1.2 Minimally invasive spine surgery and AOSpine principles

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1 Principles of minimally invasive spine surgery

In the history of surgery, reducing iatrogenic tissue trauma to a minimum has always been regarded as one of the basic principles. Modern surgical techniques and technology have shifted this goal into a new dimension. In spine surgery, the last decade of the 20th century was marked by significant advances in the field of minimally invasive surgical procedures. These developments continue to follow basic principles, and what can almost be qualified as a philosophy regarding minimally invasive surgery.

1.1 Goals

The aim of every surgical procedure is to resolve the patient's clinical problem by treating the underlying pathology (**Table 1.2-1**). This pathology can be considered as the target of each surgical procedure. So one of the goals of minimally invasive spine surgery (MISS) is to carry out efficient "target surgery" with a minimum of iatrogenic trauma. To attain this target, the surgeon has to create an access to it. So practically speaking, either the access part or the target part of the surgical procedure—or both—can be minimally invasive.

The majority of minimally invasive techniques in spine surgery primarily concern the access, and not what is performed in the target region.

Access
Target
Planning
Positioning
Skin incision
Surgical dissection techniques
Instruments and implants

Table 1.2-1 Factors that influence MISS strategy.

1.2 Access surgery

The spine can be accessed from different directions through different entry points (**Table 1.2-2**).

The surgical entry point (skin incision) is usually determined by the topography of the target region and access anatomy. For MISS, it must be adequately placed and should be as small as possible in size. The cosmetic aspects must be taken into consideration (eg, placement, length, and orientation of skin incision).

The surgical route to the target area should be reasonably fast, and must follow strict anatomical pathways, such as preexisting spaces; or, when this is not possible, access surgery should be performed with a minimum of collateral damage to the surrounding tissues. If collateral damage cannot be avoided, it should be reparable or at least have minimal effects on the clinical outcome. Whenever possible, muscular and/or ligamentous function should be fully preserved.

Skin incision	Accurate placement
	Adequate size
	Cosmetic aspects
Route to target area	Fast
	The least traumatic (anatomical pathways!)
Collateral damage	Negligible
	Reparable
Target exposure	Adequate
Target treatment	Efficient
	Unrestricted due to small approach
Surgical dissection techniques	Negligible
	Not relevant for outcome
	Risk of symptom recurrence, etc

Table 1.2-2 Access principles in MISS.

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1.3 Target surgery

One of the most important considerations in MISS, however, is to provide adequate exposure of the target area. The target (eg, disc herniation, disc, spinal nerve, tumor) must be identified and clearly visible. Treatment of the underlying pathology (eg, via discectomy, vertebrectomy, neurolysis, tumor removal) should be given full priority, and it must be possible to carry this out without any of the potential compromises that MISS approaches might come with. Spinal manipulation (eg, reduction maneuvers) should also be possible, as well as the insertion of implants for spinal stabilization.

Retreat from the surgical field should leave no or only minor traces, such as hematoma, open annulus fibrosus following discectomy, or scar tissue; and any minor sequelae should not have an effect on the clinical outcome (eg, muscle damage). In the case of staged surgical therapy (eg, dynamic posterior stabilization) or when there is a risk of pathological recurrence (eg, disc herniations), the postoperative sequelae, such as scar tissue, muscle or intervertebral joint damage should not be such that they negatively affect these further therapeutic options.

1.4 Preoperative planning

To achieve all the above-mentioned goals, meticulous preoperative planning is necessary. Positioning of the patient on the operating table requires specific modifications. Localization of the entry area under image intensifier control is mandatory, and surgical preparation techniques must be adapted to the surgery in question. Special instruments, light and magnification sources (eg, loupe, surgical microscope, head lamp), as well as retractor devices (eg, frame or ring retractors, tubes) are necessary. Positioning of the equipment and operating room personnel may require certain modifications. Moreover, the topography and “volumetry” of the surgical target area must be clearly determined before the operation.

This information is usually obtained via different imaging techniques, such as MRI and CT scan. Preoperative vascular topography can be determined with the help of color-coded three-dimensional CT scans, which provide a clear picture of the individual anatomy. The nature and extent of previous operations in the target—or access—region should also be taken into account, because they may influence the access strategy.

1.5 Patient positioning

The positioning of the patient can strongly influence the minimally invasive exposure as well as the target surgery. Preoperative positioning in MISS must enable the surgeon to operate without having to adjust the patient’s position intraoperatively. It should aim at reducing or avoiding collateral damage, such as pressure sores, and facilitate surgical dissection. Examples of this are lateral positioning and access to the lumbar levels L2–4 for anterior lumbar interbody fusion (ALIF), which allows easier access to the spine even in obese patients; or the knee-chest position in patients undergoing lumbar discectomy or decompression procedures, which allows pressure release within the epidural venous system and thus reduces the risk of epidural bleeding.

1.6 Skin incisions

In MISS, skin incisions should be as small as possible. This implies an accurate localization of the incision in terms of the target area to be reached. In the majority of mini-open techniques, the skin incision is made directly above the target. In endoscopic techniques, localization of the incision(s) is determined by the intended working direction as well as by the angles of view required during the operation.

1.7 Surgical dissection techniques

Surgical dissection techniques differ according to the type of tissue that is to be treated (eg, nerve versus bone; muscle versus blood vessel). An improved knowledge of the structure and function of these tissues has modified traditional surgical dissection techniques. In MISS, it has gained even more significance.

A muscle or a bone structure should basically be treated with the same care as a nerve or a blood vessel. Blunt muscle-splitting techniques are characteristic of MISS. The use of high-speed burrs instead of large rongeurs can help to preserve bone structures. The individual mobilization of blood vessels can decrease the vascular complication rate. The use of hemostatic agents in spinal canal surgery can reduce the risk of epidural hematoma. The microsurgical closure of the annulus fibrosus is aimed at promoting the healing potential of this structure, which is generally regarded as low.

1.8 Instruments and implants

Minimally invasive spine surgery is not possible without the use of optical aids. Light and magnification are needed, and are introduced through small skin incisions to illuminate and visualize the surgical target area that may lie deep within the body. The minimum prerequisites for the surgeon are head lamps and loupes. The surgical microscope and/or endoscope are helpful, or even mandatory for certain techniques. Surgical instruments should be bayoneted and/or sufficiently long to bridge the distance from the skin to the target area. The electrocautery instrument tips must be isolated to prevent thermal damage to the tissues in the access region.

One of the major challenges over the coming years lies in the further development of instruments and implants which will allow for improved intraoperative spinal manipulation (reduction, correction) and fixation. Last but not least, tubes or frame-type retractor systems are essential for keeping the surgical corridor open.

2 The AOSpine principles

AOSpine education has elaborated on four basic principles, which can be universally applied to every diagnostic and treatment strategy for different pathologies. These principles are: stability, alignment, function, and biology (**Fig 1.2-1**).

2.1 Stability

Each type of surgical treatment of the spine aims at the restoration and preservation of segmental stability, and the achievement of a specific therapeutic outcome. For many years, as far as spine surgery was concerned, stability tended to be synonymous with the rigid "fixation" of spinal segments, ie, fusion. This has changed in the last decade with the introduction of procedures and implants which enable the surgeon to achieve dynamic, motion-preserving stability.

2.2 Alignment

Alignment implies achieving spinal balance in three dimensions. For a number of years the importance of alignment, especially in fusion surgery of the spine, was underestimated. Surgeons who performed surgery on anatomical deformities were the first to realize the importance of sagittal balance. The fusion of spinal segments without fully taking into account proper alignment limits the ability to achieve a three-dimensional balance.

2.3 Function

Correct spinal function is based on factors, such as stability and proper alignment. The preservation and restoration of proper function, with the accompanying prevention of disability, are therefore major goals of surgical treatment.

2.4 Biology

This AOSpine principle implements knowledge regarding the etiology and pathogenesis of pathologies and diseases. It also emphasizes the importance of neural protection during or after surgical procedures, as well as aspects of tissue healing.

Each of the AOSpine principles can be applied and adapted to different groups of pathologies, such as degeneration, trauma, deformity, tumor, and infection, or to metabolic, inflammatory, or genetic diseases.

There is no general or natural consistency between the AOSpine principles and MISS tenets. However, the goal should be that MISS techniques take into account AOSpine principles and put them into practice whenever appropriate.

3 AOSpine principles for different pathologies

3.1 Degeneration

In the treatment of degenerative disorders, the four AOSpine principles imply the protection of adjacent segments (stability), restoration of balance in the case of degenerative deformities (alignment), assessment of the outcome of interventions (function) as well as determination of the pathogenesis of spinal degeneration (biology) (**Fig 1.2-2**).

3.2 Trauma

In the treatment of traumatic disorders, stability means the application of biomechanical principles of internal fixation (**Fig 1.2-3**). Achieving alignment, ie, the reduction and restoration of pretraumatic alignment, is as vital as the protection of neural elements and the enhancement of bone healing (biology). With regard to function, the preservation of healthy motion segments is of major importance.

3.3 Deformity

The goal of achieving stability acquires particular significance, for instance in the case of surgical treatment of junctional instabilities at the end zones of a deformity (**Fig 1.2-4**). In deformity surgery, correct spinal alignment depends on proper balancing in all planes, while adequate function implies the preservation of as many mobile segments as possible. An evaluation of the etiology, pathogenesis, and natural history of the spinal deformity in question forms the basis of each therapeutic strategy.

3.4 Infection

Achieving stability may also involve performing surgery to treat any pathological instability due to infection. Restoring balance in the case of a postinfective deformity means achieving alignment. The other two principles that can be seen in the treatment of spinal infection are the preservation of neurological function (function) and the use of adequate and appropriate chemotherapy (biology) (**Fig 1.2-5**).

3.5 Tumors

The main reasons for applying surgical treatment to spinal tumors are to decompress neural structures and to remove the tumor. The majority of tumors affecting the spinal column are malignant neoplasms. En-bloc resection of the tumor and the surrounding healthy structures, which can "cure" the patient, is rarely possible. In any type of surgical treatment, however, the structural integrity of the spine and its functional motion segments are affected. So restoring or keeping a sufficient level of stability, using various implants (pedicle screws, vertebral body relacement etc), is a paramount goal in tumor surgery. Stability is only useful if it is achieved in a well aligned spine. Destructing tumors often leads to deformities, such as segmental kyphosis, which needs to be corrected in order to achieve good clinical outcomes. Even though, in many tumors, larger surgical approaches that guarantee a maximum resection need to be applied, MISS approach techniques have become very useful in palliative tumor treatment (eg, spinal metastasis). The spectrum ranges from simple percutaneous vertebroplasty procedures, through to percutaneous pedicle screw stabilization, or thoracoscopic vertebrectomies. These techniques reduce perioperative morbidity and enable a faster recovery, and thus have faster functional restoration, which is particularly important for patients with a limited life expectancy due to their malignant tumor. MISS techniques currently do not allow radical tumor resection, however, reduced tissue trauma is important for better wound healing, especially in patients that are immunosuppressed due to chemotherapy and/or irradiation (**Fig 1.2-6**).

3.6 Metabolic, inflammatory, and genetic

Assessment of the need for augmentation of an osteoporotic spine addresses the principle of stability. Alignment means the restoration of balance in any type of deformity associated with metabolic, inflammatory, or genetic disorders. Biology implies the use of appropriate medical therapy, and a good functional outcome can be assessed by quality of life, and the satisfactory maintenance thereof (**Fig 1.2-7**).

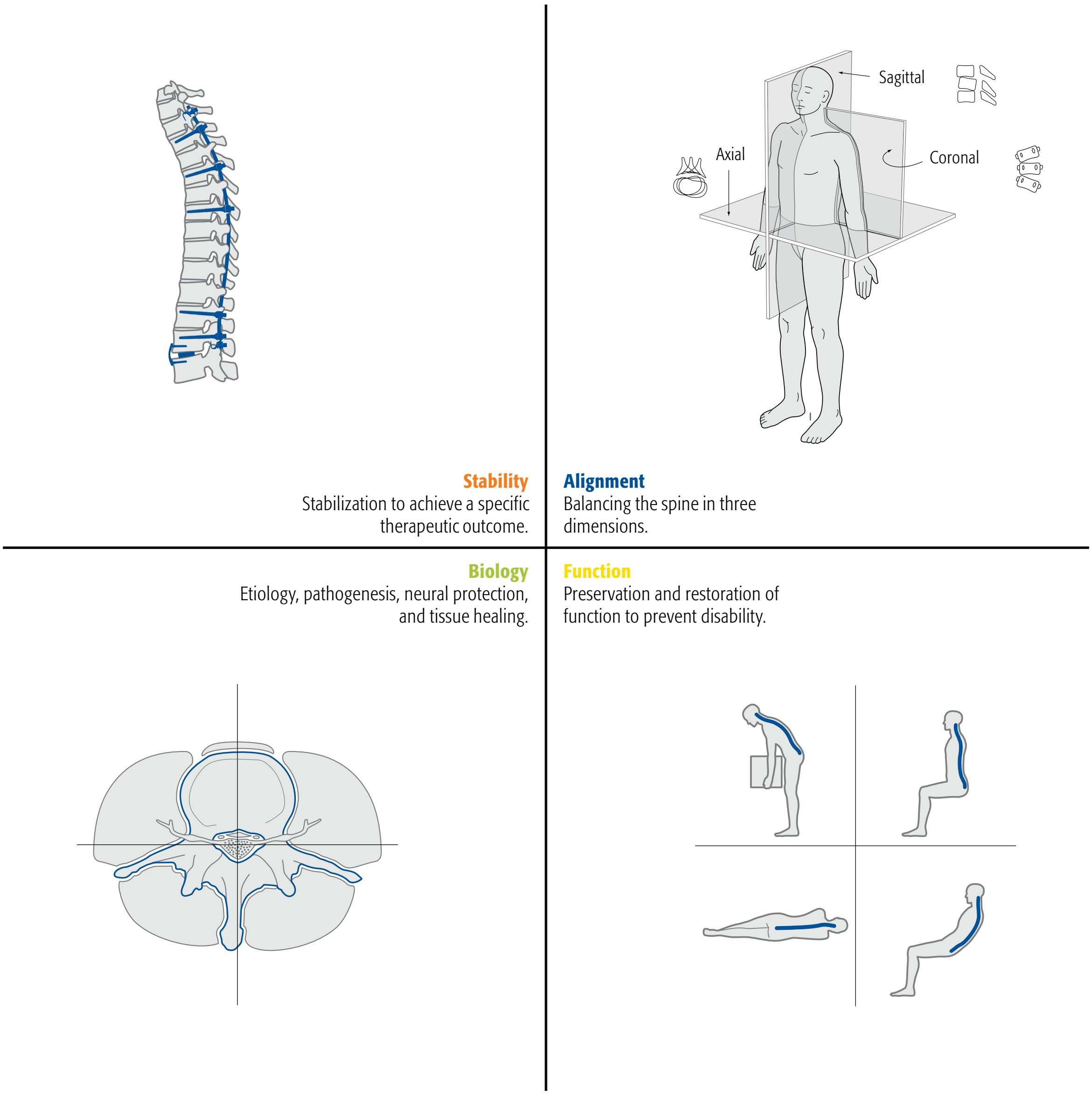

Fig 1.2-1 The four AOSpine principles to be considered as the foundation for proper spinal patient management.