treated for scoliosis and resulted in referrals for 87 children not treated; using school

screening to identify children ultimately treated for scoliosis had 56% sensitivity, 96% specificity, 5% positive predictive value and 99.8% negative predictive value; 448 children needed to be screened to identify 1 child who received treatment (Yawn BP, Yawn RA, Hodge D, Kurland M, Shaughnessy WJ, Ilstrup D, 1999), editorial can be found in JAMA 1999 Oct 20;282(15):1472, commentary can be found in JAMA 2000 Apr 5;283(13):1689

- some orthopedists recommend scoliosis screening with adolescent check-ups until girls reach menarche or boys develop axillary hair

(Dynamed, 2008)

Surgery

The goals of scoliosis surgery are threefold:

- Straighten the spine as much as possible in a safe manner.
- Balance the torso and pelvic areas.
- Maintain correction.

These goals are accomplished in a two-component process:

- By *fusing* (joining together) the vertebrae along the curve.
- By supporting these fused bones with *instrumentation* (steel rods, hooks, and other devices) attached to the spine.

Many surgical variations exist using different instruments, procedures, and surgical approaches. All of the operations require meticulous skill. In most cases, success depends less on the type of operation than on the skill and experience of the surgeon. The cause of scoliosis often determines the type of procedure. Parents of patients or adult patients should not be shy in asking the surgeon and hospital about their experience with the specific procedures being considered.

Surgical Candidates

Surgery is usually recommended for the following children and adolescents with idiopathic scoliosis:

- All young people whose curve exceeds 50 degrees.
- Growing children whose curve has gone beyond 40 degrees. (There is still some debate, however, about whether all children with curves of 40 degrees should have surgery.)
- Older children who have surgery tend to experience improved well being from the changes in their appearance, even if they have no actual improved physical functioning. Surgery may be required for the following children at as early an age as possible.
- Those whose scoliosis is due to inborn abnormalities. (The younger they are when surgery is performed the better their chances for success.)

- Children with multiple physical handicaps.

It should be noted that procedures will differ depending on whether a child has idiopathic scoliosis or scoliosis due to muscle and nerve disorders (such as muscular dystrophy or cerebral palsy). In the latter cases, children also need a team approach to reduce their risks for serious complications.

Preoperative Care

Before the operation, a complete physical examination is conducted to determine leg lengths, muscle strength, lung function, and any postural abnormalities. The patient is trained in deep breathing and effective coughing to avoid lung congestion after the operation. The patient should also be trained in turning over in bed in a single movement (called log-rolling) before the operation. Psychologic intervention using cognitive-behavioral methods that help young patients cope may be very helpful in reducing anxiety and pain after surgery.

Patients are encouraged to donate their own blood before the operation for use in possible transfusions. The patient should have no sunburn, rashes, or sores on the back before the operation, which will increase the risk for infection.

Scoliosis operations

Fusion

All scoliosis operations involve fusing the vertebrae. The instruments and devices used to support the fusion vary, however.

The Fusion Procedure. The fusion procedure generally is as follows:

- The surgeon first slices flaps to expose the backs of the vertebrae that lie along the curve.
- The surgeon then removes the processes, the bony outgrowths along the vertebrae that allow the spine to twist and bend.
- The surgeon lays matchstick-sized bone grafts vertically across the exposed surface of each vertebra, being careful that they touch adjoining vertebrae.
- The flaps are then folded back to their original position, covering the bone grafts.
- These grafts will regenerate, grow into the bone, and fuse the vertebrae together.

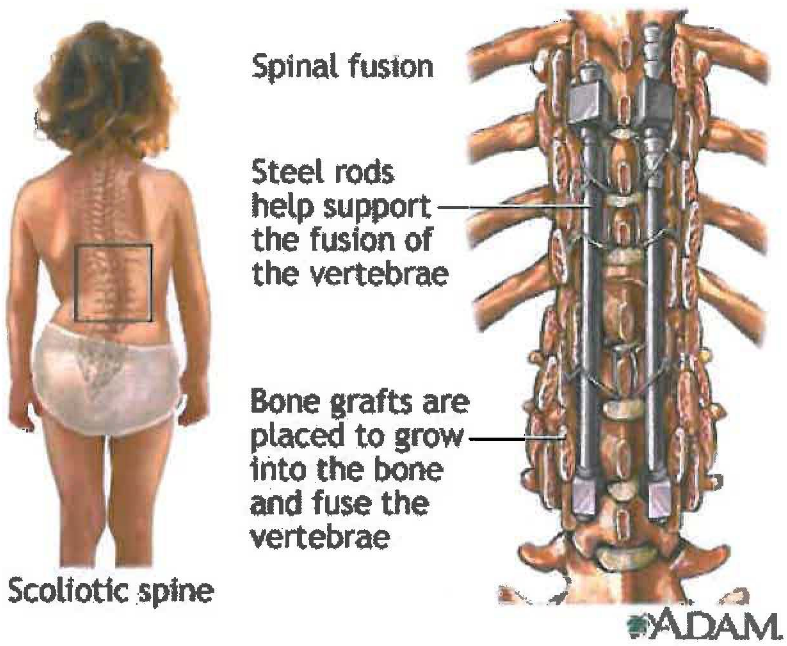


Fig. 11 Spinal fusion (Review Report on Scoliosis-Surgery, 2008, in About.com http://adam.about.com/reports/000068_9.htm)

Depending upon the severity and responsiveness to other treatment surgery may be recommended for the scoliosis. Surgical correction involves correcting the curve (although not all the way) and fusing the bones in the curve together. Bone grafts are laid across the exposed surface of each vertebra. These grafts will regenerate, grow into the bone, and fuse the vertebrae together. The bones are held in place with one or two metal rods held down with hooks and screws, which also helps to support the fusion of the vertebrae.

Graft Materials. Bone grafts are taken from the patients hip, ribs, spine, or other bones (called autografts). This is the best quality bone. However, because autografts are taken directly from the scoliosis patient, the operation is longer and the patient experiences more pain afterward. Researchers are also investigating allografts, which are bone grafts taken from another person or a cadaver. This would reduce the pain and duration of the operation. Allografts, however, pose an increased risk for infection from the donor. Longer-term studies are needed to determine the seriousness of this risk.

Investigators have been testing grafts made from ceramic material called tricalcium phosphate (Biosorb). In one comparative French study, these synthetic grafts were completely fused with the original bone in two years, while the natural bone graft was still evident on x-rays. In the study, the use of synthetic graft was associated with better spinal correction and a lower risk for viral infections.

Healing. The healed fusions harden in a straightened position to prevent further curvature, leaving the rest of the spine flexible. It takes about three months for the vertebrae to fuse substantially, although one to two years are required before fusion is complete. Fusion stops growth in the spine, but most growth occurs in the long bones of the body (such as in the legs), anyway. Patients, then, will most likely gain height from both growth in the legs and from the straighter spine. Patients make walk at slightly slower pace after fusion, but balance may improve, and **sports activities are not restricted after the procedure.**

Instrumentation

Harrington Procedure. Until ten years ago, the standard instruments used in fusion procedures were those of the Harrington procedure, first developed in the 1960s:

- To support the fusion of the vertebrae, the surgeon uses a steel rod, extending from the bottom to the top of the curve. (More than one rod may be used depending on the type of curve and whether kyphosis is present.)
- The rod is attached by hooks that are suspended from pegs inserted into the bone.
- Similar to changing a tire, the steel rod is jacked up and then locked into place to support the spine securely. The surgeon is then ready to fuse the vertebrae together.
- After this operation, patients are required to wear a full body cast and lie in bed for three to six months until fusion is complete enough to stabilize the spine.
- After one to two years, the steel rod is not really necessary, but it is almost always left in place unless infection or other complications occur.

The Harrington procedure is very difficult to undergo, particularly for young people, and although the operation can achieve a correction of the curve of over 50%, studies have reported a loss in this correction of between 10% to 25% over time. **The procedure does not correct the rotation of the spine and, therefore, does not improve an existing rib hump that was caused by the rotation.** The operation does not interfere with normal pregnancies and deliveries later in life.

Certain complications may occur from this procedure:

- About 40% of Harrington patients have a condition called the flat back syndrome, **because the procedure eliminates normal lordosis** (the inward curving of the lower back). Flat back syndrome from the Harrington procedure does not cause any immediate pain. In later years, however, the disks may collapse below the fusion, making it difficult to stand erect, and the condition can cause significant pain and emotional distress.
- Studies have reported that **five to seven years after their surgery, between a fifth and a third of patients who had the Harrington procedure experienced low back pain.** (In one study, only 3% had experienced back pain before surgery.) In such cases, however, the pain was not severe enough to interfere with normal activities and did not require additional surgery.
- In children younger than 11 whose skeleton is immature and who have the Harrington procedure, there is a fairly high risk for a specific curve progression called the **crankshaft phenomenon**. This condition occurs after the procedure when **the front of the fused spine continues to grow. The spine cannot grow longer, so it twists and develops a curvature**. In one study that followed patients for between five and 16 years, crankshaft curve progression was moderate, however, with the Cobb angle averaging 9 degrees and rotation averaging 7 degrees.

Cotrel-Dubousset Procedure. The Cotrel-Dubousset procedure not only corrects the curve but may also help to correct rotation, and it does not cause flat back syndrome.

With this procedure, parallel rods are cross-linked for better stability in holding the fused vertebrae. Improvement in correction averaged 66% in one study, with a later correction loss reported to be 5%. (Other studies have reported loss of curvature correction at less than 2%.) Over 95% of patients reported the results to be good or very good (only 86% of patients who had the Harrington procedure experienced the same levels of satisfaction). Patients often go home in five days and may be back in school in three weeks.

Complication rates are similar to the Harrington procedure, but there are some differences:

- Operation time and blood loss are greater than with the Harrington procedure.
- **Cotrel-Dubousset and other procedures that are designed to reverse the rotation of the spine have less risk for flat back syndrome but they have a higher risk for spinal imbalance than the Harrington procedure.**
- Failure rates after 10 years are about 25%, which is very high. Experts hope that the advances in current scoliosis procedures will help reduce the long-term adverse effects.

The Texas Scottish-Rite Hospital (TSRH) Instrumentation. The Texas Scottish-Rite Hospital (TSRH) instrumentation is similar to the Cotrel-Dubousset procedure in that it uses parallel rods and other devices that **reverse rotation as well as improve curvature.** TSRH, however, uses smooth rods and hooks that are designed to make removal or adjustment easier later on if complications arise. Complications are similar to the Cotrel-Dubousset procedure.

Additional Forms of Instrumentation. Other instrumentation procedures have refined the hardware used in the Harrington and Cotrel-Dubousset operations.

- *Wisconsin segmental spine instrumentation* (WSSI) may also be effective. It is as safe as the Harrington rod and nearly as strong as the Luque instrumentation.
- *Luque instrumentation* was developed to help maintain normal lordosis and experts hoped that bracing would not be needed afterward with this device. A number of studies showed, however, that **without braces, correction was lost after this operation**, and there also may be a higher **risk for spinal cord injury** than with standard procedures. **Luque instrumentation is used primarily in people whose scoliosis is due to problems of nerves and muscles, such as in children with cerebral palsy.**
- *The Dorsal Dynamic Spondylodesis (DDS) system*, under testing in Germany, is a semirigid system that allows for greater flexibility of the spine.

Instrumentation for Anterior Approach. Specific hardware is needed for the anterior approach, in which the surgeon performs the operation by opening the chest wall. Halm-Zielke instrumentation, for example, uses TSRH instrumentation with bone grafts constructed from ribs to prop open the spaces between the discs. It allows true three-dimensional curve correction. However, it does not solve specific problems with this approach, which are **higher risks for kyphosis** (an outward curve) **and pseudoarthrosis** (a false joint at the fusion site). Variants using two rod systems, fusion cages, or other instruments appear to improve this procedure.

The Surgical Approach

Posterior Approach (Through the Back). Generally, surgeons have used a *posterior* approach for scoliosis, which reaches the surgical area by opening the back of the patient. It has been the gold standard for decades and is generally used with Harrington instrumentation. The approach has advantages and disadvantages.

- Advantages of the Posterior Approach. Surgeons are familiar with it and so fusion rates are excellent, curve correction is good, and it has few complications.
- Disadvantages of the Posterior Approach. There is a risk for the crankshaft phenomenon (a worsening of the curve) later on in preadolescent children. (Newer posterior instrumentation, such as the Isola instrumentation, may prevent this occurrence.) **The posterior approach also does not always correct *hypokyphosis*** (the loss of normal outward curvature) in the thoracic (upper) spine. **The procedure is not always effective for curves in the thoracolumbar region** (the region where the upper and lower spine **meet) and may even cause spinal abnormalities there.**

Anterior Approach (Through the Chest Wall). Increasingly surgeons are using the anterior approach, in which the surgeon performs the operation by opening the chest wall (called a thoracotomy). With the anterior approach, the surgeon makes an incision in the chest, deflates the lung, and removes a rib in order to reach the spine. This rib can be used during the operation as a strut to support the spine. It also may be repositioned within the patient until it is used for bone grafting during fusion.

This approach also has its advantages and disadvantages:

- Advantages of the Anterior Approach. **Because the frontal approach allows the procedure to be performed higher up in the spine than with standard procedures, the patient may have a lower risk for lower-back injury later on**. In addition, transfusion rates are much lower with the anterior approach. With increasing experience, the anterior approach is as effective as the posterior approaches.
- Disadvantages of the Anterior Approach. It is a more recent procedure than the posterior approach, and in inexperienced surgeons there is **a higher risk for complications than in the more standard posterior approach**. One study noted poorer lung function two years after surgery than with the posterior approach, possible because **the wide chest incision produces impairment of the chest muscles, which can affect lung function afterward**. Anterior instrumentation poses a **risk for hyperkyphosis** (exaggerated outward curvature) and a higher **risk for pseudoarthrosis**, a painful condition in which a false joint develops at the fusion site. Hardware failure rates may also be higher with the anterior than posterior approach. Increasing experience and newer hardware designs are reducing many of these problems.

The Combined Anterior-Posterior Approach. The combination approach uses an anterior approach first, which allows better correction of the problems. The fusion part of the operation is done with the posterior approach. This is a very long and complex procedure. It appears to be safe, however, and is proving to be useful, even in very young patients, for **preventing the crankshaft phenomenon. It may also be used to correct large rigid curves and for specific severe curves in the thoracic spine.**

Minimal Access Spinal Approach. Minimal access spinal technologies use a few small incisions and so are far less invasive than the standard so-called open approaches that require wide cuts. The technique uses endoscopy, in which the surgeon makes small incisions and inserts tubes that contain tiny instruments and cameras through the incisions in order to view and execute the procedure. In most cases, the procedure is done in two stages:

- First, an anterior approach is employed to remove disk material and loosen the spine.
- Secondly, a posterior approach is made for fusion and instrumentation.
- Recovery after surgery is rapid. Most patients are out of bed two days after surgery.
- Corrections are reaching 68% in some patients. There is a much more cosmetically appealing result (fewer and smaller scars) with endoscopy, and an easier recovery than with the more invasive approaches.

The endoscopic procedure for scoliosis is complicated and few surgeons can perform it yet. Currently, it is generally used only for single curves in the upper back or for patients with a curve in the upper back and a curve in the lower back that compensates for it. Some surgeons are now able to operate on areas below the diaphragm, including the lumbar spine. The patients must still wear a brace for three months afterward. Long-term studies are required to determine how outcomes compare to standard procedures.

(Review Report on Scoliosis-Surgery, 2008, in About.com)

Posterior instrumentation and spinal fusion in detail with pics

This procedure is most often done for idiopathic scoliosis, the most common type of scoliosis in children. They perform this operation under general anesthesia, so that your child won't feel it or remember it.

In this procedure, the deformed part of the spine is corrected and stabilized with two long metal rods. Each rod is placed on either side of the spinal midline (see Figure 12). To provide a permanent correction, they also perform spinal arthrodesis (fusion). Arthrodesis is the surgical fusion (welding) of the bones of a joint. In this operation, they use grafted bone, which can be taken from the patient's pelvis or ribs, or bone graft substitutes. Often, they use both — a combination of the patient's bone and a bone graft expander.

Before placing the rods, the surgeon shapes them to provide as normal as possible contours for the spine. Then, with the patient fully anesthetized in state-of-the-art operating rooms, they attach the rods to the spinal vertebrae (bones) with multiple anchors. The anchors are metal implants specially designed for attachment, and may be hooks, wires, or small screws. During the process of attaching the anchor implants to the contoured rods, the spine is gradually straightened (see Figure 13).

Near the ends of this segment of the spine, the two rods are linked together with cross-linking implants. This provides additional stability and permits early mobilization, usually without a brace.

Although the rods and other spinal implants can be removed, they generally are left in place unless there is a specific reason to remove them.

The medical team will explain any activity that needs to be restricted right after the surgery. Once healing has occurred, the implanted rods will not affect a patient's mobility. **Patients enjoy the ability to resume all normal activities including recreational sports.**

Fig.12 In posterior instrumentation and spinal fusion, the deformed part of the spine is corrected and stabilized with two long metal rods anchored to the spinal vertebrae. A patient with idiopathic scoliosis is shown. Note the unbalanced torso and the trunk shift to the right. Note also the asymmetry of the rib cage. (http://www.chop.edu/consumer/jsp/division/generic.jsp?id=77107)

Fig. 13 This shows hooks placed on the concave side of the curve prior to preparing the hook sites on the convex side. (http://www.chop.edu/consumer/jsp/division/generic.jsp?id=77107)

Fig.14 A rod is placed on either side of the spinal midline and a permanent correction, using spinal fusion, is performed. The spinal instrumentation and fusion have been completed. Correction has achieved a balanced torso, and it has improved the rib cage deformity. (http://www.chop.edu/consumer/jsp/division/generic.jsp?id=77107)

Anterior instrumentation and arthrodesis detailed with pics

With certain types of curves, the correction and spinal fusion is best done anteriorly — from the front of the patient. Recently, the use of anterior spinal correction has been **indicated for some thoracic curves, particularly those that are stiff or those with poor spinal balance.**

Suggestion of an anterior rather than a posterior approach would be if the curves that need correction are located in the lower spine (thoraco-lumbar and some lumbar curves). The advantage of anterior surgery is that with a complete discectomy (disc removal), stabilizing the spine with metal rods and performing fusion becomes a highly successful way of correcting the child's deformity. **The combined procedures help achieve an excellent correction and good frontal balance with a shorter segment of the spine than is possible with the standard posterior approach. A shorter segment means flexibility can be preserved.**

In this procedure, the child will be fully anesthetized in state-of-the-art operating rooms. The front of the spine is approached from the side (see Figure 15), either through the chest, flank or both. This allows for complete removal of the intervertebral discs in order to provide greatly increased spinal flexibility and better correction of the scoliosis. Following this, screws are placed across the vertebrae (see Figure 16). A contoured rod can then be inserted into the screw heads and manipulated to make the correction. The spinal fusion is accomplished by inserting small fragments of bone graft (see Figure 17), sometimes with a cage implant, into the empty disc space.

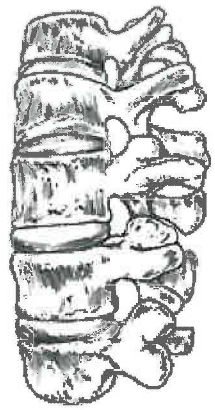


Fig. 15 **Anterior view**. In anterior instrumentation and arthrodesis, the surgeon approaches the front of the spine from the side, either through the chest, flank or both.
(http://www.chop.edu/consumer/jsp/division/generic.jsp?id=77107)

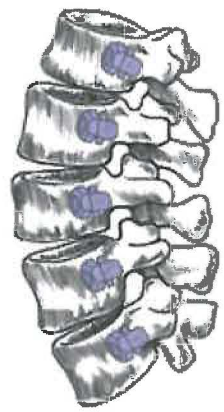


Fig.16 **Drawing with the screws in place**. The intervertebral discs are completely removed, providing greatly increased spinal flexibility and better correction of the scoliosis. Screws are then placed across the vertebrae.
(http://www.chop.edu/consumer/jsp/division/generic.jsp?id=77107)

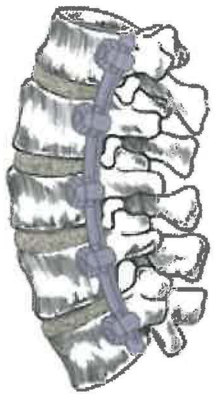


Fig. 17 **The screws and rod are in place.** The spine has been corrected. There is a bone graft in the disc spaces. The spinal fusion is accomplished by inserting small fragments of bone graft into the empty disc space. (http://www.chop.edu/consumer/jsp/division/generic.jsp?id=77107)

Anterior spinal release

Larger curves that are still flexible can generally be treated with posterior instrumentation and spinal arthrodesis (fusion) alone (see above). When the deformity is rigid, however, it does not respond as well to this method of correction. That's when the best treatment may be an anterior spinal release. This alternative will help provide flexibility for the child, and an improved ability to correct the deformity.

In this procedure, the child will be fully anesthetized in state-of-the-art operating rooms. Anterior release can be done as a conventional open surgical procedure or through an endoscope. The spine is approached from the front — through the side of the chest or flank. The intervertebral discs and restricting ligaments can be surgically released (cut), so that the stiffness of the deformity is relaxed. This allows improved correction and fusion (see Figure 19).

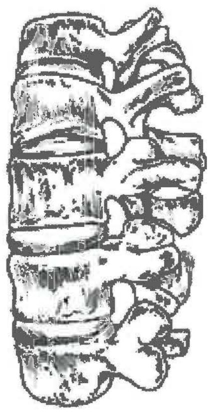


Fig.18 Drawing of the curved spine as the surgeon would see it. (http://www.chop.edu/consumer/jsp/division/generic.jsp?id=77107)

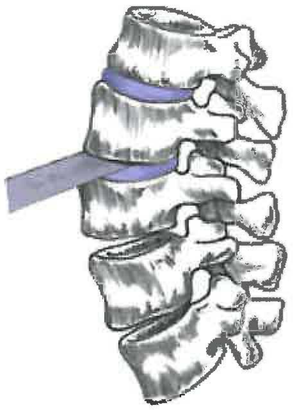


Fig.19 The discs are removed with surgical instruments. In an anterior spinal release, the invertebral discs and restricting ligaments can be surgically released (cut) to relax the stiffness of the deformity and provide improved correction and fusion. (http://www.chop.edu/consumer/jsp/division/generic.jsp?id=77107)

(Review of orthopaedic surgery, idiopathic scoliosis: surgical options, in The chidrens Hospital of Philadelphia, Jan 2008. In : http://www.chop.edu/consumer/jsp/division/generic.jsp?id=77107)

Potential risks and complications with scoliosis surgery

The most concerning risk with scoliosis surgery is paraplegia. It is very rare (about 1 in 1,000 to 1 in 10,000 chance) but is a devastating complication. To help manage this risk, the spinal cord can be monitored during surgery through one of two methods:

- *Somatosensory Evoked Potentials (SSEP's).* This test involves small electrical impulses that are given in the legs and then read in the brain. If there is the development of slowing of the signals during surgery this can indicate compromise to the spinal cord or its blood supply. Another way to monitor the cord is with *Motor Evoked Potentials (MEP's)*, and often both are used throughout a surgery.
- *Stagnara wake up test.* This test involves waking the patient during the surgery and asking them to move their feet. The patient does not feel any pain during this procedure and will not remember it afterwards.

If either of these tests indicates spinal cord compromise, the rods can be cut out and the surgery abandoned. Fortunately, this situation is extremely uncommon, and many procedures can be rescheduled if the patient is found to be neurologically intact after the surgery.

Another risk with scoliosis surgery is excessive blood loss. There is a lot of muscle stripping and exposed area during the surgery. With proper technique the blood loss can usually be kept to a reasonable amount and blood transfusions are rarely needed. As a precaution, many surgeons will ask the patient to donate his or her own blood prior to surgery (autologous blood donation), which can then be given back to the patient after the surgery. Also, during scoliosis surgery the patient's blood can be collected and transfused back to the patient.

Other potential risks and complications include:

- The rods breaking or the hooks or screws dislodging (although with modern instrumentation systems, this type of hardware failure is quite uncommon)
- Infection (less than 1%)
- Cerebrospinal fluid leak (rare)
- Failure of the spine to fuse (about 1 to 5%)
- Continued progression of the curve after surgery

(P Ullrich, October 2007)

Postoperative care

Following scoliosis surgery, patients can usually start to move around about 2 to 3 days after the surgery and when they start feeling better, and total hospital stay is usually about 4 to 7 days. Patients can return to school about 2 to 4 weeks after surgery, but their activity needs to be limited while the bone is fusing.

It is important to note that the more immobile the spine is kept the better it will fuse. Bending, lifting, and twisting are all discouraged for the first three months after surgery. For this reason, some surgeons will prescribe wearing a back brace for a period following the surgery. Any physical contact or jarring type activities are restricted for about 6 to 12 months after surgery.

Generally the patient will be monitored with intermittent examinations and x-rays for 1 to 2 years after the surgery. Once the bone is solidly fused no further treatment is required.

For the most part, patients can resume normal activity levels after a thoracic fusion since fusing the thoracic and upper lumbar spine does not change the biomechanics of the spine all that much. Female patients who have had a scoliosis fusion can still become pregnant and deliver babies vaginally.

(P. Ullrich, October 2007)

Revision (Salvage) Surgery

Patients may need corrective surgery called revision or salvage surgery, usually for one of four different reasons:

- Failure of the previous procedure.
- Curvature progression around the fusion site.
- Disk degeneration.
- Poor posture alignment.

Experimental Surgeries in Young People

Vertebral Body Stapling. Vertebral body stapling may eventually prevent curve progression in some young patients with curves less than 50 degrees. It involves stapling the convex (outer) curve of the anterior spine (the side of the spine facing the chest), which should stabilize and help reduce progression of the inner (concave) curve. The procedure uses a special metal device that is clamp-shaped at body temperature but can be straightened when subjected to cold temperatures and inserted into the spine. When it is warmed up, the staple returns to its clamp shape and supports the spine. Currently this is only being performed at one center.

(Review Report on Scoliosis-Surgery, 2008, in About.com)

2.1.2 Diagnostic techniques

Exams and Tests for Scoliosis

As soon as you think that you or the child has scoliosis, the better he/she visits a doctor. Early diagnosis and treatment is the best way to prevent curve progression.

For some parents and children, it's a school nurse who first notices the scoliosis.. The nurse generally uses the Adam's Forward Bending Test. With that, the child bends forward at the waist and reach his or her arms straight outward, positioned as though diving into a swimming pool. This usually reveals abnormalities, such as a rib hump or an incorrect shape of the back.

The Adam's Forward Bending Test helps identify an unusual curve, but it can't tell you how severe the curve is. For that, you'll need to go to a doctor. Using different tests, the doctor will be able to see and measure the curve:

- **Plumb line test:** This is a quick visual check to see if the spine is straight. In scoliosis, the plumb line will fall to the left or right of the spine instead of through the middle of the buttocks.

- **Scoliometer:** If the doctor sees a rib hump, he or she can use a scoliometer to measure the size of the hump. It's a painless and non-invasive test. (fig.15)

- **X-ray:** An x-ray can help the doctor confirm scoliosis by showing exactly where the scoliosis affects the spine and the extent of the curve.
- **Risser Sign** looks at the iliac crest growth plate, a fan-shaped part of the pelvis. The crest fuses with the pelvis at maturity (http://www.spineandscoliosis.com/subject.php?pn=idiopathic-scoliosis-009)
- **Cobb angle measurement**: This test uses a full-length anterior to posterior x-ray to calculate the angle of the curve(s) (Only shows a two dimensional view of scoliosis)
- **Nash moe** A technique used to measure vertebral rotation. The rotation of the vertebral pedicle is measured by dividing the vertebral body into segments. (http://www.spineandscoliosis.com/subject.php?pn=idiopathic-scoliosis-009)
- **Moire topography** A method of three-dimensional morphometry in which contour maps are produced from the overlapping interference fringes created when an object is illuminated by beams of coherent light

issuing from two different point sources. One source is light and second is camera (http://www.biology-online.org/dictionary/Moire_topography)

- **Lenke classification** The System helps surgeons to determine what levels of the spine to fuse and instrument. It has already been mentioned earlier
- **Photogrammetry** is the first remote sensing technology ever developed, in which geometric properties about objects are determined from photographic images (wikipedia)

Fig.20 Scoliometer (Scoliometer, http://www.komkare.com/diagnostics/misc_meas/scoliomtr.html)

If needed, the doctor will order x-rays of the entire spine. The x-rays will capture pictures of the front, back, and sides of the spine. Sometimes, bending x-rays are ordered to help your doctor see the normal and abnormal curves.

Using an x-ray (or sometimes an MRI or a bone scan) of the spine, the doctor can calculate the severity of the curve. This is done with the Cobb method. That puts the curve in terms of degrees. Curves greater than 25° to 30° are considered significant; if it's greater than 45° to 50°, it's called severe.

The doctor will also do physical and neurological exams. In the physical exam, the doctor will observe posture, range of motion, and physical condition, noting any movements that cause pain. Your doctor will feel the spine, note its curvature and alignment, and feel for muscle spasm. During the neurological exam, the doctor will test reflexes, muscle strength, other nerve changes, and pain spread. This is all to get a better picture of your general health (or your child's).

For children, the doctor will also want to determine the child's skeletal maturity (i.e., how much growing he or she has left to do). The doctor may use an x-ray to determine the skeletal age. That's an important thing to know because how much growing a child has left to do determines scoliosis treatment options. To figure out the skeletal age, the doctor can order a wrist x-ray and compare that to the Greulich and Pyle standard classification. By comparing the results of the wrist x-ray to a national standard, the doctor can decide how much growth is left and if the scoliosis is likely to progress.

Also to help determine skeletal maturity, the doctor will want to know the age of onset of puberty (for boys) and the age of onset of menstruation (for girls).

Throughout all these exams and tests, the doctor is looking for two main things: the severity of the scoliosis and the cause. Both help determine the treatment plan.

(Review on exams and tests for scoliosis, 2008
In:http://www.spineuniverse.com/displayarticle.php/article4145.html)

Cobb's angle:

Cobb's angle, a measurement used for evaluation of curves in scoliosis on an AP radiographic projection of the spine (Fig.1). When assessing a curve the apical vertebra is first identified; this is the most likely displaced and rotated vertebra with the least tilted end plate. The end/transitional vertebra are then identified through the curve above and below. The end vertebra are the most superior and inferior vertebra which are least displaced and rotated and have the maximally tilted end plate. A line is drawn along the superior end plate of the superior end vertebra and a second line drawn along the inferior end plate of the inferior end vertebra. If the end plates are indistinct the line may be drawn through the pedicles. The angle between these two lines (or lines drawn perpendicular to them) is measured as the Cobb angle. In S-shaped scoliosis where there are two contiguous curves the lower end vertebra of the upper curve will represent the upper end vertebra of the lower curve. Because the Cobb angle reflects curvature only in a single plane and fails to account for vertebral rotation it may not accurately demonstrate the severity of three dimensional spinal deformity. As a general rule a Cobb angle of 10 is regarded as a minimum angulation to define scoliosis. (Oldnall Nick, Review of Cobbs angle, March 2008) It is important to say that Cobb's angle only give us a two dimensional view of scoliosis and does not measure rotation of the spine. It is not really useful for physioherapy.

Measuring Cobb's Angle

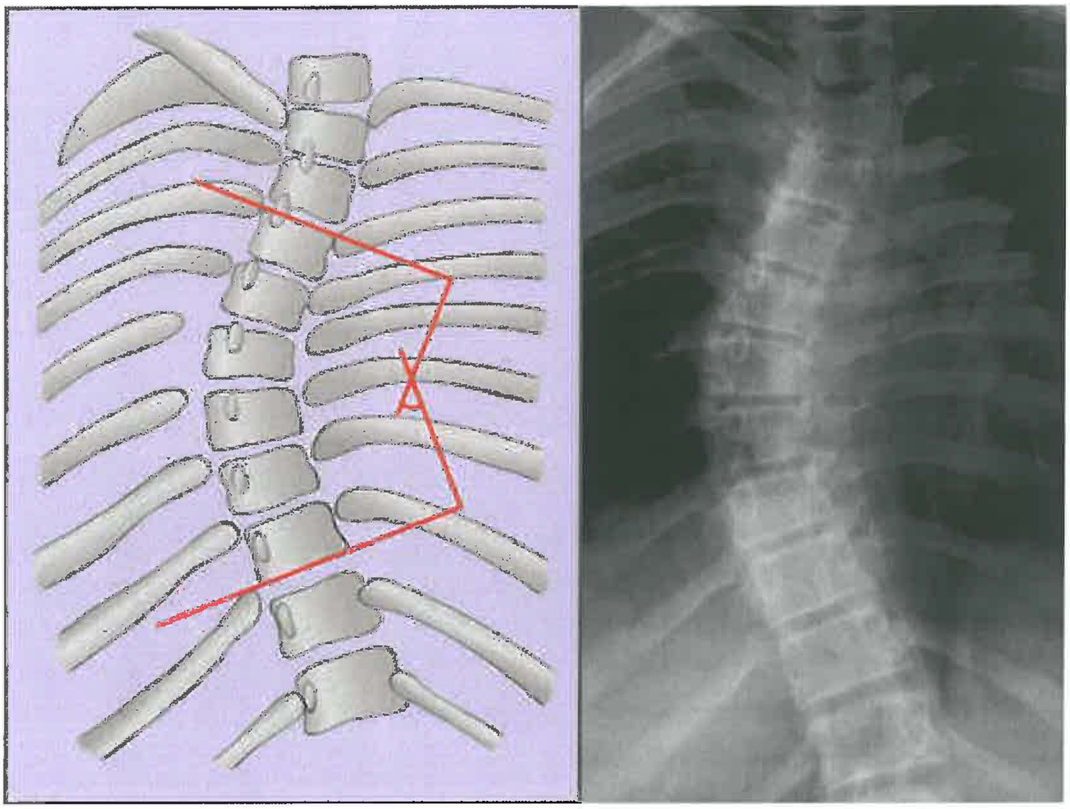


Fig 21 Cobb's Angle and Xray (Oldnall Nick, Review of Cobbs angle, March 2008)

Photogrametry

Photogrammetry is the first remote sensing technology ever developed, in which geometric properties about objects are determined from photographic images. Historically, photogrammetry is as old as modern photography itself, and can be dated to mid-nineteenth century.

In the simplest example, the three-dimensional coordinates of points on an object are determined by measurements made in two or more photographic images taken from different positions (see stereoscopy). Common points are identified on each image. A line of sight (or ray) can be constructed from the camera location to the point on the object. It is the intersection of these rays (triangulation) that determines the three-dimensional location of the point. More sophisticated algorithms can exploit other information about the scene that is known *a priori*, for example symmetries, in some cases allowing reconstructions of 3D coordinates from only one camera position.

Photogrammetry is used in different fields, such as topographic mapping, architecture, engineering, manufacturing, quality control, police investigation, and geology, as well as by archaeologists to quickly produce plans of large or complex sites and by meteorologists as a way to determine the actual wind speed of a tornado where objective weather data cannot be obtained. It is also used to combine live action with computer generated imagery in movie post-production; *Fight Club* is a good example of the use of photogrammetry in film (details are given in the DVD extras).

Algorithms for photogrammetry typically express the problem as that of minimizing the sum of the squares of a set of errors. The minimization is itself often performed using the Levenberg-Marquardt algorithm (also known as bundle adjustment).

Photogrametry methods

Photogrammetry uses methods from many disciplines including optics and projective geometry. The data model on the right shows what type of information can go into and come out of photogrammetric methods.

The *3D co-ordinates* define the locations of object points in the 3D space. The *image co-ordinates* define the locations of the object points' images on the film or an electronic imaging device. The *exterior orientation* of a camera defines its location in space and its view direction. The *inner orientation* defines the geometric parameters of the imaging process. This is primarily the focal length of the lens, but can also include the description of lens distortions. Further *additional observations* play an important role: With *scale bars*, basically a known distance of two points in space, or known *fix points*, the connection to the basic measuring units is created.

Each of the four main variables can be an *input* or an *output* of a photogrammetric method.

Photogrammetry has been defined by ASPRS (American Society of Photogrammetry and Remote Sensing) as the art, science, and technology of obtaining reliable information about physical objects and the environment through processes of recoding, measuring and interpreting photographic images and patterns of recorded radiant electromagnetic energy and other phenomena.

(Review of photogrammetry in Wikipedia, 2008)

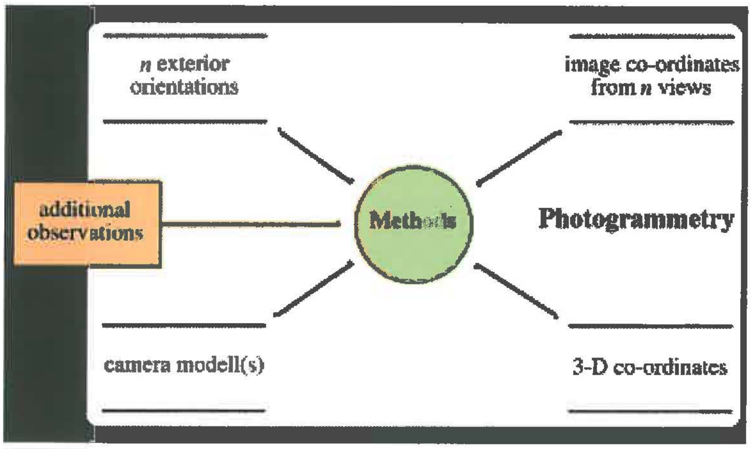


Fig.22 Photogrammetry (http://en.wikipedia.org/wiki/Photogrammetry)

In physiotherapy the concept used is that two cameras are snapping the object and a three dimensional picture is reconstructed, also used as non a invasive tactic. Also you can test the patient in all positions, wheras in MRI only lying position is mostly used since vertical apparatus is only found in select places in the world. (Otahal, 2008)

Moire topography

A method of three-dimensional morphometry in which contour maps (shades) are produced from the overlapping interference fringes created when an object is illuminated by beams of coherent light issuing from two different point sources. (Moire topography definition, 1998) One source is light and second is camera. (Kaczmarska, 2007) It is very useful in physiotherapy , it is a cheap instrumentation where two cameras are in 1m distance and it can be used during physiotherapeutic practice.

The closer the lines the steeper it is. The further the lines the change of depth is not so steep. From the shape we can estimate dysbalance. We can observe saggital plane in 3D, anteroposterior and lateral views. (Kaczmarska, 2007) **It is necessary to have instruments that detect dynamical changes.**

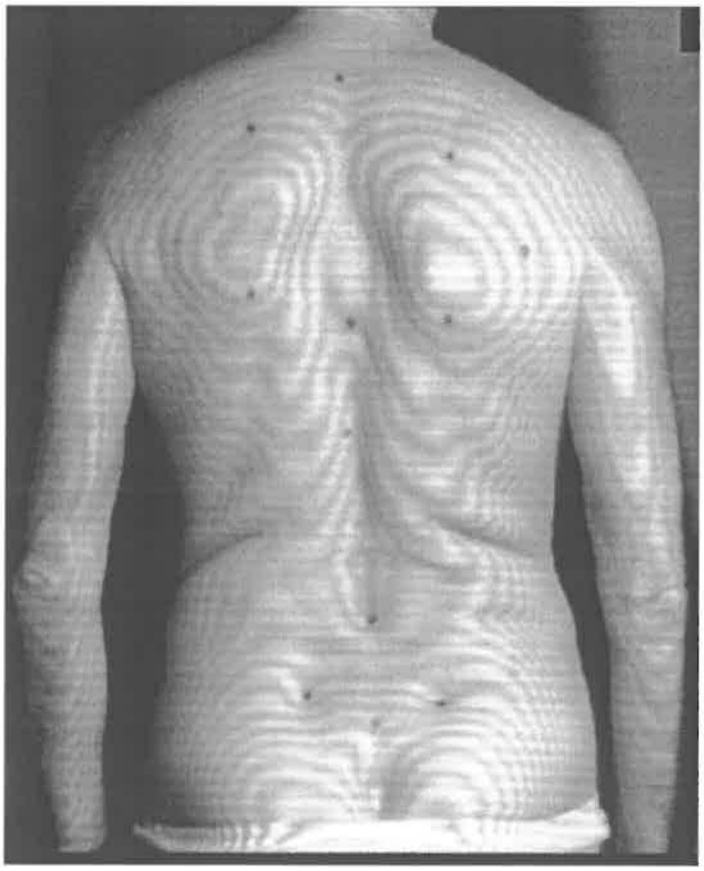
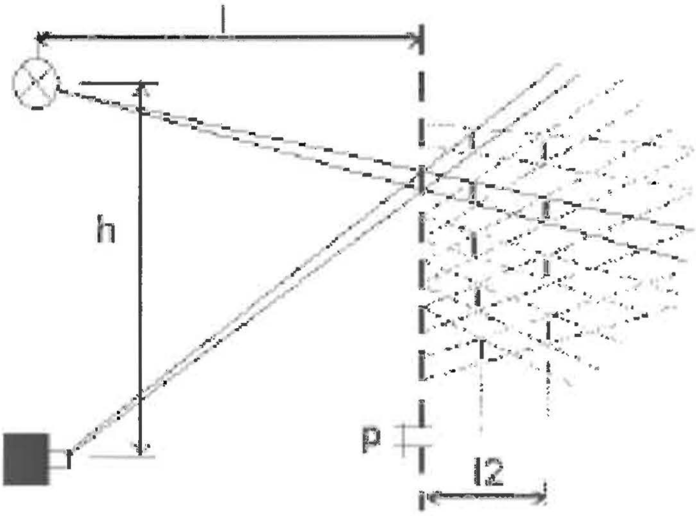


Fig. 23 Here you see a person under Moire Topography. You can see the differences in scapula positions, as well as rotations of the spine and trunk can be estimated since this gives us a three dimensional view in all axes (Otahal, 1989)



Vznik vrstevnicového obrazu moiré proužků
(h vzdálenost kamera-světlo, l vzdálenost mřížky, p rozteč mřížky, l2 hloubka druhé vrstevnice)

Fig. 24 Here is the apparatus where on the top left you can see the light beam, on the right side is the object and the reflexion goes to the camera on the bottom right; the camera is at an angle to the patient and both light from camera and light source helps us to see what we see (Otahal, 1989)

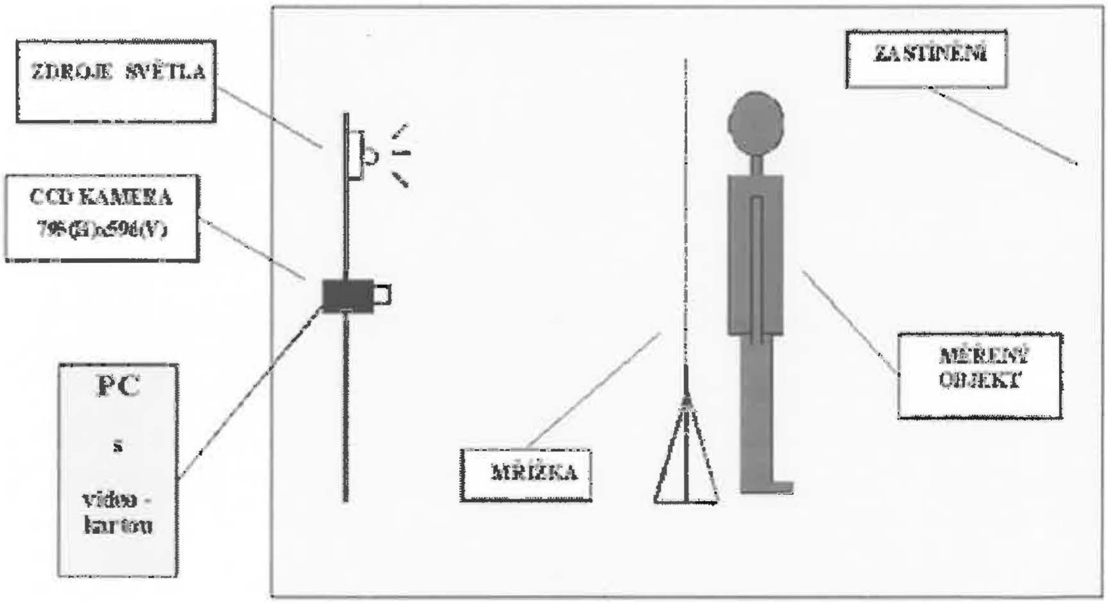


Fig. 25 The apparatus from a 2D sideview (Otahal 1989)

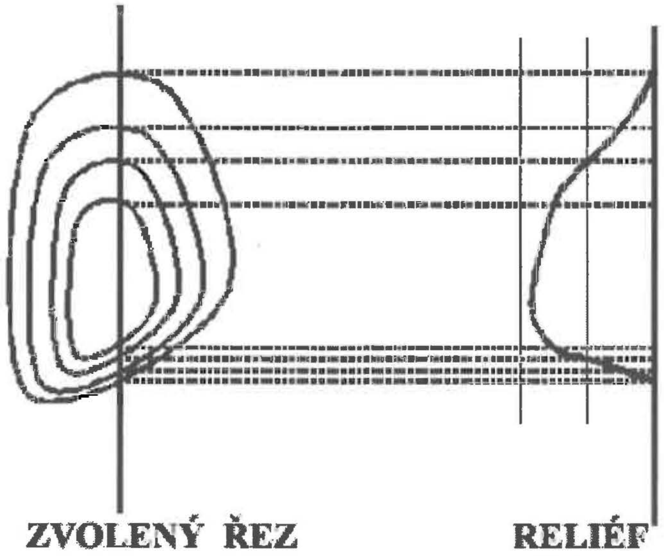


Fig. 26 Principle of the topography reconstruction of the chosen slice (Otahal, 1989)

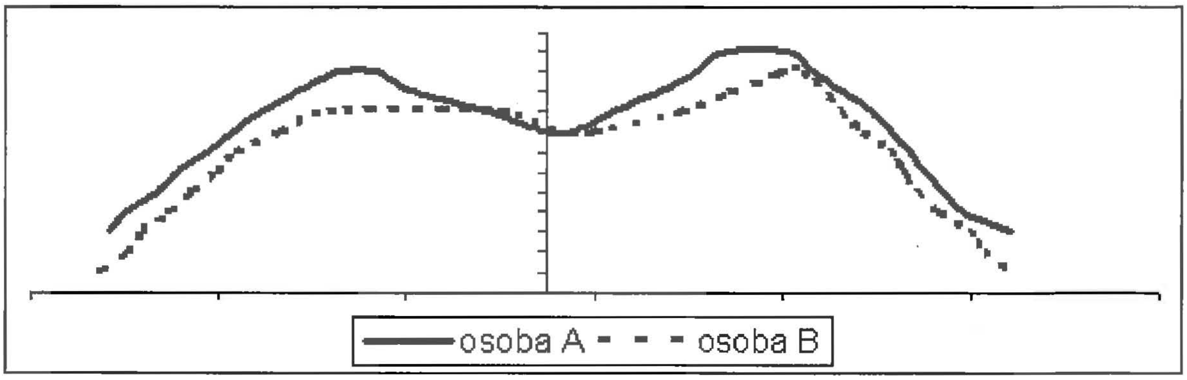


Fig. 27 Reconstruction of the horizontal relief at Th 5 level (2 patients A and B) (Otahal 1989)

Surface topography:

Surface topography is used as a non invasive acquisition of the external trunk geometry of adolescent idiopathic scoliosis (AIS). Inspeck 3D digitizers are used to acquire the external without-brace and with-brace trunk of patients. On both acquisitions, anatomical landmarks are identified. Using landmark based elastic registration, the in-brace surface is obtained by transforming the without-brace trunk into the with-brace trunk. To quantify the external trunk correction, indices of torso asymmetry are extracted from the without-brace and the in-brace surface. The external correction is then correlated to thoracic and vertebral rotations determined from three-dimensional reconstruction of the spine and rib cage from multiple Xray images. The proposed approach is a first step in establishing reliable non invasive and radiation free follow up for brace treatment while providing a quantitative three-dimensional measure of the external correction. (N. Shawfaty et al 2007, Coillard C. 2002)

A study was designed to determine whether surface topography would reflect Cobb angle status with sufficient reliability to permit it's safe use as an alternative means of documentation in some circumstances (In this case 59 scoliotic patients).

The summary of the background data where the following: Surface topography offers the possibility of describing spinal deformity more fully than radiographic measures alone. (Goldberg et al 2001) In the results there was a significant correlation between Cobb angle and Quantec(system used for measuring) spinal angle. A significant change in Cobb angle could be identified by associated change in at least one topographic measure in a significant proportion of cases. The conclusions where, that it is unlikely that topography will supplant radiography for the ascertainment of Cobb angles, because the error margins of both are wide, and the two are not measuring the same aspect of the deformity. The Quantec system is useful in patient monitoring as an alternative to radiography, without diminishing the standard of care. Also was found that, while a significant change in Cobb angle was always accompanied by a meaningful change in at least one topographic parameter, the pattern of shape change was highly individual. It is concluded that deformity in scoliosis is not determined exclusively by the spinal curve. (Goldberg et al, 2002)

2.1.3 Clinical Testing

Examination Description

Physical assessment The physician looks for asymmetry of the trunk such as uneven shoulders or hips, humpback, or listing to one side.

Cardiopulmonary testing of the function of the heart and lungs.

Adam's Forward Bending Test: The patient bends forward at the waist, with arms extended forward. The physician looks for asymmetry thoracic prominence (such as a shoulder blade), or a lumbar prominence.

Leg length: Both legs are measured to determine if they are of equal length.

Plumb line: A plumb line is "dropped" from the C7 vertebra (in the neck) and is allowed to hang below the buttocks. In scoliosis the line does not hang between the buttocks.

Range of motion The physician measures the patient's ability to perform flexion, extension, bending, and rotation movements.

Palpation: The physician "feels" for abnormalities. Perhaps the ribs are more prominent on one side.

Neurological assessment In addition to testing reflexes, the physician will want to know if the patient's symptoms include pain, numbness, tingling, extremity weakness or sensation, muscle spasm, and bowel/bladder changes.

Clinical evaluation focuses on history and physical examination findings. Consideration is given to circumstances surrounding the patient's birth, delivery and development histories. Was the pregnancy full term? What was the child's birth weight? When did the child begin to walk?--are some of the important guide posts which are sought. Abnormalities in these areas may lead one to consider neuromuscular or congenital etiologies. With congenital anomalies, if one congenital anomaly is found, others are sought, e.g., kidney abnormalities are often associated with congenital scoliosis. Intermittent backache may occur with idiopathic scoliosis, but complaints of pain radiating into the legs, night pain, or systemic complaints (for example changes in bowel or bladder habits) are highly abnormal and are not common complaints in patients with idiopathic scoliosis and usually require further study. A family history of spinal deformity is looked for since certain types of spinal deformity are more prevalent within families.

Physical examination centers on assessment of trunk symmetry. The Adam's forward bend test is done with the patient bending forward with arms extended and knees straight. Asymmetry of the trunk when viewed from the front or the back as well as abnormal increases or decreases in lordosis or kyphosis when viewed from the side are assessed (Fig.28). This test is used during school screening for scoliosis. The test is sensitive to detect trunk asymmetry but it is not specific for spinal deformity. A common finding that is often misinterpreted as spinal deformity is truncal asymmetry from unequal trunk muscle development on the patient's dominant hand side.

(Clinical review of Scoliosis, 2007)

Figure 28 Adam's Bend Test - clinical (Frontal view)
(http://www.spineuniverse.com/displayarticle.php/article1499.html)

Further physical findings depend on the patient's deformity location and magnitude. Shoulder heights may be uneven and there may be an increased space between the elbow and trunk because of trunk deviation (Fig.29). Prominence of a "hip", pelvis or breast may be seen. Examination of the skin overlying the spine assesses the presence of dimples, sinuses, hairy patches and skin pigmentation changes. The effect of any limb length inequality is tested with the patient standing on blocks to level the pelvis or seated on a flat surface. Neurological examination includes evaluation of the function of the muscles and nerves of the upper and lower limbs. (Clinical review of Scoliosis, 2007)

Figure 29 Scoliosis - clinical (Posterior view) (http://www.spineuniverse.com/displayarticle.php/article1499.html)

Radiographic Imaging

Initial imaging evaluation of a patient suspected of having scoliosis is by a standing posterior-anterior thoracolumbar spine radiograph done on a single long film. Modern radiographic techniques minimize radiation exposure (Fig.30).

A standing side view radiograph of the thoracolumbar spine is suggested if significant deformity is present in the front-to-back (sagittal) plane. Radiographs are assessed for spinal column contour and to rule out congenital, developmental, degenerative or neoplastic abnormalities. The amount of each deformity is calculated using a standard, reproducible measurement technique. An estimate of skeletal maturity is made by assessment of the growth areas at the upper pelvis and hips (Fig.31).

Figure 30. Screening PA erect (http://www.spineuniverse.com/displayarticle.php/article1504.html)

Figure 31. Risser's sign and triradiate cartilage status
(http://www.spineuniverse.com/displayarticle.php/article1504.html)

Specialized imaging studies such as (CT scans or magnetic resonance imaging (MRI)) may occasionally be needed. Magnetic resonance imaging is done to evaluate the spinal cord and spinal nerves (Fig.32).

As with all studies, MRI is done for a specific indication and correlated with clinical examination. MRI detects skeletal deformation in relation to bones,muscles and ligaments. Myelography, a radiographic study which uses an injected dye to provide contrast to study the spinal canal and its contents, has been largely replaced by magnetic resonance imaging techniques. CT scans are used to provide improved definition of abnormalities of vertebral size, shape or number (Fig.33).

(Review of Radiographic Imaging for scoliosis, in Spine Universe, April 2006)

Figure 32. Lateral T-L spine (http://www.spineuniverse.com/displayarticle.php/article1504.html)

Figure 33. Congenital lumbar
scoliosis - 3D CT reconstruction (http://www.spineuniverse.com/displayarticle.php/article1504.html)

Additionally, if the child has congenital scoliosis, the surgeon may order two more tests: a renal sonogram to test the kidneys and an echocardiogram to test the heart. Because congenital scoliosis comes from a developmental problem in utero, there are often problems with other major organ systems that develop at the same time (third to sixth week of the pregnancy). By ordering a renal sonogram and an echocardiogram, the surgeon is trying to make sure that your child's body is strong enough to undergo surgery. (Surgery for scoliosis, 2008)

Non-Surgical Treatment

Some cases of AIS can be treated non-surgically and others require surgical intervention.

Small curves (those less than 15-20 degrees) are observed for possible progression over a period of time. At this stage, no specific treatment is needed. Larger curves (those between 20-40 degrees) will require bracing to prevent further progression of the curve.

Some adolescents find wearing the brace 16 to 23 hours every day difficult. Braces can be uncomfortable, unattractive, hot, and can make a child self-conscious even though well disguised under clothing. However, when bracing works and surgery is avoided, the commitment required is worthwhile. At this point a carefully designed exercise program may also be recommended.

Unfortunately, some curves do not respond to bracing. Cervicothoracic curves (from the middle of the back up into the neck) and curves greater than 40 degrees tend not to respond well to bracing. Also, older patients who are closer to skeletal maturity may not respond to bracing.

Surgical Treatment

Surgery may be recommended for curves in excess of 40 degrees. Surgery for scoliosis involves special surgical implants such as rods, hooks, screws, and wires. The goal is to straighten and balance the spine and secure it in place (fusion) so curve progression stops while skeletal maturity is reached. Surgery does not cure scoliosis; it is simply a way to correct the curve and manage the progression of the disease to avoid greater deformity.

Spine surgeons utilize various surgical procedures to treat AIS. The overall goals are always the same, but the techniques and instrumentation used will vary from case to case. Your surgeon may perform the procedure from the front (anterior) or from the back (posterior). He may even make extensive use of minimally invasive techniques.

Small Conclusion

Left untreated, adolescent idiopathic scoliosis can cause significant physical deformity, debilitating pain, and psychological distress. However, proper treatment and care for AIS can prevent further curve progression and stabilize the spine while your child grows. Your spine surgeon can discuss the risks and benefits of different treatment options with you, so that both you and your child are well informed.

(Adolescent Idiopathic Scoliosis, in Scoliosisassociates, 2008)

2.1.4 Influence of technology: Aspects of implant and brace technologies

Bracing for Scoliosis

Bracing is designed to stop the progression of the spinal curve, but it does not reduce the amount of angulation already present. The majority of curve progression happens during a child's growth phase, and once the growth has ended, there is little likelihood of progression of a curve. Therefore, bracing is continued until the child is skeletally mature and finished growing.

Curves that tend to continue to progress after skeletal maturity are those that are greater than 50 degrees in angulation, so the treatment objective is to try to get the child into adulthood with less than a 50 degree curvature.

There are two types of commonly used scoliosis braces: a thoracolumbar sacral orthosis (TLSO) and a Charleston bending brace.

- The TLSO is a custom molded back brace that applies three-point pressure to the curvature to prevent its progression. It can be worn under loose fitting clothing, and is usually worn 23 hours a day. This type of scoliosis brace can be taken off to swim or to play sports.
- A Charleston bending back brace applies more pressure and bends the child against the curve. This type of scoliosis brace is worn only at night while the child is asleep.

Since bracing only works to stop the progression of the curvature in a growing child, it is not used for those children who are already skeletally mature or almost mature. It is only used for younger children (e.g. girls who are about 11 to 13 years old, and boys who are about 12 to 14 years). If an older child has a curve greater than 30 degrees and is almost mature, his or her curvature will be treated with observation only, as there is little growth left and bracing will be unlikely to do much good.

Unfortunately, even with appropriate bracing, some scoliosis spinal curves will continue to progress. For these cases, especially if the child is very young, bracing may still be continued to allow the child to grow before fusing the spine.

(P Ullrich, October 2007)

1. Thoraco-Lumbo-Sacral-Orthosis (TLSO)

The most common form of a TLSO brace is called the "Boston brace", and it may be referred to as an "underarm" brace. This brace is fitted to the child's body and custom molded from plastic. It works by applying three-point pressure to the curvature to prevent its progression. (See Figure 34.)

It can be worn under clothing and is typically not noticeable. The TLSO brace is usually worn 23 hours a day, and it can be taken off to swim, play sports or participate in gym class during the day.

This type of brace is usually prescribed for curves in the lumbar or thoraco-lumbar part of the spine

Thoracolumbosacral orthosis

Fig. 34 TLS orthosis (http://www.spine-health.com/Conditions/Scoliosis/Bracing-Treatment/Types-Of-Scoliosis-Braces.html)

2. Cervico-Thoraco-Lumbo-Sacral-Orthosis (known as a Milwaukee brace)

The Milwaukee brace is similar to the TLSO described above, but also includes a neck ring held in place by vertical bars attached to the body of the brace.

It is usually worn 23 hours a day, and can be taken off to swim, play sports or participate in gym class during the day.

This type of brace is often prescribed for curves in the thoracic spine.

3. Charleston Bending Brace

This type of brace is also called a "nighttime" brace because it is only worn while sleeping. A Charleston back brace is molded to the patient while they are bent to the side, and thus applies more pressure and bends the child against the curve. This pressure improves the corrective action of the brace. (See Figure 35)

This type of brace is worn only at night while the child is asleep. Patients can go to school and participate in sports normally without their friends even knowing they have scoliosis and wear a brace, avoiding any potential negative stigma.

Many studies have shown that the Charleston Night time brace is as effective as the above-described 23-hour-a-day brace wear.

Curves must be in the 20 to 40 degree range and the apex of the curve needs to be below the level of the shoulder blade for the Charleston brace to be effective.

(McAfee P, 2002)

Fig.35 Charleston nighttime orthosis (http://www.spine-health.com/Conditions/Scoliosis/Bracing-Treatment/Types-Of-Scoliosis-Braces.html) (McAfee P, 2002)

Back braces (after fusion operation)

Motion of the lumbar (lower) spine can delay healing in fractures or in post-operative fusions. Limiting the motion of the spine enhances the healing process for bone in both conditions, and will also usually decrease the patient's low back pain and discomfort.

Two types of back braces are commonly used to limit the motion in the spine:

- Rigid braces
- Corset braces (elastic braces)

1. Rigid braces

Rigid braces, such as Boston Overlap braces or Thoracolumbar Sacral Orthosis (TLSO), are form-fitting plastic braces). Provided that the rigid brace is well fitted, it is able to limit approximately 50% of the motion in the spine. Fractures (or broken bones) can often be treated with a rigid brace and may also be used after a fusion surgery.

Rigid braces are heavy and hot and tend to be relatively uncomfortable for patients. They should be worn when the patient is up, but may be removed when lying down.

2. Corset braces (elastic braces)

A corset brace is sometimes recommended to limit motion of the spine after a lumbar fusion. The brace helps limit motion in the back while the fusion sets up by not allowing the patient to bend forward. Bone grows better where there is little motion, and especially in cases where no instrumentation (devices to aid in stability) is used, a back brace can be helpful in obtaining a solid fusion.

People with jobs that involve heavy lifting also sometimes wear corset braces. These braces essentially work by limiting motion and acting as a reminder to use proper body posture when lifting. With the corset brace, one needs to lift with the back straight (not bent forward), using the large leg muscles to do the lifting.

(P Ullrich, 1999)

Conclusion to bracing treatment for scoliosis

Currently, the spine medical community advocates bracing as the only non-surgical treatment for idiopathic scoliosis. The objective of bracing treatment is to prevent the curve from progressing as the child grows, and studies have shown bracing is effective in stopping the progression of the majority of adolescent scoliotic curves.

There are a number of bracing options, and the physician will recommend a particular back brace and bracing schedule based on factors such as the location of the child's curve and degree of curvature. Compliance with wearing the back brace as prescribed is clearly vital to the success of bracing treatment.

Unfortunately, even with appropriate bracing, some spinal curves will continue to progress. Early on it is very difficult to tell which curves will be aggressive and continue to progress, and which curves will not continue to progress.

If the curve continues to progress to 40 - 45 degrees or more, then a spinal fusion surgery will usually be recommended. However, even if surgery eventually becomes necessary, the back brace can still be beneficial by helping delay the progression of the curvature and allowing the child to grow more before having a spinal fusion (which stops the growth of the spine).

(McAfee P., 2002)

Intervertebral components overview

1. Scoliosis surgery from the back (posterior surgical approach)

This approach to scoliosis surgery is done through a long incision on the back of the spine (the incision goes the entire length of the thoracic spine)

- After making the incision, the muscles are then stripped up off the spine to allow the surgeon access to the bony elements in the spine

- The spine is then instrumented (screws are inserted) and the rods are used to reduce the amount of the curvature
- Bone is then added (either the patient's own bone, taken from the patient's hip, or cadaver bone), which in turn incites a reaction that results in the spine fusing together.
- This fusion process usually takes about 3 to 6 months, and can continue for up to 12 months.

For patients who have a severe deformity and/or those who have a very rigid curvature, an **anterior release** of the disc space (removal of the disc from the front) may first be required. This involves approaching the front of the spine either through an open incision or with a scope (thoracoscopic technique) and releasing the disc space. After the discs at the appropriate levels of the spine have been removed, bone (either the patient's own bone and/or cadaver bone) is added to the disc space to allow it to fuse together.

Removing the discs allows for a better reduction of the spine and also results in a better fusion. This is especially important if the patient is a young child and has a lot of growth left. If just the posterior portion of the spine is fused, the anterior column can continue to grow, and loss of reduction can result ("crankshafting"). Fusing the spine anteriorly prevents this process.

(P Ullrich, 2007)

2. Scoliosis surgery from the front (anterior surgical approach)

For curves that are mainly at the thoracolumbar junction (T12-L1), the scoliosis surgery can be done entirely as an anterior approach.

- This approach to scoliosis surgery requires an open incision and the removal of a rib (usually on the left side). Through this approach the diaphragm can be released from the chest wall and spine, and excellent exposure can be obtained for the thoracic and lumbar spinal vertebral bodies.
- The discs are removed and this loosens up the spine.
- Screws can then be placed in the vertebral bodies and a reduction of the curvature obtained and held with a rod.
- Bone is added to the disc space (either the patient's own bone, taken from the patient's hip, or cadaver bone), to allow the spine to fuse together.
- This fusion process usually takes about 3 to 6 months, and can continue for up to 12 months.

The advantage of a purely anterior approach to scoliosis surgery in the appropriate curves is that not as many lumbar vertebral bodies will need to be fused and some additional motion segments can be preserved. Saving some of the motion is especially important for lower back curves (lumbar spine), because if the fusion goes below L3 there is a higher risk of later back pain and arthritis. Saving lumbar motion segments helps prevent loading all the stress on just a few motion segments.

Another advantage is that the anterior approach to scoliosis surgery can sometimes allow for a better reduction of the curve and a more favorable cosmetic result.

The major disadvantage of the anterior approach is that it can only be done for thoracolumbar curves, and most scoliotic curves are in the thoracic spine.

(P Ullrich, 2007)

2.1.5 Therapeutical possibilities: Usable techniques of approach of physiotherapy and rehabilitation using literature and experience from the field

Managing Scoliosis before and after surgery

For anyone, exercise has many health benefits and is important for maintaining strength and muscle tone and stabilizing weight. Early studies did not find any reduction in or slowing of progression of curves with exercise. Few were performed, however, and researchers in Germany are suggesting that such studies were done before specific exercises were developed that might be helpful. Some centers claim that an in-patient program with exercise-based therapies can reduce progression. In one German study, patients with an average curvature of 27% showed less progression after physiotherapy than that expected in patients with no treatment.

Stretching exercises may be beneficial in children whose scoliosis is due to uneven leg lengths or a shortened tendon.

Alternative Nonsurgical Procedures

Strengthening the Muscles That Turn the Torso. A promising approach focuses on training and strengthening the muscles that turn the torso. Studies using specific equipment (e.g., MedX Torso Rotation machine) are showing promise. In a 2003 California study, 16 of the 20 patients study experienced curve reduction and no curves progressed. In an earlier study, patients increased strength from 12% to 40%. One girl with a severe lumbar curve required surgery, but there was no progression of curvature in the remaining 11 patients, and four of the patients experienced a reduction in their curvature. No braces were used. Clinical trials using this approach are underway in California, Maryland, Missouri, and Tennessee. Exercising the torso to build muscle strength is important, in any case, in conjunction with braces.

ASCO Scoliosis Treatment Method. ASCO Scoliosis Treatment Method is a Russian approach that consists of isometric and stretching exercises, vibration, spinal manipulation, and electrical muscle stimulation. Some US centers are reporting success in halting curve progression but more research is needed to determine possible benefits. (before any surgery)

Biofeedback. Biofeedback has been investigated on the premise that being given a signal to improve ones posture when slumping may reduce spinal deformities in some cases. (Some experts believe that braces work only because the young patients self-correct their curves by retraining their posture to avoid the discomfort of the brace.)

Chiropractic Care. There are numerous case reports that chiropractic manipulation of the spine may help stop progression of mild curves. However, no rigorous studies have been done to prove this. One small 2001 study reported no benefits from chiropractic in girls with spinal curves less than 20 degrees. (About 80% of such curves will not progress significantly without any treatment.) (before any operation)

(Review Report on Scoliosis- Managing scoliosis, In about.com, 2008)

Improving Lung Function

Breathing Exercises. Breathing exercises may help improve lung function in children with scoliosis and signs of lung problems. (before and after operation possible) For these breathing exercises is recommended assymetric spinal exercises in conjuction with breathing used for stabilization of the pelvic girdle and spine (Vele, 2008).Symmetric spinal exercises are not used for stabilization and are used for prevention of vertebral disorders. Hence the spine is already stabilized in our problem, but breathing exercises train also breathing depth and muscle force necessary; Otherwise for example in crying there is a lot of breathing but no muscle force so it leads to cramps. (Vele, 2008) We also know that in some cases of scoliosis operations of the anterior approach, there were in some cases of chest cage disruptions impairing pulmonary functions in the long run. Thereby it's good to check breathing exercises with these patients. I suggest a future research be done on this.

Buteyko: It is a non medical way of treatment for breathing disorders. The base is directed on mechanism of development of asthma and of allergies, rhinitis, hypertonia, stenocardia and a range of other diseases. It allows in several minutes to stop breathlessness (stop of breathing) during asthma, to stop coughing and remove allergical syndromes It helps eliminate allergy or rhinitis stuffiness in nose and to remove the most important symptoms of the diseases and the most important is to stop the developing of attacks in the future without using any medicine. It also helps to gradually stabilize metabolism, improve immunity and get rid of the disease (i.e. achieve the steady prolonged remission). (Vladimir Konstantinovich Buteyko and Marina Mihaylovna Buteyko, 1999) It may be used in postoperative patients of scoliosis that have a pulmonary function impairment.

Heel Lifts for Secondary Scoliosis

When secondary scoliosis is caused by differences in leg lengths, adding lifts to the heels may decrease a mild curvature. In one study it decreased by an average of 5.3 to 7.5 degrees. (Curvatures were all less than 20 degrees.) Patients with the greatest curvature experienced some muscle pain, fatigue, and even nausea during the first few days they were using the lifts, but these symptoms eased within 10 days. (before surgery)

(Review Report on Scoliosis- Managing scoliosis, In about.com, 2008)

There is also an Australian concept of Spine Segmental Stabilization where there they describe ways to reduce low back pain using spine stabilization. The book is called 'Therapeutic Exercise for Spinal Segmental Stabilization in Lower Back Pain' by Carolyn Richardson. It does not speak specifically about postoperative physiotherapy about Spinal Stabilization but it has some bases that can be used for further research. There was a research on 2000 patients for low back pain as Dc. Pavlu has told me on low back pain in this book. (Pavlu, 2008)

Brunkow therapy

The author of this method, German physiotherapist Roswitha Brunkow, based the approach on her experience in treating transient, post-traumatic lack of physical fitness. Brunkow was a paraplegic and was on a wheelchair and she observed that standing of the trunk was possible.(Vele, 2008)

Initially, sets of exercises were used in the treatment of stereotaxic syndromes and intervertebral disc damage. Brunkow's exercises were applied to patients with scoliosis, central lesions of the nervous system, peripheral paralysis, or non-discopathic incidents of low back pain. Brunkow's approach has not been widely used in Poland, thus the aim of this study was to demonstrate beneficial effects of Brunkow's exercises in chronic dysfunctions of lumbar spine. (E Saulicz, 2006)

Brunkow used a concept of Hettinger physiology that said that isometric contraction performed with maximum force three times a day, will cause increased muscle force (clinically). (Vele, 2008)

It is isometric muscle training to stabilize muscles without actual movement. This therapy activates the correct movement programs from the master brain. The controls of the musculature become corrected and all joints of the body will be correctly adjusted and stabilized.

Through this the false load (attitude) reduces and the pain disappears. The body is again in the muscular equilibrium, because a joint, which stands correctly, does not indicate pain. This therapy is great for different conditions such as back pain, scoliosis, sciatica, muscle imbalances, headaches, and also neurological conditions as MS(Multiple Sclerosis) and Apoplexy.

(Review of: Brunkow Therapy, In Therapeutika centre, 2008)

Two groups of patients (n = 30 each), rehabilitated due to overload-degenerative changes in the lumbar spine, participated in the study. Patients from both groups were subjected to 20 sessions of physio- and kinesitherapy but one group had additional sets of Brunkow's exercises. Just before the first and after the last session, every patient was examined with respect to the lumbar spine mobility in all planes, Schober's test, and lifting straight leg. Statistical analysis of data demonstrated that the "Brunkow" group exhibited somewhat better improvement in mobility, especially in flexion and side bends, compared with the other group.

(E Saulicz, 2006)

Hence we can deduce that Brunkow therapy may be used after spine stabilization surgeries. I suggest further research needs to be done with the effectiveness of this treatment after spine stabilization.

Water therapy exercise program

Fig.36 aqua therapy (http://www.spine-health.com/Wellness/Exercise/Water-Therapy/Water-Therapy-Exercise-Program.html)

Water therapy

For people with that type of affection, it's good to use water therapy. It can be used for all operations of scoliosis because of the benefits that I describe below. The basic principles that Archimedes put forth.

Benefits of water during exercise therapy

The physical properties of water make it a highly desirable medium in which to exercise to treat back pain and other musculoskeletal injuries. Some of the most important properties of water that make exercise easier are:

- **Buoyancy**: water counteracts gravity and helps to support the weight of the patient in a controlled fashion as the patient is immersed. This can aid the development of improved balance and strength.
- **Viscosity**: water provides resistance by means of gentle friction, allowing strengthening and conditioning of an injury, while reducing the risk of further injury due to loss of balance.
- **Hydrostatic pressure**: there are powerful effects produced by hydrostatic pressure that improve heart and lung function, making aquatic exercise a very useful way to maintain and strengthen heart and lung function. This pressure effect also aids in improving muscle blood flow.

(A Cole, 2006)

Vojta treatment for scoliosis

My idea is that it's good to check strategy by Vojta method ie. If vertebral fusion by this technique is possible to be compensated. There need to be checked if there is a relationship between Vojta and implants techniques with respect to the limitations of each surgery It can be checked individually for each patient and as a therapy in general it is possible to try.

Special **acupuncture** treatments have been found to help scoliotic patients below 35 degrees in Cobb angle and I recommend it for research for postoperative patients of scoliosis with low curvatures of scoliosis. It would have interesting findings.

Lastly on this chapter Dc. Vele mentioned to me about **Alexander technique** and it means "knowing one self"; in other words if the therapist first does the exercises on him/herself and understands them on his own body, then he can instruct them on the patient also (Vele, 2008). In these ways the patient can learn and understand which parts of his body are working during different exercises. An example like, diaphragm going down during breathing in for example and pelvic floor muscles going up, it is possible to perceive it if glottis is open. However, effectiveness of Alexander technique has been found to be very little and very subjective from different authors (in low back pain) and I don't recommend it for further research.

Chapter 3

Methodology

This is a critical review. It is based in studying and comparing different text and trying to find new methods to solve this problem.In my methodology I have used some books that professor Otahal lended me. One of them was Clnical Biomechanics of the Spine by Panjabi second edition. Another one was Movement, Stability and Lumbopelvic pain-Integration of Research and therapy second edition by Andry Vleeming. Another one was Spine Technology Handbook by Steven M. Kurtz. Also for further knowledge I have been visiting the first medical faculty library of Charles university and have used a lot of references from their databases. Concretly Elsevier's science direct.com; Journals available that I have used such as Journal of Biomehanics, Spine Journal, Journal of Clinical Biomechanics. Also I have used some gathered information about scoliosis from Dynamed (a part of EbscoHost) and Journal of Orthopaedics and Traumatology. Futhermore I have used webpages such as spineuniverse.com, spine-health.com, scoliosisjournal.com, http://adam.about.com and vojta.com. Lastly I have written things that I learned from consultations wth Dr. Otahal and from some researches of his Phd students in the department of Biomechanics of FTVS. Lastly I had some consultations with Dc. Vele about some physiotherapy techniques usable for scoliosis.

Chapter 4

DISCUSSION

There is an antagonism between surgery and care. The question risen is, is this problem solvable, is it dramatic and is it possible to correct it. Has physiotherapy sufficient methods to correct such a way of operation. Here I present some researches that have been done for comparing different surgical approaches to idiopathic scoliosis, different bioimplants and biocompatibility issues well as changes in loads in internal spinal fixation devices during different positions during physiotherapy and in general. Furthermore I discuss about some new imaging methods studies.

4.1. Problem of Biocompatibility

Biocompatibility is the ability of a material to perform with an appropriate host response in a specific application. (D. Williams, 1999)

Three definitions of biocompatibility

1. the ability of a material to perform with an appropriate host response in a specific application. – Williams definition.
2. the quality of not having toxic or injurious effects on biological systems. - Dorland's Medical Dictionary.
3. comparison of the tissue response produced through the close association of the implanted candidate material to its implant site within the host animal to that tissue response recognised and established as suitable with control materials- ASTM (American society for testing and materials).

Comments on the above three definitions

1. this is also referred to as the Williams definition. It was defined in the European Society for Biomaterials Consensus Conference I
2. the Dorland Medical definition is not recommended since it only defines biocompatibility as the absence of host response and does not include any desired or positive interactions between the host tissue and the biomaterials.
3. the ASTM is not recommended since it only refers to local tissue responses, in animal models.

All these definitions deal with materials and not with devices. This is a drawback since many medical devices are made of more than one material. Much of the pre-clinical testing of the materials is not conducted on the devices but rather the material itself. But at some stage the testing will have to include the device since **the shape, geometry and surface treatment etc of the device will also affect its biocompatibility.**

Suggested sub-definitions

The scope of the first definition is so wide that D Williams tried to find suitable subgroups of applications in order to be able to make more narrow definitions. In the MDT article from 2003 the chosen subgroups and their definitions were:

Biocompatibility of long-term implanted devices

The biocompatibility of a long-term implantable medical device refers to the ability of the device to perform its intended function, with the desired degree of incorporation in the host, without eliciting any undesirable local or systemic effects in that host. This goes in our case with implanted artificial intervertebral components for AIS treatment.

Biocompatibility of short-term implantable devices

The biocompatibility of a medical device that is intentionally placed within the cardiovascular system for transient diagnostic or therapeutic purposes refers to the ability of the device to carry out its intended function within flowing blood, with minimal interaction between device and blood that adversely affects device performance and without inducing uncontrolled activation of cellular or plasma protein cascades.

Biocompatibility of tissue-engineering products

The biocompatibility of a scaffold or matrix for a tissue-engineering products refers to the ability to perform as a substrate that will support the appropriate cellular activity, including the facilitation of molecular and mechanical signalling systems, in order to optimise tissue regeneration, without eliciting any undesirable effects in those cells, or inducing any undesirable local or systemic responses in the eventual host.

In these definitions the notion of biocompatibility is related to devices rather than to materials as compared to top three definitions.

Critiques

The critique against the Williams definition usually boils down to the fact that **it is not possible to make a single test that determines whether a material is biocompatible or not. Indeed, since the hemostasis of the immune response and repair functions in the body are so complicated it would seem odd that one can make one test to determine the biocompatibility of any given material.** Sometimes one hears of biocompatibility testing that is a large battery of in vitro test that is used in accordance with ISO 10993 to determine if a certain material (or rather biomedical product) is biocompatible. **These tests do not determine the biocompatibility of a material, but they constitute an important step towards the animal testing and finally clinical trials that will determine the biocompatibility of the material in a given application, and thus medical devices such as implants or drug delivery devices.**

(D. Williams, 2003)

We still have a long time ahead of us until we see the artificial-natural components and I believe until then predicting the biocompatibility of an artificial material will be very difficult according to what I wrote above. (Otahal, 2008)Despite the limitations, biocompatibility evaluation remains a necessary screening test before a device can be approved.

In some tests the material will be used directly. In other tests the material will be extracted in a liquid and the extract tested. The extract used will vary depending on the test methods to be used or on the nature of the material. The tests are designed to test for cytotoxixity, stimulation of the immune response, irritation to tissues, provocation of chronic inflammation, effects on blood and blood components and effects on genetic factors including mutations and tumor formation. (Steven M. Kurtz, 2006)

Implanted materials must be **biocompatible** and "get along with" your internal chemistry — it's not like you can easily take out an implant, so you absolutely need to be sure that the material that the implant is made of is safe for long-term implantation.

The good news is that the medical industry has done an enormous amount of research for us into this subject and we know that we have a number of options; **the most common ones include metals such as implant grade steels, titanium and titanium/aluminum/niobium alloys, as well as polymers such as Teflon and silicone.** An important thing to note is that it is often not entirely legal to buy (let alone implant) proper medical grade plastics for non-doctors — that's not to say that they aren't available through a multitude of gray market suppliers (or suppliers who don't ask questions, or supply raw materials), but we are aware that there are no guarantees that high quality materials are being used on patients, and there is no reasonable way for a customer to tell the difference between even low grade industrial polymers and higher grades.

Ensuring that the materials being used on you are of a suitable grade can minimize this risk. Most artists should have no problem providing us with some documentation as to the makeup of the material being used. (Review of : Implant Biocompatibility in Bmezine encyclopedia, May 2006)

Biocompatible material

In surgery, a **biocompatible material** (sometimes shortened to **biomaterial**) is a synthetic or natural material used to replace part of a living system or to function in intimate contact with living tissue. Biocompatible materials are intended to interface with biological systems to evaluate, treat, augment or replace any tissue, organ or function of the body. Biomaterials are usually non-viable, but may also be viable.

A biocompatible material is different from a biological material such as bone that is produced by a biological system. Artificial hips, vascular stents, artificial pacemakers, and catheters are all made from different biomaterials and comprise different medical devices.

Biomimetic materials are not made by living organisms but have compositions and properties similar to those made by living organisms. The **calcium hydroxylapatite** coating found on many artificial hips is used as a bone replacement that allows for easier attachment of the implant to the living bone.

Surface functionalization may provide a way to transform a bio-inert material into a biomimetic or even bioactive material by coupling of protein layers to the surface, or coating the surface with self-assembling peptide scaffolds to lend bioactivity and/or cell attachment 3-D matrix.

Different approaches to functionalization of biomaterials exist. Plasma processing has been successfully applied to chemically inert materials like polymers or silicon to graft various functional groups to the surface of the implant. Polyanhydrides are polymers successfully used as a drug delivery materials.

(Review of Biocompatible material in Wikipedia, 2007)

It is also important if the material is aggressive to it's surrounding tissue, it's chemical nature (metabiocompatibility) and also it's mechanical properties.ie. Flexible polymer is more adaptable to forces and how this pressure changes it's shape in extension is interesting. (Otahal, 2008)

Biomaterials example used in anterior or posterior approach

UCL Lumbar Pliff Cage

Fig 32 (Review of UCL Lumbar Plif Cage in Advance Health, 2007)

The traditional solution, the UCL Lumbar Plif Cage is a large product line of radiolucent cages, offering a variety of alternatives for Lumbar Surgery that can be used by **posterior or anterior fixation.**

Key benefits include:

- **Anatomical shape with large variety of type and sizes:**
  Available in normal or tapered versions for a perfect fit. Primary and secondary stability supported.
- **Serrated finish:**
  Teeth are provided for further stability.
- **Bone graft:**
  Large fusion surface is provided to fuse the implant in place. Can be used with real or substitute bone.
- **Custom fit bone substitute:**
  This can be inserted in the central cavity of cage during procedure.
- **X Ray Witness:**
  Titanium spot to accurately verify correct insertion.
- **Reinforced:**
  To withstand any impact.
- **Simplified instrumentation:**
  Provides ease of use, distributes impact stress and eliminates any risk of the cage cracking during insertion.

It is recommended with MPM or ERS osteosynthesis posterior support.

The material of manufacture, PEEK-OPTIMA LT®, a poly-ether-ether-ketone, gives this product radiolucency on x-ray, plus durability **and flexibility comparable with natural bone, plus the high standard of biocompatibility necessary for long-term implantation.**

(Review of UCL Lumbar Plif Cage in Advance Health, 2007)

a. Polyurethanes as **biomaterials**:

After almost half a century of use in the health field, polyurethanes (PUs) remain one of the most popular group of biomaterials applied for medical devices. Their popularity has been sustained as a direct result of their segmented block copolymeric character, which endows them with a wide range of versatility in terms of tailoring their physical properties, blood and tissue compatibility, and more recently their **biodegradation character**. While they became recognized in the 1970s and 1980s as the blood contacting material of choice in a wide range of cardiovascular devices their application in long-term implants fell under scrutiny with the failure of pacemaker leads and breast implant coatings containing PUs in the late 1980s. **During the next decade PUs became extensively researched for their relative sensitivity to biodegradation and the desire to further understand the biological mechanisms for in vivo biodegradation. The advent of molecular biology into mainstream biomedical engineering permitted the probing of molecular pathways leading to the biodegradation of these materials.** Knowledge gained throughout the 1990s has not only yielded novel PUs that contribute to the enhancement of biostability for in vivo long-term applications, but has also been translated to form a **new class of bioresorbable materials** with all the versatility of PUs in terms of physical properties but now with a more integrative nature in terms of biocompatibility. **The current review surveyed the literature, which initially identified the problem of PU degradation in vivo and the subsequent studies that have led to the field's further understanding of the biological processes mediating the breakdown. An overview of research emerging on PUs sought for use in combination (drug+polymer) products and tissue regeneration applications was presented.** (J.P. Santerrea et al, 2005)

PUs have had a popularity due to their versatility in terms of tailoring their physical properties, blood and tissue compatibility, but in the 70's and 80's have been found their biodegradation qualities during vivo, due to molecular pathways. Lately in the 90's a new class of bioresorbable materials was formed with all the good things of PUs and also good biocompatibility. It will be interesting to see some research on PUs as spinal implans biocompatibility.

b. PEEK biomaterials and spinal implants:

Since the 1980s, polyaryletherketones (PAEKs) have been increasingly employed **as biomaterials for trauma, orthopedic, and spinal implants.** What has been done was the synthesis of the extensive polymer science literature, as it relates to structure, mechanical properties, and chemical resistance of PAEK biomaterials. With this foundation, one can more readily appreciate why this family of polymers will be inherently strong, inert, and biocompatible. Due to its relative inertness, PEEK biomaterials are an attractive platform upon which to develop novel **bioactive materials**, and some steps have already been taken in that direction, with the blending of HA (hydroxyapatite) and TCP into sintered PEEK. However, to date, blended HA-PEEK composites have involved a trade-off in mechanical properties in exchange for their increased bioactivity. **PEEK has had the greatest clinical impact in the field of spine implant design, and PEEK is now broadly accepted as a radiolucent alternative to metallic biomaterials in the spine community**. For mature fields, such as total joint replacements and fracture fixation implants, radiolucency is an attractive but not necessarily critical material feature. (Steven M., 2007)

PEEk's in spine implants as I described before are durable, flexible, distribute impact stress and eliminate any risk of the cage cracking during insertion, impact resistant, they have high level of biocompatibility. Here from this article I mentioned their bioactivity and possibility to fuse with HA and TCP, with a trade-off in properties. It is now an alternative to metallic implants.

Material properties and clinical application are important. I.e. stainless steel has been the traditional material of choice of plates and screws (as well as rods and hooks) for spinal fusion. The reason is that it is the easiest of the alloys to machine, and can be used in different work hardened conditions with minimal galvanic corrosion problems. Thus, a plate or rod might be manufactured in the annealed position, with a cold work reserve to permit the surgeon to bend the device to fit the anatomy of the patient. The screws and hooks would be more heavily cold worked for increased strength. If the surgeon is concerned about osteoporotic bone and stress shielding, they use titanium 6A1 4V with a low elastic modulus. Similarly, titanium, PEEK and carbon-fiber reinforced PEEK are used for spinal cages because they have the low modulus needed to facilitate bone regeneration and fusion. On the other hand, vertebral disc prostheses with articulating bearing surfaces need to be highly wear resistant. The materials of choice in that case would be UHMWPE, cobalt chromium alloy, or alumina. (Steven M. Kurtz, 2006)
As new materials and applications are developed the mechanical properties and biological effects will have to be evaluated always.

4.2. Problem of shape identification, postoperative drugs and correction of scoliosis

a. Rasterstereographic back shape analysis in idiopathic scoliosis after posterior correction and fusion

The objective was to determine the accuracy of rasterstereographic three-dimensional back surface analysis and reconstruction of the spine in idiopathic scoliosis treated by posterior correction and fusion.
In the design of the study the prospective imaging study of 25 patients with idiopathic scoliosis who underwent posterior correction and fusion and were followed for one year.
Background: In an earlier study published in this journal **rasterstereography had proved to be an accurate imaging modality for quantifying the changes in the three-dimensional shape of the spine and posterior rib cage after anterior correction and fusion.**
The goal of the present study was to determine the accuracy for the more common posterior correction and fusion with attention paid to the presence of the posterior implants and scarring.
Methodology used: Twenty-five patients with idiopathic scoliosis with maximum Cobb angles of 78 degrees were examined by rasterstereography and radiography. Seventy-one anterior–posterior radiographs were digitised. Twenty-four were preoperative and 47 postoperative radiographs. Rasterstereographic and radiographic curves were compared by best-fit superimposition. Root-mean-square differences were calculated as parameters of accuracy.

Results. The accuracy of rasterstereography in severe idiopathic scoliosis with Cobb angles between 48 degrees and 78 degrees was satisfactory with root-mean-square differences of 5.8 mm for the lateral deviation and 4.8 degrees for vertebral rotation. Following posterior correction the accuracy was good. The root-mean-square difference was 4.5 mm for the lateral deviation and 4.3 degrees for vertebral rotation.

Conclusion. **The accuracy obtained for posteriorly-operated scolioses between 50 degrees and 80 degrees was similar to the findings for scoliosis operated via anterior approach, as well as those with curves up to 50 degrees Cobb angle. Therefore rasterstereography can be used postoperatively to reduce the number of radiographs and radiation exposure. Additionally, the method provides an objective quantification of the postoperative improvement in the cosmesis of the back shape.** (Lars Hackenberg et al, 2003)

This method has proven to be acurate in measuring three dimensional spine changes in both anterior and posterior corrections and provides a less radioactive way as well as a more objective view of the cosmesis of the back shape (how it looks).

b. Moire topography in scoliosis. Correlations with vertebral lateral curvature as determined by radiography

The backs of 42 subjects were examined using moiré topography; 22 of these subjects had scoliosis (range of lateral curvature, 6 degrees-95 degrees; mean, 31 degrees) and had recent radiographs of the spine. Two experienced observers, each an orthopedic surgeon, determined moire angles and number of fringe deviations for each subject. Two radiologists assessed radiographic Cobb angles for each scoliotic subject. For major curves superior to T10 (n = 9), significant correlations were found between Cobb angles and fringe deviations in the W1 region (r = .64, p less than .05). Cobb and moire angles were correlated in the upper O1 region (r = .60, p less than .05) and in the lower O1 region (r = .78, p less than .01). For major curves at or inferior to T10 (n = 13), the angles were correlated in the W region (r = .57, p less than .05). After one hour of training, three physical therapists averaged 87% accuracy in analyzing moire fringe deviations. Complex moire patterns, as observed in obese subjects or those with severe curvature, made fringe-deviation analysis unreliable. **The most accurate moire data were obtained at the approximate level of the apex of the scoliotic curve.**

(Ruggerone M, Austin JH, 1986)

c. Concordance of back surface asymmetry and spine shape in idiopathic scoliosis

In order to determine why topographic methods have shown a poor correlation with radiographically measured scoliosis in clinical studies, the accuracy of detection of the presence, side, apex, and magnitude of a scoliosis curve was determined topographically (by moire fringe photography and by projected raster photography) in 104 patients attending a scoliosis clinic. The presence or absence of thoracic curves was correctly shown by the topograms in 77% of cases, and in the lower region (lumbar and thoracolumbar curves) in 79% of cases. For correctly identified curves, the greatest back surface rotation was, on average, 1.0 vertebral levels below the skeletal curve apex in the thoracic region and 0.5 levels below the apex in the lower region. The moire fringe with the greatest asymmetry occurred on average at 1.5 and 1.8 vertebral levels above the spinal apex in upper and lower regions, respectively. The magnitude of the Cobb angle was determined to within +/- 5 degrees in 24% of cases by moire measurements, and in 27% by the raster technique. The side of the scoliosis was incorrectly diagnosed by topography in ten patients with minimal or 'nonstandard' vertebral rotation. **It was concluded that the presence, level, and side of a scoliosis curvature is well demonstrated by back surface topography in patients with 'standard' rotation, but the magnitude of the scoliosis cannot be determined from topograms sufficiently accurately for most clinical purposes.** (Stokes IA, Moreland MS, 1989)

From here we can conclude that surface topography can detect rotation well in common scoliotic patients, but the magnitude of scoliosis can be measured by other ways better, like an Xray. The same would go for postoperative patients.

d. Three-dimensional spinal curvature in idiopathic scoliosis

Scoliosis is usually considered as a deformity of the spine in the frontal plane, without reference to curvatures in other planes. In this study, the three-dimensional shape of the spine of 104 patients with untreated idiopathic scoliosis (5-55 degrees Cobb) was studied by means of stereo radiographs to determine relationships between curvature of the spine in the frontal plane view, in the lateral view, and in the intermediate views. There was a weak but statistically significant correlation (r = 0.2) relating greater scoliosis with lesser kyphosis or greater lordosis. In the thoracic region, the sagittal plane spinal curvature was less than that measured in a population without scoliosis (mean difference, 7.72 +/- 9.9 degrees). Seventy-four of 76 scolioses in the upper region of the spine with lateral curvature greater than 5 degrees Cobb were kyphotic. Sixty-four of 84 curves greater than 5 degrees Cobb in the lower region were lordotic. Measuring curvatures in the plane of symmetry of the rotated apical vertebra altered these ratios to 69 of 76 kyphotic in the upper region and 68 of 84 lordotic in the lower region. The plane of maximum curvature of sections of the spine with scoliosis was not related to the plane of symmetry of the rotated apical vertebra, for in kyphotic regions of the spine the rotations of these two planes were in opposite directions. In all cases, the magnitudes of the rotations were quite different, i.e., by a factor of -0.22 for curves in thoracic region and by a factor of 0.24 for curves in the lumbar region.

This implies that mechanical measures to correct this spinal deformity or to prevent progression should apply different rotations to the apex from those applied to the curve as a whole and, in opposite senses, in curves in kyphotic regions. There was no evidence of an abnormality of sagittal curvature of a magnitude to implicate it in the etiology or in the treatment. (Stokes IA et al, 1987)

After reading this research, I believe that physiotherapeutic ways to prevent progression of scoliosis, as it is found in non operated idiopathic scoliotic patients (5-55 degrees) must have in mind to apply different rotations to the apex than to the curve as a whole and in opposite sense in kyphotic parts. Also, as we know from the previous article ((Ruggerone M, Austin JH, 1986) moire data is mostly accurate in the apex of the scoliotic curve.

e. Study on use of ketorolac tromethamine in children undergoing scoliosis surgery: an analysis of complications

Background context:

Ketorolac Tromethamine (ketorolac) is a nonsteroidal anti-inflammatory drug (NSAID) with proven efficacy in decreasing postoperative pain in various surgical settings, including the treatment of spine deformities. However, some studies have raised questions regarding the potential side effects of this agent, such as increased bleeding and inhibition of bony fusion.

Purpose:

This study was conducted to determine whether there is any association between the use of ketorolac and postoperative complications in a group of children who underwent scoliosis surgery.

Study design/setting:

This was a retrospective review of a group of children who underwent spinal fusion between 1989 to 1999 at some institution.

Patient sample:

Data on a total of 208 children were analyzed in this study. Sixty received ketorolac and 148 did not.

Outcome measures:

Postoperative transfusion and reoperation rates were the two main outcome measures of interest.

Methods:

A retrospective review of 208 children who underwent scoliosis surgery was conducted, with a focus on ketorolac use. Univariate analysis and logistic regression were used to quantify the determinants of postoperative complications.

Results:

Their analyses detected no significant differences in a broad range of socioclinical variables between the two patient groups, including age at surgery, gender, type of scoliosis, surgical approach, use of erythropoietin, levels of curvature and degree of curvature. Analysis of complication rates focusing on postoperative transfusion and revision surgery showed that there were no significant differences between the two groups.

Conclusions:

In this retrospective study of 208 children undergoing spine surgery, postoperative use of ketorolac did not significantly increase complications, including transfusion and reoperation. (Michael G. Vitale, MD, MPH , Julie C. Choe, MPH, Matthew W. Hwang, MD, MPH, Rebecca M. Bauer, MPH, Joshua E. Hyman, MD, Francis Y. Lee, MD, PhD, David P. Roye, Jr., MD, 2003)

This ketorolac tromethamine (NSAID) has shown to have no side effects and no reoperations in already postoperative patients of scoliosis and it is important for physiotherapists to know the function of NSAIDS and influence of pain perception, as well as muscle relaxation effects of these group of drugs.

f. Transverse plane pelvic rotation in adolescent idiopathic scoliosis: primary or compensatory

Several studies have suggested that the pelvis is involved in the etiology or pathogenesis of adolescent idiopathic scoliosis (AIS). The purpose of this retrospective, cross-sectional radiographic study is to identify any correlation between the transverse plane rotational position of the pelvis in stance and operative-size idiopathic or congenital scoliosis deformities, using Scheuermann's kyphosis and isthmic spondylolisthesis patients for comparison. **The hypothesis tested was that the direction of transverse pelvic rotation is the same as that for a thoracic scoliosis.**

As a group, AIS patients had a significant transverse plane pelvic rotation in the same direction as the thoracic curve. When subdivided into the six Lenke curve patterns, this was true for the groups with a major thoracic curve: thoracic (1), double thoracic (2) and double curve patterns (3). It was not true for patterns with a major thoracolumbar/lumbar curve: single thoracolumbar/lumbar (5) and double thoracic-thoracolumbar/lumbar (6). Nor was it true for triple (4) curves. The Lenke 1 and 2 major thoracic curves without compensatory thoracolumbar/lumbar curves did not have the predicted pelvic rotation. All congenital scoliosis patients studied had main thoracic curves and significant transverse plane pelvic rotation in the same direction as the thoracic curve. There was no transverse plane pelvic rotation in the Scheuermann's kyphosis or isthmic spondylolisthesis patients. **They interpret these findings as consistent with a compensatory rotation of the pelvis in the same direction as the main thoracic curve in most patients with a compensatory thoracolumbar/lumbar curve as well as in patients with main thoracic congenital scoliosis.** (Jeff L. Gum, 2007)

From here can be concluded that in patients with AIS a transverse plane pelvic rotation in the same direction with the main thoracic curve exists and this is compensatory. Hence the hypothesis was correct and I believe this may be true in postoperative patients with a main thoracic curve also.

g. Accuracy of thoracic pedicle screw placement in scoliosis using the ideal pedicle entry point during the freehand technique

Previously, in another research I don't explicitly describe here,was described the ideal pedicle entry point (IPEP) for the thoracic spine at the base of the superior facet at the junction of the lateral one third and medial two thirds with the freehand technique on cadavers.

Here was measured the accuracy of thoracic pedicle screw placement on post-operative computed tomography (CT) scans in 43 scoliosis patients who underwent operation with the freehand technique taking the same entry point. Of the 854 inserted screws, 268 (31.3%) were displaced; 88 (10.3%) and 180 (21.0%) screws were displaced medially and laterally, respectively. With regard to the safe zone, 795 screws were within the safe zone representing an accuracy rate of 93%; 448 and 406 thoracic screws inserted in adolescent idiopathic and neuromuscular scoliosis showed an accuracy of 89.9 and 94%, respectively (p=0.6475). The accuracy rate of screws inserted in the upper, middle and lower thoracic pedicles were 94.2, 91.6 and 93.7%, respectively (p=0.2411). **The results indicate that IPEP should be considered by surgeons during thoracic pedicle screw instrumentation.** (Hiteshi M., 2008)

This research shows that this ideal pedicle entry point during the freehand technique is most effective over 90% in thoracic screw instrumentation.

h. Intra and interobserver variability of preoperative planning for surgical instrumentation in adolescent idiopathic scoliosis

Surgical instrumentation planning for the correction of scoliosis involves many difficult decisions, especially with the introduction of multi-segmental and other instrumentation technologies. **A preliminary study has shown a high variability in planning among a small group of surgeons. The purpose of this paper was to evaluate and analyze the selection of fusion levels and instrumentation choices among a more extended group of scoliosis surgeons.** Thirty-two experienced spinal deformity surgeons were asked to provide their preferred posterior instrumentation planning for five patients with adolescent idiopathic scoliosis (AIS) using a graphical worksheet and the usual preoperative X-rays. Overall, the number of implants used ranged from 8 to 30 per patient (mean 16; SD 6): 71% of these were mono-axial screws, 20% multi-axial screws, and 9% hooks. The selected superior and inferior instrumented vertebrae varied up to six levels. The following significant groups of strategies were identified: A- ''All Pedicle Screws Constructs'' [NA = 103; 66%]; B- ''All Hooks constructs'' [NB = 5; 3%]; C- ''Hybrid Constructs'' [NC = 48; 31%]. A top-tobottom attachment sequence was selected in 49% of all cases, a bottom-up in 46%, and an alternate order in 4%.

Results where that a large variability in preoperative instrumentation strategy exists in AIS within an experienced group of orthopedic spine surgeons. The impact of such choices on the resulting correction is questioned and will need to be determined with adequate clinical, biomechanical, and computer simulation prospective studies. (M. Robitaille et al, 2007)

From here we can conclude that for each patient an individual set of exams are necessary such as MRI, CT, biomechanical are necessary before surgery and according to the experience of each doctor, will be decided at which levels the fusion will be selected and which instrumentation devices will be chosen. This is also important for physiotherapy because for example in screw instrumentation there is better curve correction than in hook, or in anterior approach sometimes respiratory therapy may be necessary after some complications. The more experienced the doctor the easier the job of the physiotherapist after the surgery.

i. In a comparative analysis of pedicle screw versus hook instrumentation in posterior spinal fusion of adolescent idiopathic scoliosis

It was a cohort analysis of fourty patients with adolescent idiopathic scoliosis. The research was divided in twenty patients with hook and twenty patients with screw instrumentation. The assumption was that the posterior pedicle screw instrumentation was better than the segmental hook for scoliosis. The Cobb angle improved 73.8 % after surgery in screw, while in hook only 51.6%. Also apical vertebral translation corrected 41.2% in hook group and 62.6% in the screw group. The time duration of operations was the same as well as blood loss was the same. SRS (Stereotactic radiosurgery) score was similar. One of the downsides of screw group is that it's more expensive.

Two years after surgery the screw group had shown better pulmonary functions whereas the hook group was the same as before operation. There were no neurologic complications in both. (Dilip K. et al, 2003) **In the end, the predicle screw instrumentation is better due to three colume purchase of the vertebrae, there is better curve correction, improved pulmonary function and slightly shorter fusion length than segmental hook instrumentations. Also as a generalization, better correction of the spine deformity may provide better chest cage mechanic and better percent predictive pulmonary function values.**

j. On a Short anterior correction of the thoracolumbar/lumbar curve in King 1 idiopathic scoliosis: the behaviour of the instrumented and non-instrumented curves and the trunk balance

This was a retrospective clinical, radiological and patient outcome assessment of 21 consecutive patients with King 1 idiopathic adolescent scoliosis treated by short anterior selective fusion of the major thoracolumbar/lumbar (TL/L) curve. **Three-dimensional changes of both curves, changes in trunk balance and rib hump were evaluated**. The minimal follow-up was 24 months (max. 83). The Cobb angle of the TL/L curve was 52% (45–67_) with a flexibility of 72% (40–100%). The average length of the main curve was 5 (3–8) segments. An average of 3 (2–4) segments was fused using rigid single rod implants with side-loading screws. The Cobb angle of the thoracic curve was 33% (18–50_) with a flexibility of 69% (29–100%). The thoracic curve in bending was less than 20% in 17 patients, and 20–25% in 4 patients. In the TL/L curve there was an improvement of the Cobb angle of 67%, of the apex vertebral rotation of 51% and of the apex vertebral translation of 74%. The Cobb angle of the thoracic curve improved 29% spontaneously. Shoulder balance improved significantly from an average preoperative imbalance of 14.5–3.1 mm at the last follow-up. **Seventy-five percent of the patients with preoperative positive shoulder imbalance (higher on the side of the thoracic curve) had levelled shoulders at the last follow-up**. C7 offset improved from a preoperative 19.8 (0–40) to 4.8 (0–18) mm at the last follow-up. There were no significant changes in rotation, translation of the thoracic curve and the clinical rib hump. There were no significant changes in thoracic kyphosis or lumbar lordosis. The average score of the SRS-24 questionnaire at the last follow-up was 91 points (max. 120).

We conclude that short anterior selective fusion of the TL/L curve in King 1 scoliosis with a thoracic curve bending to 25% or less (Type 5 according to Lenke classification) results in a satisfactory correction and a balanced spine. Short fusions leave enough mobile lumbar segments for the establishment of global spinal balance. A positive shoulder imbalance is not a contraindication for this procedure. Structural interbody grafts are not necessary to maintain lumbar lordosis. (Kan M. et al, 2006)

From here we conclude that short anterior correction of ThL/L curves corrects at most cases shoulder imbalance, lives free mobile lumbar segments and this operation is very satisfactory. It also means the physiotherapist can have the ThL/L patient exercise some parts of the lumbar spine, hence more mobility will be possible.

k. Texas Scottish Rite Hospital instrumentation for correction of idiopathic scoliosis: short-term results

In this prospective study 27 consecutive patients of an average age of 20 + 8 years suffering from idiopathic scoliosis were operated on using the Texas Scottish Rite Hospital (TSRH) instrumentation in the period from 1992 to 1995 and were evaluated at a minimum follow-up of 26 months postoperatively.

Curvature correction, derotation of the apical vertebra, frontal and sagittal trunk balance, and L3-L4 and L4-L5 disc-space wedging were evaluated prepostoperatively and at the maximum follow-up of 54 months. **The average correction of the thoracic and lumbar scolioses that was obtained immediately postoperatively averaged 41% and 51% respectively**. An average 2-4 ~ and 4-5 ~ loss of correction was dependent on King type in the thoracic and lumbar scoliotic curves respectively was observed at the longest follow-up. **Thoracic kyphosis and lumbar lordosis did not significantly change. No significant derotation of thoracic and lumbar apical vertebral rotation was achieved by TSRH but the preoperatively laterally shifted apical vertebra was translated by**

TSRH instrumentation towards the midline (p < o.ool). The position of the T1, and C7 vertebrae in the sagittal frontal (*Code Mdary:* 6293.3 *Correspondence to:* P. Korovessis, 65-67 Haralbi Str, GR-26224 Patras, Greece) plane was not significantly changed by TSRH instrumentation postoperatively. The preoperative wedging of the intervertebral spaces L3-L4 and L4-L5 was simultaneously significantly (p < O.Ol) reduced by TSRH with subsequent horizontalization of the L3, L4 and L5 vertebrae. No trunk decompensation, neurologic complications, infection or pseudarthroses occurred. Lumbar hook dislodgment occurred in the early postoperative period in two patients because of insufficient TSRH rod contouring at the beginning of our learning curve.

TSRH is a safe instrumentation that corrects idiopathic scoliosis satisfactorily, maintains frontal and sagittal vertebral balance by translating the apical vertebra towards the midline and simultaneously correcting the lowermost lumbar vertebral tilting without associated infection, neurologic complications or decompensation. (P. Korovessis et al, 2000)

By TSRH in idiopathic scoliosis thoracic kyphosis and lumbar lordosis do not seem to change but the one thing that seems to be achieved is the laterally shifted apical vertebra that is translated towards the midline. Position of Th1 and C7 is not significantly changed postoperatively. L3,L4 and L5 horizontalization signficantly reduces intervertebral spaces L3-L4 and L4-L5. No complications. Generally it is a safe method that maintains frontal and sagittal vertebral balance and corrects the lumbar vertebral tilting. I suspect physiotherapy will be good after these operation type.

l. P82. Anterior versus posterior spinal instrumentation for the treatment of thoracolumbar curves in adolescent idiopathic scoliosis

The **purpose** of this study was to compare anterior vs. posterior instrumentation in a well-defined population of patients with adolescent idiopathic scoliosis with thoracolumbar scoliosis.

The **methods** used were as follows: Medical records and radiographs of all patients undergoing spinal instrumentation for the treatment of adolescent idiopathic scoliosis with primary thoracolumbar curves, defined as curve apices between T10 and L2, between 1993 and 2001 were reviewed. The study group consists of 12 patients treated with anterior spinal instrumentation and 16 with posterior instrumentation. Various radiographic and outcome measures were compared between groups.

The **results** found where as follows: **The anterior group had 75% correction of the primary Cobb angle compared to 56% in the posterior group** (p=0.019). An average of 3.8 vertebral levels in the anterior and 6.7 in the posterior procedures were fused (P<0.001). **Less blood loss was observed in the anterior group** (p=0.007), **with fewer transfusions as well** (P<0.001). **The anterior group produced more lumbar lordosis** (p=0.03) **than the posterior group.** In the **anterior group there was a 0% rate of revision surgery** (0/12) where as the **posterior group had a 31% revision rate** (5/16) which was a significant difference (p=0.047).

The **discussion** is as follows: This study comparing anterior versus posterior instrumentation is unique in that it is **limited to thoracolumbar curves.** While earlier series of anterior instrumentation revealed high rates of hardware failure and pseudoarthrosis, this series found no instance of either in the anterior group. In addition, **concern over anterior compression instrumentation causing kyphosis proved unwarranted.** In fact, **the anterior instrumented group had improved lumbar lordosis compared to the posterior.** (David L. 2003)

The **conclusion** of this research was and my discussion: **In thoracolumbar idiopathic curves, anterior instrumentation had a significantly improved Cobb angle, less levels fused, and more lumbar lordosis, and less blood transfusions when compared to posterior instrumentation. In addition, patients undergoing anterior instrumentation had a significantly lower rate of revision surgery compared to those with posterior instrumentation.** So if we have AIS patients of thoracolumbar curves and had an anterior spinal instrumentation, we can expect more mobility in lumbar spine, since less levels were fused and there is more lumbar lordosis.

m. The treatment of large (greater than 70 degrees) thoracic curves in patients with idiopathic scoliosis with posterior instrumentation and arthrodesis: when is anterior release indicated?

Purpose of study:

The increasing use of thoracoscopic techniques in deformity surgery has led several authors to advocate anterior release followed by posterior instrumentation when treating "stiff" thoracic curves of 60 to 70 degrees. This study was undertaken to examine our results in these large curves utilizing posterior surgery alone.

Methods used:

This is a retrospective review of patients 20 years and younger with idiopathic scoliosis and thoracic curves greater than 70 degrees treated with isolated posterior instrumentation and arthrodesis at two institutions from 1989 to 1999. Forty-two patients were identified, and 38 were available for minimum 2-year follow-up. Thirty-four of 38 patients had bend films taken before surgery. All patients were treated with thirdgeneration segmental spinal instrumentation using a varied combination of hooks, wires and screws.

Summary of findings:

The average age at surgery was 14.5 years (10.7 to 20 years), and the average follow-up was 4.1 years (2 to 11.5 years). The average preoperative thoracic curve was 75 degrees (70 to 88 degrees), and the average bend was 49 degrees (30 to 60 degrees). The average postoperative curve was 28 degrees (12 to 46 degrees), and it was 29 degrees (11 to 48 degrees) at latest follow-up. The average length of surgery was 5.3 hours, mean hospital stay was 8 days and average blood loss was one liter. SRS 22 was available at minimum 2 years in 31 of 38 patients. Mean domain scores were as follows: Pain, 4.25; Self Image, 4.15; Function, 4.18; Mental Health, 4.12; Satisfaction, 4.52 and Total, 4.24. Complications included one pseudarthrosis and one implant removal for late operative site pain.

Relationship between findings and existing knowledge:

As the morbidity of anterior release has decreased with the use of thoracoscopic techniques, the indications for using anterior surgery in conjunction with posterior instrumentation and arthrodesis appear to have relaxed. Using isolated posterior surgery, we have been able to at least equal the results reported in the literature by authors using combined approaches.

Overall significance of findings:

Isolated posterior instrumentation and arthrodesis achieves satisfactory radiographic and patient-based outcomes in adolescents with idiopathic scoliosis with thoracic curves of 85 degrees and less without the added expense and morbidity of anterior release. (Douglas Burton et al, 2002)

Significance of these results is that now, the anterior release combined with the posterior instrumentation appears to have equal results with a simpler posterior instrumentation with arthrodesis, hence less expenses and less morbidity of anterior release.

n. Study of 10 years follow-up surgical results of adolescent idiopathic scoliosis patients treated with TSRH instrumentation:

During recent years, besides radiological and clinical studies, questionnaires like SRS-22 assessing subjective functional and mental status and life-quality of patients have gained importance for the evaluation of these results. In this study, surgical outcome and Turkish SRS-22 questionnaire results of 109 late-onset adolescent idiopathic scoliosis patients surgically treated with third-generation instrumentation [Texas Scottish Rite Hospital (TSRH) System] and followed for a minimum of 10 years were evaluated. **The balance was analyzed clinically and radiologically by the measurement of the lateral trunk shift (LT), shift of head (SH), and shift of stable vertebra (SS)**. Mean age of the patients was 14.4±1.9 and mean follow-up period was 136.9± 12.7 months. When all the patients were included, the preoperative mean Cobb angle of major curves in the frontal plane was 60.8_±17.5_. Major curves that were corrected by 38.7±22.1% in the bending radiograms, postoperatively achieved a correction of 64.0±15.8%. At the last follow-up visit, 10.3_±10.8_ of correction loss was recorded in major curves in the frontal plane with 50.5±23.1% final correction rate. Also, the mean postoperative and final kyphosis angles and lumbar lordosis angles were 37.7degrees±7.4degrees, 37.0degrees±8.4degrees, 37.5degrees±8.7degrees, and 36.3degrees±8.5degrees, respectively.

A statistically significant correction was obtained at the sagittal plane; mean postoperative changes compared to preoperative values were 7.9degrees and 12.9degrees for thoracic and lumbar regions, respectively. On the other hand, normal physiological thoracic and lumbar sagittal contours were achieved in 83.5% and 67.9% of the patients, respectively. **Postoperatively, a statistically significant correction was obtained in LT, SH, and SS values (P<0.05)**. Although, none of the patients had completely balanced curves preoperatively, in **95.4% of the patients the curves were found to be completely balanced or clinically well balanced postoperatively**. This rate was maintained at the last follow-up visit. Overall, four patients (3.7%) had implant failure. Early superficial infection was observed in three (2.8%) patients. **Radiologically presence of significant consolidation, absence of implant failure, and correction loss, and clinical relief of pain were considered as the proof of a posterior solid fusion mass**. About ten (9.2%) patients were considered to have pseudoarthrosis: four patients with implant failure and six patients with correction loss over 15 degrees at the frontal plane. About four (3.7%) patients among the first 20 patients had neurological deficit only wake-up test was used for neurological monitoring of these patients. No neurological deficit was observed in the 89 patients for whom intraoperative neurological monitoring with SSEP and TkMMEP was performed. Overall, average scores of SRS-22 questionnaire for general self-image, function, mental status, pain, and satisfaction from treatment were 3.8±0.7, 3.6±0.7, 4.0±0.8, 3.6±0.8, and 4.6±0.3, respectively at the last follow-up visit.

Results of about 10 years of follow-up these patients treated with TSRH instrumentation suggest that the method is efficient for the correction of frontal and sagittal plane deformities and trunk balance. In addition, it results in a better life-quality. (I. Teoman et al, 2006)

This research has a little bit different results than the short term results I mentioned earlier. It still suggests it is a good method and that in both short and long term frontal and sagittal plane correction is efficient. What is different is that in the long term the thoracic and lumbar region correction has improved, rather than stay stable.

o. Study on effect of different surgical strategies on screw forces after correction of scoliosis with a VDS implant

Pullout of the cranial end-vertebra screw following the correction of a scoliosis with the VDS implant is a common complication. **Very little is known about the forces acting on the screws during ventral derotation spondylodesis (VDS) in ventral scoliosis surgery. These forces determine the risk of screw-loosening. The purpose of this study was to identify implant properties and to determine surgical correction strategies that reduce the risk of cranial end-vertebra screw pullout.** For this aim, a three-dimensional nonlinear finite element model of a scoliotic thoracic spine was created with a Cobb angle of 61° and 32° rotation. The VDS implant was inserted between T5 and T9. The longitudinal rod diameter, the implant material and seven surgical correction strategies were examined to determine their influence on the Cobb angle as well as on derotation and on axial and transverse forces in the screws.

A stiffer implant achieves a better correction but causes higher axial and transverse screw forces. Axial tensile forces act on the screws fixed to the cranial end vertebra and the middle vertebra, while axial compressive forces act on the other screws. A strong correction at the cranial segment leads to high axial and transverse screw forces in the farthest cranial screw and thus to a high risk of screw pullout. The resultant transverse force is often much higher than the axial force component.

Simulation of local trunk muscle forces has only a minor effect on the results. The axial tensile forces and thus the risk of screw pullout are highest at the cranial end vertebra. A strategy in which surgical correction is strong in the middle segments and moderate in the outer ones leads to a good reduction of the Cobb angle, a wide derotation angle, and relatively low axial tensile forces at the cranial end vertebra screw. (Antonius Rohlmann et al, 2006)

This means that with a simulation of different kind of surgeries we can achieve a better understanding of what will really happen after each approach is used. Thereby we can choose the best method. Experience of doctors will not play such an important role, comparing with what I mentioned before then (earlier research look up), since most of the weight will go on simulation I believe. Also here is shown the importance of preparing a surgery with perharps a less stiff implant and less correction, or surgically correcting middle segments, since cranial segments correction leads to screw pullout.

p. Costs and effects in lumbar spinal fusion. A follow-up study in 136 consecutive patients with chronic low back pain.

Although cost-effectiveness is becoming the foremost evaluative criterion within health service management of spine surgery, **scientific knowledge about cost-patterns and cost-effectiveness is limited. The aims of this study were to establish an activity-based method for costing at the patient-level, to investigate the correlation between costs and effects, to investigate the influence of selected patient characteristics on cost-effectiveness and, to investigate the incremental cost-effectiveness ratio of (a) posterior instrumentation and (b) intervertebral anterior support in lumbar spinal fusion.**

They hypothesized a positive correlation between costs and effects, that determinants of effects would also determine cost-effectiveness, and that posterolateral instrumentation and anterior intervertebral support are cost-effective adjuncts in posterolateral lumbar fusion. A cohort of 136 consecutive patients with chronic low back pain, who were surgically treated from January 2001 through January 2003, was followed until 2 years postoperatively. Operations took place at University Hospital of Aarhus and all patients had **either (1) non-instrumented posterolateral lumbar spinal fusion, (2) instrumented posterolateral lumbar spinal fusion, or (3) instrumented posterolateral lumbar spinal fusion + anterior intervertebral support.** Analysis of costs was performed at the patient-level, from an administrator's perspective, by means of **Activity-Based-Costing. Clinical effects were measured by means of the Dallas Pain Questionnaire and the Low Back Pain Rating Scale at baseline and 2 years postoperatively.** Regression models were used to reveal determinants for costs and effects. Costs and effects were analyzed as a net-benefit measure to reveal determinants for cost-effectiveness, and finally, adjusted analysis (for non-random allocation of patients) was performed in order to reveal the incremental cost-effectiveness ratios of (a) posterior instrumentation and (b) anterior support. The costs of non-instrumented posterolateral spinal fusion were estimated at DKK 88,285(95% CI 81,369;95,546), instrumented posterolateral spinal fusion at DKK 94,396(95% CI 89,865;99,574) and instrumented posterolateral lumbar spinal fusion + anterior intervertebral support at DKK 120,759(95% CI 111,981;133,738).

The net-benefit of the regimens was significantly affected by smoking and functional disability in psychosocial life areas. Multi-level fusion and surgical technique significantly affected the net-benefit as well. Surprisingly, no correlation was found between treatment costs and treatment effects. Incremental analysis suggested that the probability of posterior instrumentation being cost-effective was limited, whereas the probability of **anterior intervertebral support being cost-effective escalates as willingness-to-pay per effect unit increases.** This study reveals useful and hitherto unknown information both about cost-patterns at the patient-level and determinants of cost-effectiveness.

The overall conclusion of the present investigation was a recommendation to focus further on determinants of cost-effectiveness. For example, patient characteristics that are modifiable at a relatively low expense may have greater influence on cost-effectiveness than the surgical technique itself--at least from an administrator's perspective. (Soegaard R, Christensen FB, Christiansen T, Bünger C, 2007)

In this research an analysis of costs at patient-level was performed, pain questionnaires and low back pain rating scales two years after operation. The costs of instrumented and non-instrumented posterior instrumentation and anterior support were measured. Interesting is the fact that psychosocial life and smoking affect the net-benefit of the regimens, as well as multi-level fusion and surgical technique affect the regimens also. What they found also is that posterior instrumentation is not cost effective, but anterior instrumentation's costs escalate as willingness to pay per effect unit increases. The result of this research is that they can find, if possible cheap modifiable characteristics for individual patient that can reduce costs. Further investigation was recommended.

q. Chronic low back pain and fusion: a comparison of three surgical techniques: a prospective multicenter randomized study from the Swedish lumbar spine study group.

STUDY DESIGN:

A multicenter randomized study with a 2-year follow-up period and an independent observer was conducted.
OBJECTIVE:

To compare three commonly used surgical techniques to achieve lumbar fusion primarily in terms of their ability to reduce pain and decrease disability in patients with severe chronic low back pain. SUMMARY OF BACKGROUND DATA:

Lumbar fusion can be used to reduce pain and decrease disability in patients with chronic low back pain, and different surgical techniques are available. The reported results after fusion surgery vary considerably, but most studies are retrospective and/or performed on heterogeneous patient groups. Spine surgeons commonly use the techniques presented in this report. However, **in the absence of randomized trials it is difficult to know whether any one of them is better than the others for these patients.**

METHODS:

From 1992 through 1998, 294 patients referred to 19 spinal centers were blindly randomized into four treatment groups: three surgical groups (n = 222) and one nonsurgical group (n = 72). The sociodemographic and clinical characteristics did not differ among the groups. Eligibility included patients 25 to 65 years of age with therapy-resistant chronic low back pain that had persisted for at least 2 years and radiologic evidence of disc degeneration (spondylosis) at L4-L5, L5-S1, or both. Only patients randomized to one of three surgical groups were analyzed in the current study: **Group 1 (posterolateral fusion;** n = 73), **Group 2 (posterolateral fusion combined with variable screw placement, an internal fixation device;** n = 74), and **Group 3 (posterolateral fusion combined with variable screw placement and interbody fusion;** n = 75). The "circumferential fusion" in Group 3 was performed either as an anterior lumbar interbody fusion (n = 56) or as a biomechanically similar posterior lumbar interbody fusion (n = 19). The groups were composed of 51%, 58%, and 40% men respectively, and the respective mean ages were 44, 43, and 42 years. The patients had experienced low back pain for at least 2 years (mean, approximately 8 years). They had been on sick leave for approximately 3 years. **Pain was measured by a visual analog scale, and disability was assessed by the Oswestry Low Back Pain Questionnaire, the Million Visual Analogue Score, and the General Function Score.** Depressive symptoms were measured by the **Zung Depression Scale.** The global overall rating of the result was assessed by the patient and an independent observer after 2 years. Hospitalization data including operation time, blood loss, blood transfusion, and days of hospitalization in connection with surgery were reported, along with complications and the fusion rate. Records from the Swedish Social Insurance Board providing information on sick leave and economic compensation for Swedish residents were used to evaluate the patients' work status.

RESULTS:

An independent observer examined 201 (91%) of 222 patients after 2 years, after 18 "group changers" and 3 dropouts had been excluded from the analyses. **All surgical techniques were found to reduce pain and decrease disability substantially, but no significant differences were found among the groups**. In all three groups, the patients rated the overall outcome similarly, as did the independent observer. The more demanding techniques in Groups 2 and 3 consumed significantly more resources in terms of operation time, blood transfusions, and days in hospital after surgery. The early complication rate was 6% in Group 1, 16% in Group 2, and 31% in Group 3. The fusion rate, as evaluated by plain radiograph, was 72% in Group 1, 87% in Group 2, and 91% in Group 3. CONCLUSIONS: **All the fusion techniques used in the study could reduce pain and improve function in this selected group of patients with severe chronic low back pain. There was no obvious disadvantage in using the least demanding surgical technique of posterolateral fusion without internal fixation.** (Fritzell P. 2002)

In this research there was a division of 294 patients, three surgical and one non surgical group, but only patients randomized to one of three surgical groups were analyzed in the study. 1st group had posterolateral fusion, 2nd group had posterolateral fusion combined with variable screw placement, an internal fixation device, and last group had posterolateral fusion combined with variable screw placement and interbody fusionThe patients had experience of at least 2 years in low back pain. Pain was measured analogically, low back pain questionnaires were given, visual analog score, general function scores and lastly depression scales were used. Hospitalization data was also measured. The results were that all fusion techniques have the same results, as far as low back pain. We can see the difference with scoliotic surgical approaches that each type of surgery has different effects and some are more favored according to the type of scoliosis, where as in low back pain or disc degeneration in this research, it makes no difference.

4.3. Problem of mobility, exercise and load effect

a. From a prospective evaluation of pulmonary function in adolescent idiopathic scoliosis relative to the surgical approach: minimum 5-year follow-up

The purpose of study was: to evaluate pulmonary function changes 5 years or more prospectively after surgery in patients with adolescent idiopathic scoliosis (AIS) relative to the type of surgical approach used for the spinal arthrodesis.

Methods used: A total of 109 patients with AIS undergoing surgical treatment were prospectively evaluated with pulmonary function tests (PFTs), forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV1) before surgery, 3 months, 1 year, 2 years and a minimum 5 years after surgery (5 to 14 years). All patients were divided into four groups. Group 1 (n=43) posterior spinal fusion with iliac crest bone graft (PSF-IC); Group 2 (n=39) PSF with thoracoplasty (PSF-TP); Group 3 (n=15) anterior fusion (ASF) with a rib resection thoracotomy (ASF-TC) and Group 4 (n=12) combined ASF and PSF with autogenous rib and iliac crest graft (ASF/PSF).

Summary of findings: Irrespective of the surgical approach used for the spinal arthrodesis, postoperative PFTs (absolute values) improved continuously until 2 years after surgery, then did not change between 2- and 5-year follow-up, except Group 1 (PSF-IC), which continued to improve up to 5 years after surgery. Five years after surgery, Group 1 had statistically increased PFTs both in absolute value and percent predicted, whereas patients in Groups 2, 3 and 4 had unchanged (Groups 2 and 4) or significantly decreased (Group 3) pulmonary function values ($p<.05$).

Relationship between findings and existing knowledge: Irrespective of the surgical approach used, postoperative pulmonary function tests (absolute values) increase until 5 years after surgery. **Patients who had no chest cage disruption (Group 1) had a significantly greater improvement in their pulmonary function values at 5 years after surgery than patients with chest cage disruption (Groups 2, 3 and 4).**

Overall significance of findings: We can choose more appropriate approaches for surgical candidates and predict the change of the pulmonary functions 5 years after operation.

(Yongjung Kim, MD1, Lawrence Lenke MD1, Keith Bridwell, MD1, Kyoungnam Kim, HS2, Brenda Sides, MA1, Joetta Whorton, RN3, Kathy Blanke, RN1; Washington University in St. Louis, St. Louis, MO; 2Parkway Central High School, St. Louis, MO; 3Shriners Hospital-St. Louis, St. Louis, MO, 2002)

Here is shown that in people with chest cage disruptions, following anterior approach, had decreased pulmonary function values, so in these patients respiratory therapies may help.

There are two goals of respiratory therapies:

1. Through air pressure to act on spine or thorax, this way to form corrective prodecures.
2. By means of ventilation, of flow of air to stimulate receptors and sensors to support corrective mehanisms.

Respiratory dynamics induce loading processes by direct influence of pressure by i.e. apnoe, coughing and can also induce stimulation of sensors which are producing different muscle actions of whole trunk muscles; there is a possibility how to act on shape of trunk.

Coughing regime, smiling regime are not steady, they are explosive ie. Singing is breathing with acoustic feedback. (Otahal, 2008)

Playing on the flute is also good, because the acoustic feedback exists in this type also. This instrument needs much more expressive pressure, flow, strategy (also saxophone for example). (Otahal, 2008)

According to this singing trainings, it's possible to train different breathing muscles. There are two effects of singing:

1.Fast change of activation and relaxation with sung staccato.

2.It lift's up the activation with holding one long tone of voice.

Besides positive influence of voice on this respiration function, there is a positive influence on psychology which can help itself in case of psychosomatic diseases. Again is reminded the importance of singing like breathing strokes on posture.

Singing, like a therapeutic technique, against other techniques has difference in using acoustic analyzers. In using acousting analyzers with return structure, that is dominant in this case. This stucture we can intensify by using other loops through optical analyzers and device (PC). On graphics we would see the required graphical aim, ie. The frequency and intensity of sung staccato, the patient would try to reach the aim by his singing voice(principle Tracking task).

The problem of breathing during singing and possibilities of therapeutic using in physiotherapy are interesting and deserve more attention in medical and scientific areas.
(Hana Kopečková, 2007)

b. Study on loads on an Internal Spinal Fixation Device During Physical Therapy:

Modified internal spinal fixation devices allow the measurement of the forces and moments acting on the implants. Loads on an internal spinal fixation device were measured in 10 patients with degenerative instability or compression fractures using a telemeterized implant. **Most exercises performed in lying position had low implant loads than for standing and are less likely to break the screws.** Also fixation device loads were lower for sittng relaxed than for standing. The highest implant loads were measured during walking (128% of the value for standing). Standing up, sitting down, and lateral bending and axial rotation of the upper body while standing led to fixation device loads between 111% and 120% related to the value for standing. Even higher fixation device loads were measured for ventral flexion and extension of the upper body while standing. Kneeling on hands and knees, and flexing and extending the back in this position, caused implant loads that were lower than for standing.
The conclusions from these are that: **Standing up, sitting down, and lateral bending and axial rotation of the upper body while standing may slightly increase the risk of pedicle screw breakage, whereas ventral flexion and extension of the upper body while standing may increase this risk considerably if the region bridged by the implant is distracted (the distance between upper and lower screws was increased) during surgery.** (Antonius R. et al, 2002) However, walking is the exercise that plays the major role concerning pedicle screw breakage because it causes the highest bending moments of all exercises studied and it loads the fixation devices most frequently. (Rohlmann A, Graichen F, Bergmann G. Loads on an internal spinal fixation device during physical therapy. *Phys Ther*. 2002;82:44 –52.)

c. Study on Loads on an internal spinal fixation device during walking

Only little knowledge exists concerning the loads on internal spinal fixation devices during walking. In this study, forces and moments were measured in two patients using telemeterized spinal fixators. Although implant loads differed strongly before and after anterior fusion as well as between the two patients, some results were consistent. **In every test series, implant loads were higher in walking than in lying, sitting or standing. Walking speed had little influence on implant loads. Staircase walking put slightly higher loads on the implants than normal level walking. Normal use of two crutches reduced implant loads only slightly, whereas a wheeled invalid walker reduced them by about 25%.** (Antonius Rohlmann, 1997)

d.Study on loads on an internal spinal fixation device during sitting

Sitting is often assumed to involve high loads on the spine as well as on implants for stabilising the spine. Loads on internal spinal fixation devices were therefore measured in ten patients sitting on several types of seats, including a stool, a stool with a padded wedge, a chair, a physiotherapy ball, a knee-stool, and a bench. The patients also successively sat relaxed and erect on a stool. In addition, six of them sat on a special chair allowing different inclinations of the backrest. Implant loads were also measured for standing up and sitting down. **There were only minor differences in fixator loads for sitting on the different types of seats. Sitting erect caused an average of 11% higher implant loads than sitting relaxed. Implant loads decreased with increasing inclination of the upper body while sitting on a chair with an adjustable backrest. Implant loads were about 27% higher for standing up and sitting down than for sitting.** (Antonius Rohlmann, 2001)

From these three researches (done by almost the same people), were found many interesting things that are important in physiotherapy. They may have not been on scoliotic patients but the results count the same. Lying position has the least implant loads on the spine and all exercises on lying position must be optimal. Hence therapies performed only in lying position are recommended for research. Then sitting relaxed has less load on the spine than sitting erect, as well as the higher the inclination of the upper body during sitting the more relaxed (on adjustable chairs). We can instruct the patients to prefer sitting relaxed to sitting erect during he day. Following that, standing position has even more loads on the spine than sitting, as well as higher loads during flexion and extension of the upper trunk; I suggest kneeling on hands and knees to be tried in physiotherapy, since it has less loads during flexion and extension of the upper body. The highest loads are during walking (especially walking on stairs), than in standing, even though walking speed has found to have no role on implant loads (danger of a break). I don't recommend physiotherapy exercises with walking in any way according to these findings. Perharps exercises on scoliotic patients would show different results but from what we know walking is contraindicated. It is also interesting that the difference between upper and lower screws plays some role in screw breakage.

e. The effects of McKenzie and Brunkow exercise program on spinal mobility comparative study.

This study encompassed 64 participants with symptoms of low back pain, 33 in McKenzie group and 31 in Brunkow group. Patients attended exercise program daily and they were asked to do the same exercise at home--five times a day in series of 5 to 10 repetition each time, depending of stage of disease and pain intensity. All patients were assessed for the spinal motion, before and after the treatment. All parameters for spinal movements showed improvement after exercising McKenzie program for lower back pain with a significant difference of $p<0.01$ for all motions. Also, in Brunkow group, all of the parameters showed statistically significant improvement at the end of treatment in relation to pre-treatment values, with significant difference of $p<0.01$ for all motions. Statistically comparison between McKenzie and Brunkow difference in score at the end of the treatment showed statistically significant improvement in McKenzie group, for extension, right and left side flexion, while flexion score didn't show statistically significant difference. McKenzie exercises seemed to be more effective than Brunkow exercises for improvement in spinal motion.

Both, McKenzie and Brunkow exercises can be used for spinal mobility improvement in patients with lower back pain, but is preferable to use McKenzie exercises first, to decrease the pain and increase spinal mobility, and then Brunkow exercises to strengthen the paravertebral muscles.

(Mujić Skikić E et al, 2004)

My idea is that both techniques need to be tried for postoperative spine stabilization operations of scoliosis, especially Brunkow, which is used in non-surgical scoliotic treatments. Mckenzie exercises are mostly done during standing so I don't recommend it, because of high implant loads. Of course further research can show otherwise.

f. Brunkow exercises and low back pain.

Brunkow exercises starting with dynamic contraction of hands and feet with fixed point on the wrist or/and heal. Dynamic contraction from the beginning, transferring through kinetic chain, leads to isometric contraction of the group of muscles, which has to be included in the exercise. Starting positions determine the group of muscles to be trained. **The purpose of this study was to investigate influence of Brunkow exercises on spinal motion improvement and pain relief and to evaluate use of Brunkow exercises, as a routine method for lower back pain** in Physical Medicine and Rehabilitation Centres. Thirty-four patients with symptoms of low back pain were included in study. Patients received a mean of 14.9 treatments with standard deviation of 8.96. All patients were assessed before and after the treatment for spinal mobility and flexibility as well as pain intensity. All parameters for spinal movements showed statistically significant improvement in patients with low back pain who practiced Brunkow exercise program at the end of treatment in relations to pre-treatment values, with significant difference of $p<0.01$ for all motions. Pain was reduced on VAS for X=1.,7 with S.D. 1.97. Difference Test was $t=6.020$ with significant difference $p<0.01$. Flexibility of spine increased, so average difference in values before and after treatment for Shober test was 0.5 cm with SD 0.65. Difference test was $t=3.794$ with significant difference $p<0.01$. **Brunkow exercises for low back pain are beneficial treatment for increasing flexibility and mobility of spine and improving the pain.** (Skikic EM et al, 2004)

Again is shown from the same researchers the effectiveness of Brunkow technique in flexibility and mobility of the lower (lumbar) spine as well as improving pain pereption. This article agrees with the previous artile about the effectiveness of Brunkow technique and further research is necessary.

g. Alexander technique effectiveness for low back pain

The effectiveness of the Alexander Technique has not been thoroughly verified in peer-reviewed scientific journals. Lengthy learning time seems to be a drawback in testing for short term results. In 1999, Dennis ran a controlled study of the effect of AT on the "Functional Reach" (associated with balance) of women older than 65 arguing for a significant improvement in performance. (Dennis, RJ, 1999) In 2005 Cacciatore et al. found **the technique improved a single patient's posture thereby reducing their lower back pain**. (Cacciatore, TW; FB Horak, SM Henry, June 2005) Further, in 2004 **Maher concluded that "Physical treatments, such as ... Alexander technique ... are either of unknown value or ineffective and so should not be considered" when treating lower back pain with an evidence-based approach**. (Maher, CG, 2004) Finally, in 2002, Stalibrass et al. published the results of a significant controlled study into the effectiveness of the technique in treating Parkinson's disease. Four different measures were used to assess the change in severity of the disease. By all four measures, Alexander Technique was better than no treatment, to a statistically significant degree (both P-values < 0.04). However, when compared to a control group given massage sessions, Alexander technique was only significantly better by two of the measures. The other two measures gave statisticially insignificant improvements (P-values of approximately 0.1 and 0.6). This appears to lend some weight to the effectiveness of the Technique, but more studies and data are required. (Stallibrass, C; P Sissons, C Chalmers, July 2002)

Finally, while there is an abundance of anecdotal evidence which suggests that AT instruction contributes to improved vocal quality and vocal health (including its apparent success in treating the vocal health issues of its creator, Alexander), only two studies of AT use with voice were found (Harris, C; S Pehrson 1993) (Jones, FP 1987), , neither of which were published in peer-reviewed journals. In both, there was an apparent attempt to measure the effects of AT on voice and to analyze some data; however, neither methodology nor statistics were provided to lend scientific credence to the interpreted results (e.g., representative sampling, control groups or blind testing) or acoustic measurements (i.e., microphone type, microphone placement, microphone directionality, recording environment, recording media – all of which could affect the spectral characteristics of the recording).

Thus, while both studies may report actual effects, one cannot have confidence that they demonstrate anything more than possibly placebo improvements without the inclusion of carefully designed methodologies, legitimate metrics or statistical analysis.

(Alexander technique, in Wkipedia, 2007)http://en.wikipedia.org/wiki/Alexander_Technique)

From the Maher's conclusion about low back pain I exclude Alexander technique for further research of post operative spine stabilization physiotherapy. It may be only a placebo technique as fas as they say.

h. Acupucture in the treatment of scoliosis – a single blind controlled pilot study

Background: Today, acupuncture therapy is commonly used for pain control throughout the world, although the putative mechanisms are still unclear. A Pub Med search for the key words "Acupuncture" and "Scoliosis" reveals 3 papers only, not containing any results of studies designed for the treatment of scoliosis with the help of acupuncture. Because of this lack of trials especially designed for the treatment of scoliosis this pilot study has been performed.

Methods: 24 girls undergoing in-patient rehabilitation, 14 – 16 years of age (at average 15,1 years, SD 0,74) with the diagnosis of an Adolescent Idiopathic Scoliosis (AIS) have agreed to take part in this controlled single blind crossover study. Average Cobb angle was 33 degrees (SD 9,2) ranging from 16 to 49 degrees. 10 of the girls had a thoracic, one a lumbar, 7 a double major and 6 a thoracolumbar curve pattern. The patients have been scanned with the Formetric® surface topography measurement system before and after lying on the left side [L], before and after sham acupuncture [S] and before and after real acupuncture [R].

Results: For the whole group of patients no significant changes have been found during lying, sham acupuncture or real acupuncture. There were no differences between the patient groups with different curve pattern. In the explorative subgroup analysis of Patients with curvatures from 16 to 35 degrees, however significant changes in surface rotation have been found after R intervention as well as a strong differences in lateral deviation while in the L or S intervention no real changes have been achieved.

Conclusion: One session with real (verum) acupuncture seems to have an influence on the deformity of scoliosis patients with no more than 35 degrees. The findings during verum acupuncture clearly are different

to sham acupuncture or just lying, while in the whole group of patients also including patients with curvatures of more than 35 degrees no obvious changes have been found. The results of this study justify further investigation of the effect of acupuncture in the treatment of patients with scoliosis. (Hans-Rudolf Weiss, Silvia Bohr, Anja Jahnke and Sandra Pleines, 2008)

From these findings I believe that acupuncture may be tried for scoliotic patients after surgical correction with a Cobb angle that does not exceed 35 degrees. Further research is expected on this.

4.4 Problem of efficiency of traditional Physiotherapeutic methods

This is a complicated problem and in literature I didn't find any meaningful articles. Perharps it is due to the youth of the problem, not having been discussed or researched yet. Therapists have no valid examinations for this problem.

There doesn't exist any specific physiotherapy written after stabilization of the spine surgery. My idea is that since the lesser the load on the spine, the lesser the stress exerted; Vojta therapy and water exercises do this job with the least stress exerted on the spine, I believe. Hence Vojta is only used in lying positions, where the least loads are exerted on the spine, and also the patient on knees and hands (crawling) is used in some phases of Vojta therapy (loads in those positions are relatively low as I discussed before). In combination with muscle-breathing exercises for good function of the lungs, coactivation of breathing muscles and controlling breath depth and muscle force the patients will have improvements in mobility and posture. Assymetric exercises are used for stabilization but the spine is already stabilized after operation. Importance is to use symmetrical exercises for prevention. Added to that, soft tissue techniques for active scars, it seems the most optimal proposal from my perspective. Brunkow therapy, singing, that helps in posture in ways that I have describe before, Buteyko as breathing exercises, acupuncture, all of these treatments are recommended to be tried further for AIS post-op patients. The traditional approach of physiotherapy does not solve this problem. Further practical research needs to be done with different techniques.

CHAPTER 5

5.1 CONCLUSION

It was quite difficult to find the right resources for this work, since the amount of literature written does not solve this problem in any concrete way. By reading all of these articles, books and consultations I had with different teachers I have brought a lot of knowledge fourth. AIS patients have many options for operations and according to the type of Lenke or older King's classification and how big the Cobb angles are, the surgery may be chosen. The experience of doctors, the right choice of biomaterials as well as simulation of the surgery play a role in choosing the right type of operation. A three dimensional view of scoliosis is necessary to give the right diagnosis with Moire, topography, MRI, CT as I have described above. Sometimes we have to take into consideration if the surgery is actually worth it according to the patient's psychosocial life, but adolescents are still young and adaptable. One of the most concrete things that I found was the implant loads in different positions and the importance of exercises in lying position. Traditional physiotheraputic methods do not solve the problem yet and further research need to be done with already existing therapies and possibly brand new approaches, always respecting the individuality of the patient's case.

The problem of scoliosis is very complex and very wide in nature without artificial ways. Artificial components and braces bring new phenomena. These properties of artificial components ie. braces are compensating from external point of view, the thorax and trunk, but implants are correcting scoliosis by operation. These two factors attack the nature of the organism. It's a new structure added to organism, but bracing is different.

These two treatments, bracing and implants are so different that they need a different approach. The first is focused on a structural reorganization of the body and the second one focuses on restriction of function.

Is it true that artificial components, or this surgical implantation and rehabilitation will continue? These approaches will adopt new results of discovery in tissue engineering branches. Physiotherapy must count this trend and find a way how to be a partner of this new approaches.

Complexity of the spine, is based in different structures which play a role. Hard tissue structures, soft tissue structures, nerves, muscles, proprioception, exteroception. Complexity is a source of complex reactions i.e.

a. Dysfunction between single intervertebral communication logically can produce a complex answer along whole spine.

b. Reversibly, global influence, external or internal influences, complex immobilization will probably produce drastic changes in single intervertebral communication.

So each approach to this new problem must be based on testing and adapting individuality and is very difficult to generalize the results.

5.2 Appendix

Water therapy:

Water therapy exercise programs (sometimes called pool therapy, hydrotherapy, or aquatic therapy) consist of a variety of aquatic-based treatments and exercises that are designed for back pain relief, to condition and strengthen muscles. Water therapy exercise offers many of the same benefits associated with a land-based exercise program, including development of a treatment plan that is carefully tailored to the individual. Water therapy exercise is especially helpful in cases where a land-based exercise program is not possible due to pain, decreased bone density, disability or other factors. As such, water therapy is a versatile exercise and is particularly good for people with conditions such as:

- People who are under spine stabilization
- Osteoarthritis
- Advanced osteoporosis (with susceptibility to and/or pain from fracture)
- Muscle strain or tears

In addition to those conditions, water therapy is frequently recommended as one form of exercise therapy to treat those with diabetes as well as individuals with high blood pressure. Both conditions can improve and become more manageable with aquatic exercise. All of these conditions can make it uncomfortable or painful to exercise on a hard or even padded surface, or while standing. Water provides a much gentler, welcoming environment. (http://www.spine-health.com/Wellness/Exercise/Water-Therapy/Water-Therapy-Exercise-Program.html)

VOJTA:

INBORN MOVEMENT STEREOTYPES AS THE KEY TO VOJTA THERAPY

By the age of one year healthy children normally reach all the *chronological milestones* that provide all the proficiency necessary for developing advanced motor skills like unassisted *uprighting* (straightening) and moving forward (walking). These precursory milestones include inborn movement stereotypes such as grasping, turning, creeping and crawling. Frequently however due to a disruption in the Central Nervous System, automatic activation of these movement stereotypes becomes delayed or inhibited impairing further development. Vojta therapy *activates* and restores inborn moment stereotypes by stimulating related areas of the brain thereby inducing coordinated movement in the body and extremities.

THE DEVELOPMENTAL MILESTONES OF HUMAN FORWARD MOVEMENT

Turning and crawling are two primary movement patterns that represent immediate precursors of human unassisted upright movement forward. They are triggered by the Central Nervous System following genetically predetermined sequence that corresponds to the growth and development of the locomotor system components of the child enabling the baby to perform more and more advanced tasks. All separate elements that constitute such complex movement patterns like human uprighting and walking are imbedded into these two primary movement stereotypes.

Reflex Locomotion method that forms the basis of Vojta Therapy initiates crawling and turning movement stereotypes on the involuntary (without patient's participation) level. The patients are placed in one of the primal positions emulating those of an infant ready to turn or to crawl. The therapist stimulates specific reflex zones applying targeted, tri-dimensional vector, non-painful pressure. This type of stimulation induces patients, regardless of their age, to reflexively either turn or crawl, depending on the therapist's purpose.

THE EFFECT OF ACTIVATION

Turning and crawling movement patterns contain all elements of more complex motor tasks that require higher degree of coordination and balance. Automatic regulation of balance (postural control), body uprighting (straightening), targeted grasp as well as stepping forward (phasic movement) are all based on movements executed by turning or crawling infants. Repeated activations of these two basic reflex movements help to form or restore pathways in the functionally blocked neural network that connects the brain and the spinal cord. This results in better coordination of muscle contractions along the spine, upper and lower extremities and in the facial area.

Vojta therapy improves the quality of every-day spontaneous and automatic movements as well as postural support of the body. The effect of the therapy is such that after a single session patients with movement disorders display improved ability for contact and communication with their environment. The neural pathways formed at the inducement of movement stereotypes remain lodged in the brain for many hours after the session. Repeated on the same day, the therapy strengthens accomplished results enabling the voluntary use of activated movement stereotypes by these patients.

THE SOONER THE BETTER

Vojta therapy is suitable for all ages. However, younger patients are more susceptible to the treatment and more stable and longer lasting results can be expected.
In infants it is relatively easy to repair disruptions of Central Nervous System due to its enormous plasticity at this age. Blocked neural pathways are readily re-established and new stable connections are easily formed because flawed compensatory motor stereotypes are not yet fixed and can be seamlessly overwritten.

In older children and teenagers, whose Central Nervous System plasticity is diminished proportionally to the age, the therapy can still produce a significant positive impact on the process of maturation and growth setting the grounds for a healthy gratifying adulthood.

In adult and elder patients, whose Central Nervous System is irreversibly rigid, Vojta therapy, still widely beneficial, is primarily used in back pain relieve, trauma prophylactics, post-traumatic rehabilitation, posture adjustment and other corrective interventions. Its means, when introduced at this stage, are limited to reinstating dormant ideal motor stereotypes thereby evoking co-activation of deep musculature establishing deep spinal stability that helps to alleviate pain and restore functional efficiency.

VOJTA METHOD - ACTIVATION WITHOUT TRAINING

Reflex Locomotion is induced with the patient in one of the three primal positions: on the back, on the stomach and on the side. Activation is achieved by tri-dimensional vector stimulation of one or several specific zones (ten in all) located throughout the body which were discovered and described by Prof.Vojta. The optimal placement of extremities at specific angles is essential. The therapist provides measured resistance against certain elements of the induced movement, for example against turning head, while reflex crawling is activated. This creates stronger isometric (generating force without changing length) contraction in muscles attached to the body part to which the resistance is applied. The result is improved coordination of multiple muscle contractions in throughout the body.

REFLEX CRAWLING

Reflex Crawling is a movement stereotype, which includes basic elements of walking such as regulation of body position, uprighting (overcoming gravity) and voluntary stepping movement by arms and legs. Patient is positioned on the stomach with the head rotated slightly to the side. In infants it is possible to induce reflex crawling by stimulating a single breast zone. In older children and adults combined stimulation of several zones is necessary.

The goals of Reflex Crawling are:

- Activation of mechanisms necessary for support, grasping, verticalization and walking;
- Activation of muscles responsible for deep breathing;
- Activation of abdominal muscles and their coordinated differentiated activity;
- Activation of pelvic floor muscles responsible for stability of the spine;
- Activation of rectal and urinary sphincters;
- Activation of swallowing and mastication (chewing);
- Activation of eye muscles;
- Straightening of the spine;

The movement is induced with patient's body restrained, while right leg is moving simultaneously with left arm and vice-versa simulating forward motion. The therapist provides measured resistance to the head, which, in accordance with the reflex nature of the movement, begins to turn to the side. This enhances the Global Response (activation of muscles of the whole body), which in infants creates the basis for uprighting (movement against gravity).

Reflex creeping

Note*: Used with caution if used postoperatively. Carefull not to move the stabilized parts of the spine.

The starting position for reflex creeping is prone. The head is placed in the body's longitudinal axis (cephalo-caudal axis) and rotated approximately 30 degrees to the side, sothat it lies on the frontal eminence. The body half that is on the side to which the eyes are orientated is termed the "facial side", the opposite body half is termed the "occipital side". Correspondingly this results in the differentiation into a facial -arm and -leg as well as an occipital -arm and -leg.

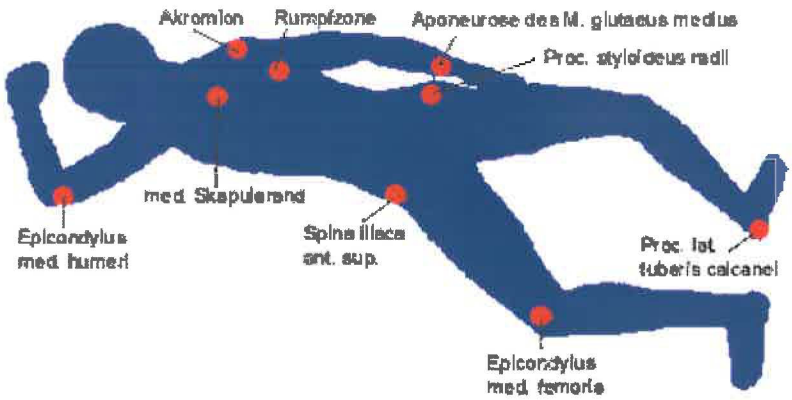


Fig. 37 (Review of Therapy, Reflex creeging in Internationale Vojta Gesellschaft e.V, April 2007)

The above figure illustrates the starting position for Reflex creeping and the available choice of activation zones. These stimulation points set off a discharge of muscle activity necessary for the creeping sequence. In the neonate a single zone is sufficient to evoke the entire process. In children and adults several zones must be combined with one another.

The combination of various zones, their stimulation over a period of time, and resistance given against the arising sequence of movement leads to an intensification of the reaction.

Reflex creeping proceeds in various phases characterised by cyclical stepping actions of the extremities that conform to a reciprocal pattern. The extremities take over the differentiated functions of both support and movement, that can likewise be seen in crawling or walking. Movement of the entire trunk forwards only takes place through the appropriate support function of the extremities. The resulting sequence of movement is illustrated below.

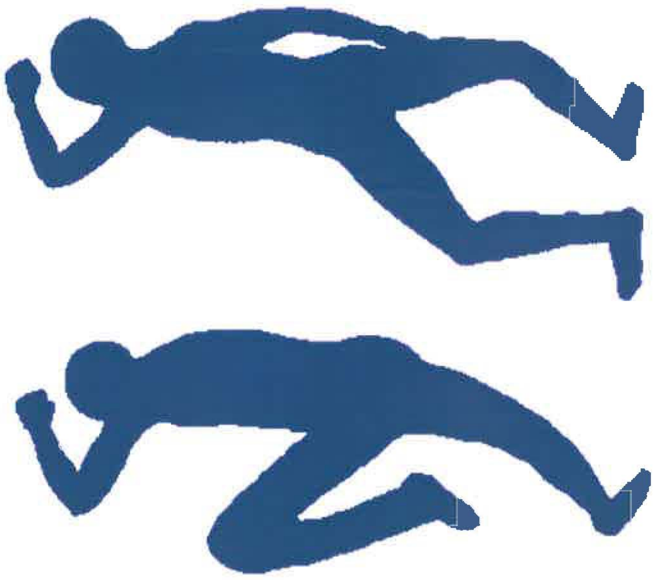


Fig. 38 (Review of Therapy, Reflex creeging in Internationale Vojta Gesellschaft e.V, April 2007)

The entire sequence of movement, shown above, is not permitted to occur in the therapeutic application of Reflex creeping. For example, resistance is given against the rotation of the head to intensify the reactions occurring throughout the trunk and the extremities.

Extensive activity takes place throughout the entire body musculature leading to the process of up-righting of the trunk over the extremities, which prepares the individual for the higher orientated locomotion patterns like crawling and walking.

Activity of the stomach muscles supports the functions of the internal organs and has an effect on the pelvic diaphragm up to and including the sphincter muscles of the bladder and bowel. In the head region; eye movements, swallowing movements, and movements of the tongue occur that are important to mastication.

(http://www.vojta.com/cgi-local/ivg_eng.cgi?id=105)

ONE PRINCIPLE-MANY VARIATIONS

From the three basic reflex movement positions we can generate 30 therapeutic variations. The variations result from combination of activation zones selection, degree of resistance against the induced movement, changes in stimulation vector and changes in the type of pressure applied to the stimulation zone. Such a high degree of variability allows tailoring the therapy to a specific diagnosis and therapeutic goal.

VERSATILE EFFECTS

Due to its wide spectrum of effects, Vojta therapy can bring significant improvements in variety of adult and pediatric disorders like Cerebral palsy, Torticollis , Hip dysplasia, Central Coordination Disorder (either by itself or as a part of Attention Deficit Disorder), Motor Delay, **Scoliosis**, Stroke, Multiple sclerosis, Spinal cord trauma, variety of Breathing Disorders, Muscle and Back Pain.

The versatility of Vojta therapy effects is especially fully reflected in the following areas:

SKELETAL MUSCULATURE

- The spine straightens segmentaly and becomes more functional;
- The head moves freely at the atlanto-occipital joint (where the cranium is attached to the spine);
- All joints become centrated especially such key proximal joints like hips and shoulders;
- The arms and legs become more functional for targeted support and grasp;

FACE AND MOUTH

- Sucking, swallowing and chewing is facilitated;
- Eye movement becomes better targeted;
- Movement of the eyes becomes independent of head movement;
- Clarity of speech improves

RESPIRATION

- The rib cage expands evenly in all directions;
- The breathing becomes deeper and more balanced;

AUTONOMOUS NERVOUS SYSTEM

- The subcutaneous vessels become more perfused;
- The sleep cycle becomes more balanced;
- The regulatory function of urinary bladder and intestines is activated;

BALANCE AND PERCEPTION

- Balance reaction improves;
- Spatial orientation and body awareness improves;
- Perception of cold/warm and sharp/dull contrasts is more pronounced and becomes better defined;
- Recognition of forms and shapes of objects is enhanced due to improvement of stereognosis;
- Concentration becomes longer lasting and more flexible;

EMOTIONAL HEALTH

- The patient is better emotionally balanced and is better able to withstand increasing amounts of stress;

CONTRAINDICATIONS:

Vojta therapy should not be used in the presence of following physical conditions:

- High fever or inflammatory diseases;
- Severe osteoporosis;
- Certain heart conditions;
- Pregnancy;

HOW THERAPY IS CONDUCTED (REGIMEN)

The success of Vojta therapy depends on the skill of the therapist and proper dosage. The more severe the condition the higher the frequency of therapy sessions is recommended. In extreme cases it can be applied up to four times a day. One *therapeutic block* can last from five to twenty minutes.

In such severe cases like cerebral palsy in children the decisive role in application of Vojta therapy is played by parents or caregivers. The therapist prepares an individual program and together with the patient's parents establishes main therapeutic goal of the treatment. Then the therapist teaches the techniques and exercises to individuals responsible for the administering the treatment at the patient's home. This allows establishing desired levels of the therapy intensity. The therapist provides professional guidance modifying the course if necessary.

HOW SMALL CHILDREN REACT TO VOJTA THERAPY

In infants Reflex Locomotion evokes unusually rigorous muscular activity that may be uncomfortable and as a natural reaction to anything uncomfortable at this age small children often respond with crying. This may alarm some parents with a suspicion that their child is hurt. Crying however is an adequate reaction at this age and constitutes a normal response of a child to activation of an unusual movement. After a short while the crying becomes less intense and eventually ceases. Older children who are able to speak do not cry at all although at times they may voice complaints and become less cooperative.

THE ADVANTAGES OF VOJTA THERAPY

Vojta therapy has been extensively used for over forty years in Europe and Asia. It has been scientifically proven to be effective in various pathologies in children and adults where movement of the body was affected neurologically due to irregular maturation of the Central Nervous System (due to fixation of deficient compensatory motor patterns), abnormal motor development, brain or spinal cord injury, motor delays and other conditions affecting movement of the spine and body.

The versatility of Vojta therapy is explained by the fact that it acts on neural connectivity on many different levels of the nervous system - Autonomic, Somatic and Central, from the periphery (skeletal muscles and internal organs) to most complex functions of the brain.

Vojta therapy uses natural locomotion. Instead of teaching routine movements (as is the case with other therapies) Vojta therapy activates in patients their inborn ability to move.

The therapeutic effect of Reflex Locomotion empirically discovered by Prof. Vojta has been scientifically studied and compared to other methods. It has been proven to be the most effective method of treatment of children up to one year of age and at least as effective as other popular methods when applied to older children and adults.

Due to its broad approach the effect of Vojta therapy is especially magnified when it is used in conjunction with methods that focus on specifically selected neurological functions. The combination of Vojta therapy and Conductive Education method has been acknowledged as the most productive. Other combinations have also yielded very satisfying results. Vojta therapy has been successfully incorporated with NDT, MANUAL THERAPY AND SENSORY INTEGRATION.

Vojta therapy can be instrumental as the background therapy for pathologies that do not have direct relationship with the motor system. The control of body movement activated by Vojta therapy is paramount for spontaneous communication of developing child. Many developmental disorders that affect speech, eating, cognition, sensory perception and fine motorics are connected to motor deficiencies. Therefore Vojta therapy can significantly enhance outcomes of other therapies in treatment of these conditions.

Long-lasting effects of Vojta therapy reinforce motor function and help to maintain the body under control of the Central Nervous System. This results in complete independence of a child from an adult caregiver.

In Europe Vojta therapy is accepted by all governmental and private health insurers that have long recognized Vojta therapy's cost-effectiveness when it is compared to the conventional medical procedures. Its economical value is determined by the fact that it does not involve expensive machinery and medications. It can be conducted domestically, limiting the participation of the therapist to supervisory capacity therefore eliminating frequent and costly visits to the clinic or medical office. Also, treating motor dysfunctions early, the notion Vojta therapy specialists actively profess, improves overall health of the patient having prophylactic effect on the development of neuro-musculo-skeletal diseases later in life thereby eliminating future costs of medical and disability care.

{(Cerebral Palsy (Vojta Therapy), Lev Kalika, April 2007)}

Findings by palpation after operation

On the skin, subskin and fascia we use soft tissue techniques to release hyperalgetic zones that may be present. It is extremely important to start this after any operation in the area even just after operation with the stitches. We observe color, turgor, and perspiration. (Jalovcova, 2005) Depending if the surgery has been done anteriorly or posteriorly different scars will be present and in different regions. Possibly some reflex reactions (cuterovisceral) may be present according to where were the incissions

Stroking

Stroke-gently touch –the scar and around the scar also by using whole palm

Effect of stroking

Effect is normalization of the muscle tone, skin fascias,stereognosis

Soft tissue techniques

Soft techniques-on the soft tissue (skin and fascias), we find the barier and stop at the first resistance that we feel. Physiological barrier means the tissue is relaxed and tension is normal. Pathological precedes the physiological barrier, there is no elasticity.

With both hands we can use S type, C type, diagonally stretch, stretch at right angles while hands are not touching directly on the scar. We elongate the scar horizontally while hands are directly on the scar. When examining or pressing against barrier, angle of touch of fingers corresponds to deeper tissue level, the steeper the deeper; For this we use thumb or two fingers. (Springrova, 2005) We must always review both sides and breathing under the scar.

Effect of soft tissue techniques

Shifting of the scar is renewed, the barrier is decreased

Pressure massage

We can massage when the stitches are inside but the scar is without edema. After removal of the stitches we always apply a gentle massage.After fall of cruscles we can do massage over the scar

Effect of pressure massage

Change in congestion and uncongestion. Promotes healing and prevention of complications

Note

After pressure massage we put some cream. We must care about the scar up to three to six months after operation and if we have an active scar after those months we should keep caring for it for further complications.

(Kyskova, 2006)

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List of terms (Abbreviations)

AIS -Adolescent Idiopathic Scoliosis

HA -Hydroxyapatite

Th-Thoracic

Thl/L- Thoracolumbar

L -Lumbar

C- Cervical

MRI- Magnetic Resonance Imaging

CT- Computer tomography

SRS- Stereotactic Radio Surgery, Scoliosis Research Society

SSEP- Somatosensory Evoked Potentials

MEP- Motor Evoked Potential