Minimally Invasive Spine Surgery

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Primum non nocere – First do no harm

In the long history of surgery it always has been a basic principle to restrict the iatrogenic trauma done to a patient during surgery to a minimum. Modern surgical technology and techniques have shifted this principle into a new dimension. In spine surgery, the last decade of the twentieth century has been the decade of minimally invasive surgical procedures. The chapters of this book describe in detail the different techniques which are applied to improve symptoms or cure a variety of spinal diseases. They all follow the basic principles of what is more or less a "philosophy" of minimally invasive surgery.

In the following, this philosophy will be described.

1.1 Goals of Minimally Invasive Spine Surgery (MISS)

One of the main goals of MISS is to do an *efficient* "target surgery" with a minimum of iatrogenic trauma. Thus, either the "access surgery" or the "target surgery" itself can be minimally invasive. The majority of minimally invasive techniques in spine surgery refer to the access and not to what is done in the target region. However, the surgical strategy depends on the localization and patho-anatomy of the region or structure which has to be treated (Fig. 1.1). They determine the access, as well as the target strategy.

1.2 Access Principles

The spine as the central "axis" organ can be reached from different directions through different entrances (Fig. 1.2). The surgical entrance (skin incision) must be determined by the topography of the target and the access anatomy. It should be adequately placed and should have an adequate (smallest possible) size. Cosmetic aspects should be considered (e.g., skin incision follows skin lines) (Fig. 1.3).

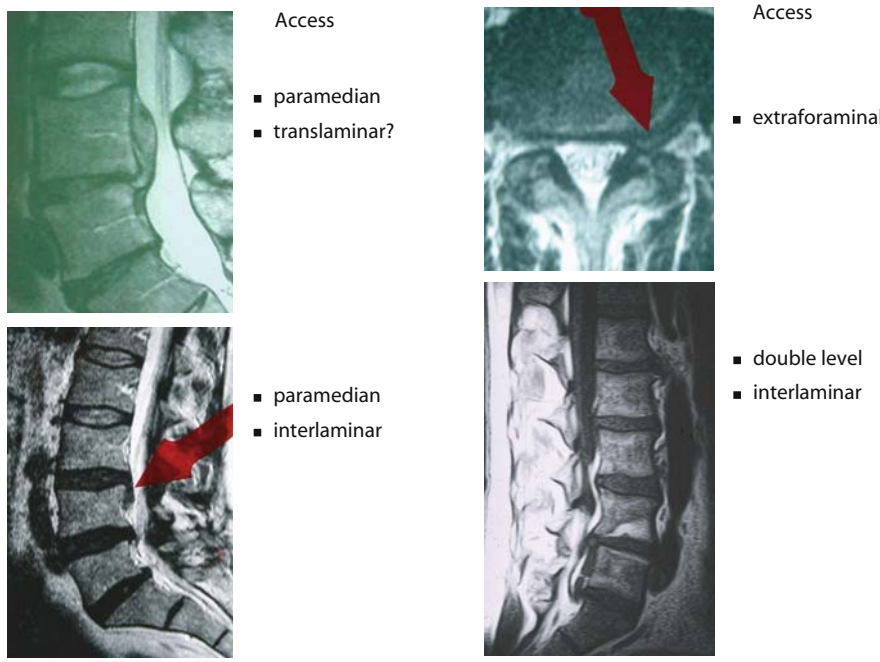


Fig. 1.1. Different localization, size, and configuration of surgical targets (lumbar disc herniations) require different access routes for adequate exposure

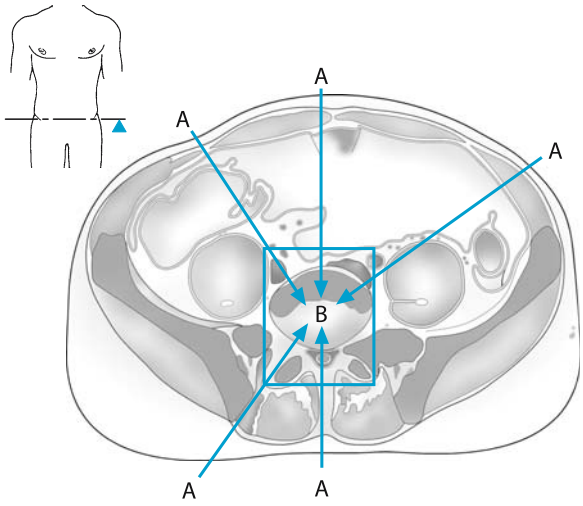


Fig. 1.2. Common access routes to the spine

Fig. 1.3. Transverse (cosmetic) skin incision for anterior approach to the cervical spine

Fig. 1.4. Blunt, muscle-splitting (function-preserving) anterior approach to the lumbar spine

The surgical route to the target area should be the least traumatic, i.e., it should strictly follow anatomical pathways such as preformed spaces or, if this is not possible for the whole skin–target distance, it should be performed with a minimum of collateral damage to surrounding tissues. If collateral damage cannot be avoided, it should be reparable and have a negligible effect on the clinical outcome. If possible, the function of the abdominal and paravertebral muscles should be preserved (Fig. 1.4)

The most important aspect is the adequate exposure of the target area. The target (e.g., disc herniation, disc, spinal nerve, tumor) should be clearly visible and identified. The target treatment (e.g., discectomy, vertebrectomy, neurolysis, tumor removal) should be possible without any restrictions due to the small approach. Spinal manipulation (e.g., reduction maneuvers) should be possible, as well as the insertion of implants for spinal stabilization.

The retreat from the surgical field should leave no or only minor traces (e.g., hematoma, "open" annulus fibrosus following discectomy, scar tissue) and it should not be relevant for the outcome (e.g., muscle damage). In the case of a staged surgical therapy (e.g., dynamic posterior stabilization) or in cases were there is a possibility for a recurrent pathology (e.g., disc herniations) the postoperative traces, such as scar tissue, muscle damage, or intervertebral joint damage, should not negatively influence these further therapeutic options (Table 1.1).

To achieve all these goals, meticulous preoperative planning is necessary. Positioning of the patient on the operation table requires modifications. Localization of entry area under fluoroscopic control is mandatory and surgical preparation techniques must be adapted. Special instruments (see Chapter 4), light and magnification sources (loupe, surgical microscope, headlamp), as well as retractor devices (e.g., frame or ring retractors, tubes, etc.) are necessary (Table 1.2)

Table 1.1. Access principles in minimally invasive spine surgery (MISS)

Skin incision	Adequate placement Adequate size Cosmetic
Route to target	Least traumatic (anatomical pathways!!) Fast
Collateral damage	Negligible Reparable
Target exposure	Adequate
Target treatment	Efficient Without restrictions due to small approach
Postoperative traces	Negligible Not relevant for outcome Options for return (recurrences, etc.)

Table 1.2. Factors which influence MISS strategy

Preoperative planning
Positioning of the patient on OR table
Localization of skin incision
Dissection technique
Instruments and implants

1.3 Preoperative Planning

Topography and volumetry of the target must be clear. This information is usually given by different imaging techniques such as MRI, CT, etc. (Figs. 1.1, 1.5). Especially in anterior approaches to the spine, knowledge of the topography of the prevertebral space can be valuable. Retraction of the prevertebral blood vessels is an important surgical step to expose the anterior circumference of the lumbar spine. Minimally invasive approaches do not allow a wide exposure and mobilization of these vessels. This can increase the risk of indirect damage to branches entering or exiting the arteries and veins. Preoperative vascular topography can be determined with the help of color-coded three-dimensional CT scans which give a clear picture of the individual anatomy (Fig. 1.6; see also Chapter 43). Traces of previous operations in the target of access region also influence the access strategy.

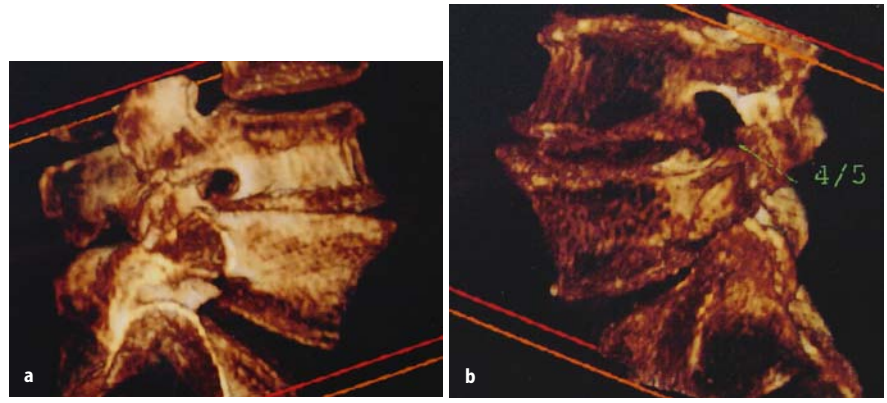


Fig. 1.5. Three-dimensional color-coded CT scan showing the three-dimensional extent of a foraminal stenosis at L4-5.
a Foramen L4-5 right side, marked narrowing. **b** Foramen L4-5 left side, normal size

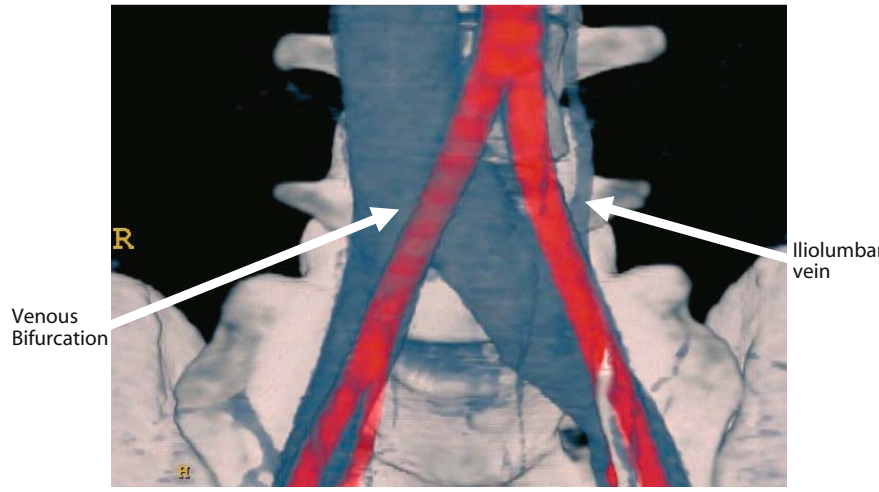


Fig. 1.6. Three-dimensional color-coded CT scan showing angiography of the retroperitoneal, prevertebral blood vessels in front of the lumbar spine

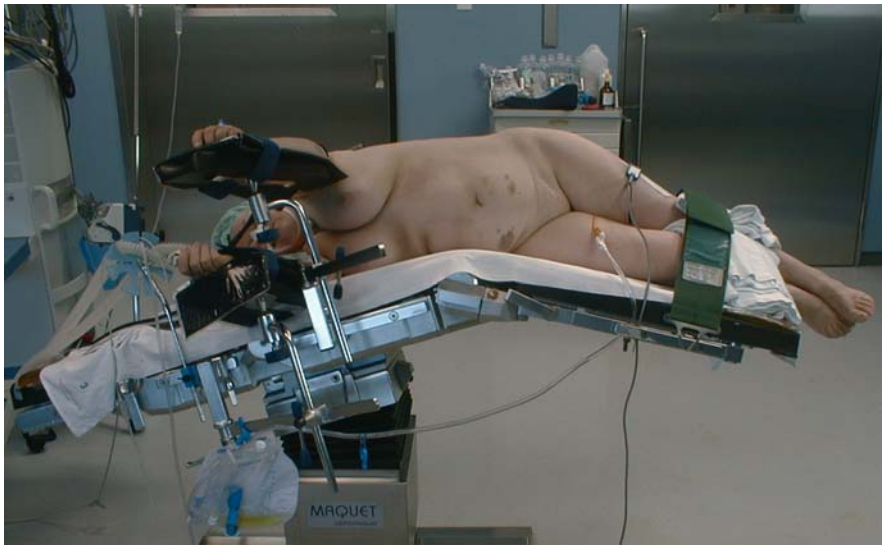


Fig. 1.7. Lateral positioning of patient for anterior lumbar interbody fusion of L2-4. Note: abdominal contents (and abdominal fat) "fall away" from the surgical field by gravity

1.4 Positioning of the Patient

Positioning of the patient can strongly influence the minimally invasive exposure as well as the target surgery. Examples are the lateral positioning and access to the lumbar levels L2-4 for anterior lumbar interbody fusion which eases the access to the spine even in obese patients (Fig. 1.7) or the knee–chest position of patients for lumbar discectomy or decompression procedures which leads to a pressure release in the epidural venous system and thus diminishes the risk of epidural bleeding (see Chapters 32, 44). You will find more examples of "sophisticated" positioning in the following chapters.

1.5 Localization of Skin Incision

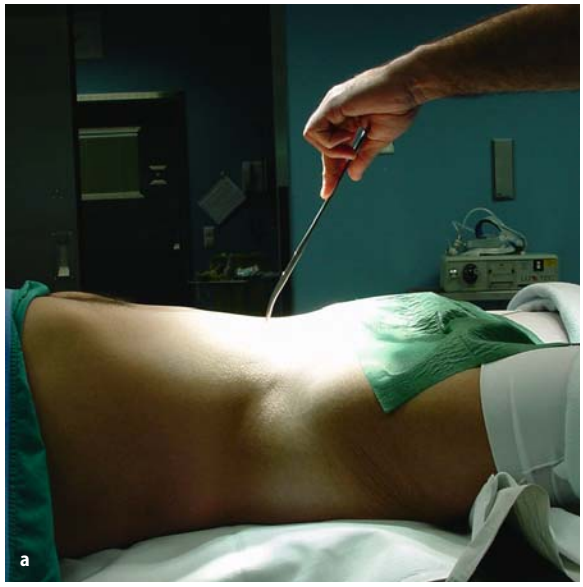
Skin incisions are supposed to be small in MISS. This implies an adequate localization as referred to the target area (Fig. 1.8). In the majority of mini-open techniques, the skin incision is placed directly above the target. In endoscopic techniques, the skin localization of the incision(s) is determined by the intended working direction as well as by the view angles necessary during the operation (see also Chapter 23).

1.6 Surgical Dissection Techniques

The paramount goal of MISS is to minimize tissue trauma. Traditional surgical techniques show striking differences between the surgical dissection and handling of different tissues (e.g., nerve versus bone, muscle versus blood vessel). The increasing knowledge of structure and function of tissues requires a modification of traditional surgical dissection techniques. A muscle or bony structure should basically be treated with the same care as a nerve or a blood vessel. Blunt, muscle-splitting techniques are characteristic for MISS. The use of high-speed burrs instead of large rongeurs can preserve bony structures (see Chapter 44). The individual mobilization of blood vessels can decrease the vascular complication rate (see Chapter 43). The use of hemostatic agents in spinal canal surgery can reduce the risk of epidural hematoma. The microsurgical closure of the annulus fibrosis is supposed to promote the low healing potential of this structure (see Chapter 32).

1.7 Instruments and Implants

Minimally invasive spine surgery is not possible without optical aids. Light and magnification are needed to illuminate and visualize the surgical target in the depth of the human body through small skin incisions. The minimum requirement is provided by headlamps and loupes. The surgical microscope and/or endoscopes are helpful or mandatory for certain techniques (see Chapters 2, 9, 10, 12, 20 – 23). Surgical instruments need to be bayonet-shaped and/or long enough to bridge the distance from the skin to the target. The branches of instruments for electrocoagulation must be isolated to avoid tissue damage in the access region (see Chapter 4). One of the major challenges for the future will be the development and improvement of instruments and implants which allow for intraoperative spinal manipu-



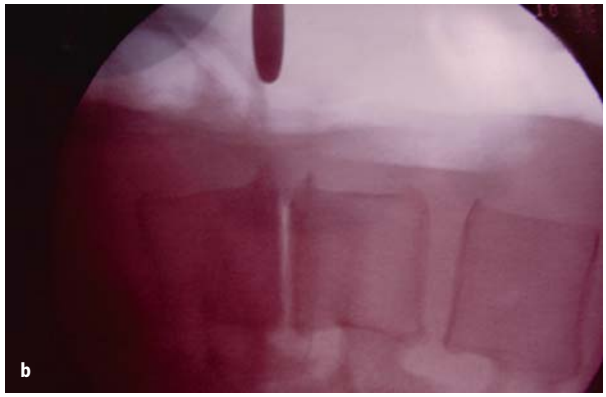


Fig. 1.8a, b. Localization of skin incision for total lumbar disc replacement of anterior interbody fusion

lation (reduction, correction) and fixation. Last but not least, tubes or frame-type retractor systems are mandatory to keep the surgical corridor open (see also Chapters 4, 15, 21, 22, 31, 36, 37).

1.8 Summary

Minimally invasive techniques are currently applied in large variety of spinal surgical procedures (Tables 1.3, 1.4). Surgical invasiveness has been minimized mainly for surgical accesses but not for target surgery. Despite different techniques there are general principles which have to be considered. Only with preoperative planning, the (educational) elaboration of a surgical strategy, the thorough knowledge of the patient's individual-anatomy, the respect of the anatomy, properties, and function of tissues, and the well-trained use of modern surgical high-tech equipment will there be an improvement in peri- and postoperative morbidity and clinical results for our patients.

Table 1.3. Application of minimally invasive techniques in anterior spine surgery

Lumbar spine	**Cervical spine**
Mini-ALIF	Uncoforaminotomies
Nucleus replacement	Discectomy
Total disc replacement	Total disc replacement
Fractures/tumors	SS Decompression
Spinal canal decompression (Instrumentation)	Fractures
	Tumors
Anterior extraforaminal decompression	Vertebral artery decompression
Thoracic spine	
Disc herniations	

Table 1.4. Application of minimally invasive techniques in posterior spine surgery

Lumbar spine	**Thoracic spine**
Disc herniations medial/paramedian/intra/extraforaminal	Costotransversectomy
Spinal stenosis (central/lateral)	**Cervical spine**
Foraminal stenosis	Foraminotomies
Synovial cysts	Craniocervical junction – decompression
PLIF/TLIF preparation	Laminoplasty
Disc excision in severe spondylolisthesis	