Cervical Spine Surgery: Standard and Advanced Techniques

Cervical Spine Research Society - Europe Instructional Surgical Atlas

Heiko Koller
Yohan Robinson
Editors

CERVICAL SPINE RESEARCH SOCIETY
EUROPEAN SECTION
Founded 1983

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Preface

During residency and fellowship training, most of us had a surgical atlas we consulted for planning and technical understanding of the procedures performed. This surgical atlas was our best friend: it provided consolation before difficult approaches and gave us confidence in communication with other surgeons, and we sometimes went literally to bed with it.

Subspecializing in cervical spine surgery, we lost this friend. Suddenly, we had no surgical atlas anymore. The techniques were so specialized, and the case load for certain procedures is so rare that no comprehensive surgical atlas has been written so far.

While in surgical solitude, we found in the Cervical Spine Research Society a soulmate. The CSRS-Europe—founded in 1983 as a subsection of the North American CSRS—had rapidly become the educator in cervical spine surgery techniques. The biannual CSRS-Europe cadaveric dissection courses at the University of Barcelona were the training grounds of leading cervical spine surgeons throughout the world. Most importantly the CSRS provided us with a network of surgeons; we could consult whenever we needed a second opinion on a surgical technique or senior advice while encountering complications.

The "CSRS-Europe book on surgical techniques (? title)" is the result of the bold project to collate the current knowledge on technical approaches in a surgical atlas, reflecting approaches and techniques applied by respected surgeons all over the world. Every chapter was written by an expert in this topic, documenting the feasibility of each approach with case reports. Collaborations across physical and philosophical borders were required, where differences between surgical schools were subordinated to educational quality. We are grateful to every one of the 150 (? exact number) coauthors, who worked hard to condense decades of surgical experience into single chapters. Furthermore, we thank the medical illustrator Alexis Demetriades, who drew complex surgical knowledge into highly pedagogical illustrations, which are now the backbone of this atlas.

This book is not another textbook; it is a surgical atlas representing the technical expertise of the network of the CSRS-Europe. This book is the friend we need, when we are performing cervical spine surgery, covering even the most complicated approaches.

We hope you enjoy reading this book and wish you all the best.

Munich, Germany — Heiko Koller
Gothenburg, Sweden — Yohan Robinson

Acknowledgments by the CSRS-E

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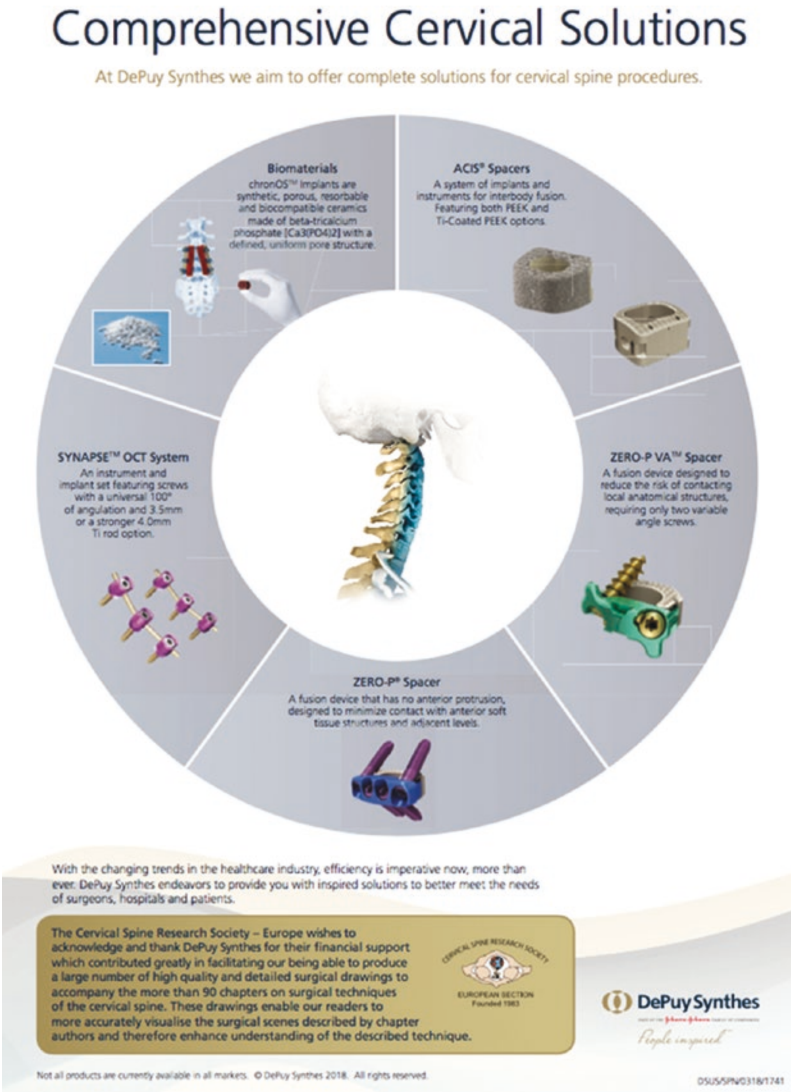
The Cervical Spine Research Society-Europe wishes to acknowledge and thank DePuy Synthes for their generous financial support which contributed greatly in facilitating our being able to produce a large number of high-quality and detailed surgical drawings to accompany the more than 90 chapters on surgical techniques of the cervical spine. These drawings enable our readers to more accurately visualize the surgical scenes described by chapter authors and therefore enhance the understanding of the described technique.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Part I

Introduction

1 Introduction: Cervical Approaches, Access Ranges and Indications

Andre Jackowski

Approaches to the cervical spine can first be conveniently divided and considered with regard to the three readily distinguishable cervical levels: the craniocervical spine, the subaxial spine and the cervicothoracic junction (Fig. 1.1). At each of these three cervical levels, the most appropriate approach corridor, access and indications can then be further considered as regards the 360° of approach which are encompassed within the anterior, posterior, lateral, anterolateral and posterolateral approaches as conventionally described (Fig. 1.2).

The individual approaches and their relevant surgical anatomy are described in more detail in the various chapters that follow. Whilst individual patient cases will clearly always require their own detailed specific consideration, there are some overall guiding principles that should first be considered when choosing the most appropriate surgical approach. These are outlined as follows:

1. The primary localisation and extent of the pathology in relation to the potential approach corridors. In general, the default position should be to choose the most direct approach to the causative pathology e.g. anterior for ventral pathology, posterior for dorsal pathology and so on.

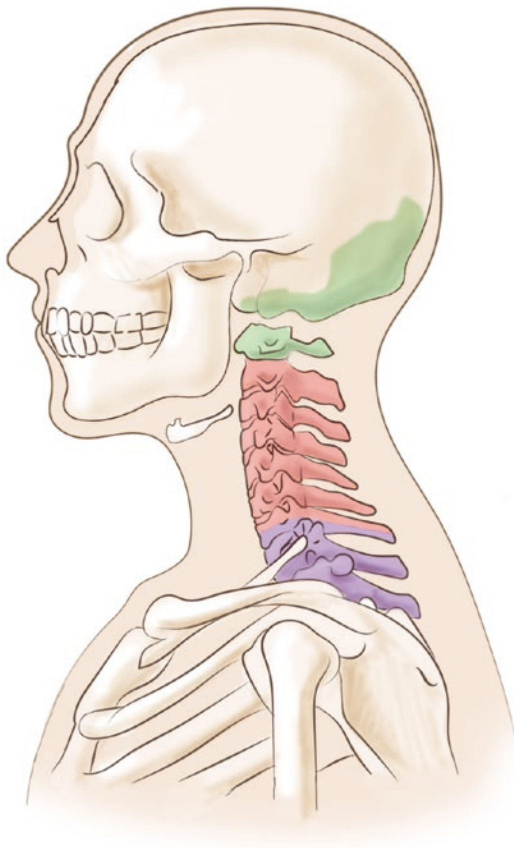

Fig. 1.1 Craniocervical-green; subaxial-red; cervicothoracic-blue

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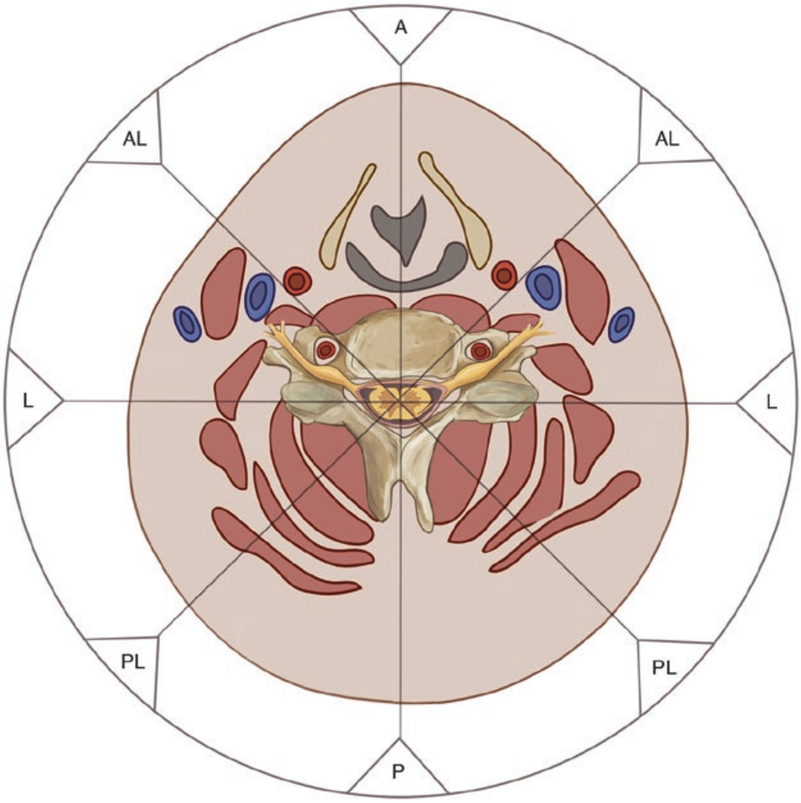

Fig. 1.2 *A* anterior, *P* posterior, *L* lateral, *AL* anterolateral, *PL* posterolateral

2. Avoidance of retraction or manipulation of the spinal cord and as much as possible to direct operative force away from, rather than towards, vulnerable neural structures.
3. The likely nature of the pathology to be addressed. Is it semi-solid e.g. abscess or haematoma, soft e.g. disc or certain tumours or hard e.g. ossified ligaments, osteophytes, retropulsed bone and certain tumours? Is it totally benign pathology? What is the extent of removal necessary? Has it a low recurrence or high recurrence potential? Is it a primary malignant or secondary tumour?
4. The degree of instability and/or deformity already present or likely to follow on from surgical removal of the pathology and what approach will best address this at the time of the initial surgery or will more than one approach be required?
5. The local anatomy specific to the cervical level according to the approach. This varies significantly depending upon whether the surgery is at the craniocervical, subaxial spine or cervicothoracic junction.

Determination of the above can only be done after careful review of all the relevant patient imaging together with a full knowledge and understanding by the surgeon of the surgical anatomy at that cervical level as well as the likely pathology that needs to be dealt with. It is important that a surgeon considers and chooses the best surgical approach based upon the five principles outlined above. Not every spinal surgeon will have the necessary case-mix, experience or resources to undertake all of the cervical approaches and procedures described in the chapters that follow. However, knowledge of all the various approaches will allow a spinal surgeon to correctly determine the optimal surgery for his or her patient and to either perform the procedure or to refer the patient to a surgeon already experienced in that particular surgical approach and technique.

Craniocervical Junction

Anterior approaches to the craniocervical junction include the transoral transpharyngeal approach with or without trans-maxillary or mandible splitting osteotomy approaches. The latter two procedures will require help from a maxillofacial surgeon in addition to a spinal surgeon. The transoral approach is frequently used for many lesions in the location ranging from the anterior foramen magnum to the C2 vertebral body. The craniocervical junction can also be reached by an anterior retropharyngeal approach giving an access range from the lower clivus to C3. It is essentially a superior extension of the standard anterior cervical approach and remains extramucosal. Its limitation is in giving less direct access to ventral pathology. The posterior approach to the craniocervical junction is familiar to all spinal surgeons being a relatively straightforward extension of the commonly employed posterior approach to the subaxial spine. It may be extended either in the midline to expose the occiput or curved somewhat to one side to allow posterolateral access. The craniocervical junction may, if indicated, also be approached by the far lateral approach which is a modification of the traditional lateral suboccipital approach as used in neurosurgery for removal of pathology at the foramen magnum. Lesions located laterally at the craniocervical junction potentially suitable for the far lateral approach can include primary, secondary or intradural tumours, congenital anomalies and irreducible atlantoaxial dislocations.

Subaxial Spine

The subaxial cervical spine, particularly in cases of one- or two-level anterior degenerative compressive disease and in kyphotic deformity, is most appropriately approached by the anterior approach staying anterior to the carotid sheath. This is the surgical approach commonly employed for the removal of soft disc prolapse or osteophytes presenting with radiculopathy or myelopathy. It is usually the approach of choice for most vertebral body pathologies such as tumour and compression fractures. It readily allows the insertion of an anterior support construct and stabilisation by anterior plate-screw fixation. The anterolateral approach with its closer proximity to or actual exposure of the vertebral artery, as described by Hank Verbiest and promoted by Bernard George, although less frequently employed, is both highly effective in decompressing the cord and nerve roots and has the benefit that it does not require a fusion procedure. Cervical stenosis when there is no kyphotic deformity, from multilevel degenerative disease, most cases of ossification of the posterior longitudinal ligament and where there is mainly posterior compression e.g. by ligamentum flavum hypertrophy, is more appropriately decompressed by the posterior approach. Posterior decompression can be achieved in many cases by a laminectomy alone, either at multiple levels, by skip or split laminectomy or alternatively by one of the laminoplasty techniques. If required, supplemental instrumentation with lateral mass or other screw placements can then easily be performed. A direct lateral approach to the subaxial spine, in contrast to the craniocervical junction, is rarely necessary. However, for certain pathologies such as a lateral mass primary tumour e.g. osteoblastoma, and some recurrent pathology that necessitate a fresh surgical approach and potentially in cases where there is involvement of a vertebral artery, it may be indicated to perform the direct lateral approach.

Cervicothoracic Junction

As with other spinal levels, an anterior approach is more direct and provides better exposure for ventral or ventrolateral pathology presenting at the cervicothoracic level. It will, for example, be appropriate in low cervical degenerative disease such as a patient presenting with C8 radiculopathy from C7/T1 disc prolapse. The approach is essentially a lower than normal, but otherwise standard, anterior approach performed just above the clavicle. Another ventral pathology affecting the spine at the cervicothoracic junction that commonly necessitates decompression and stabilisation is compression or collapse of a vertebral body due to metastatic deposits. Such pathology is best approached by an anterior approach extended inferiorly onto the upper sternum, together with varying degrees of resection or osteoplastic flap formation involving the clavicle and manubrium. If more extensive anterior access is required, then a sternal splitting procedure can be performed. Access for anterior column reconstruction may be limited; however, the use of expandable cages or even bone cement alone should provide adequate anterior column support. The plate chosen for supplemental fixation should be one that allows divergent screw placement as this will facilitate placement of screws in the thoracic levels. The posterior approach to the cervicothoracic junction is better known to most spinal surgeons and is logically indicated if the pathology is dorsally located. In such cases, it can be better accessed and treated from that direction rather than by the anterior approach. Examples would include cases of posterior extradural tumour, cases of tumour with mainly posterior bony element involvement and spinal infection with epidural abscess but no or minimal anterior column compromise. The posterior approach has the advantage that the achieving of a strong and stable spinal instrumentation construct is generally more easily accomplished from posteriorly than anteriorly at this level.

2 Upper Cervical Spine: A Surgical Challenge—Past, Present, and Future

Eva-Maria Buchholz

All pathologies affecting bone, joints, muscles, vessels, and all neural structures (spinal cord, nerves, CSF, meninges) can be present in the very small area of upper cervical spine.

The reasons for these pathologies are common: trauma—infectious changes—degenerative disorders—chronic diseases with pathological changes in the spine (e.g. rheumatoid arthritis)—tumours (bone, nervous system, spinal cord, muscles).

The structural changes from such pathologies in the upper cervical spine cause similar problems as they do below: we will face instabilities, deformities, spreading infections, and/or compressed/injured nerve roots, spinal cord, and/or extreme pain.

The peculiarities of the upper cervical spine make basic anatomical and biomechanical knowledge necessary to understand clinical symptoms and signs, to make the right diagnosis with clinical and radiological investigations, and finally to identify the right therapeutic procedure in case of pathological changes in the upper cervical spine.

If a surgical procedure becomes necessary, the extraordinary anatomical surroundings of the upper cervical spine present a serious surgical challenge. The specific biomechanics in the upper cervical spine pose a challenge for surgical procedure, tools, and equipment—the materials used, design of screws, plates, hooks, cables, and the instruments to place them. Instruments to remove tumours in bone or by/in the spinal cord have to be adapted to the local requirements. The same applies to visual assistance by microscope or navigation. These were meant to make the procedure as safe and as adequate as possible.

Historically, trauma to the upper cervical spine resulted in sudden death—only anecdotal reports of survivors exist. If survived, the injury often did lead to extreme pain or to delayed sudden death, because of missing investigation methods to diagnose the instability. Other non-traumatic pathologies of the upper cervical spine (i.e. tumour) progressed to neurological dysfunction, extreme pain, finally ending in death.

Since the invention of radiography and the possibility to visualize the complete bony spine we get more direct information about traumatic impact on the spine's bony structures with the possibility to decide about immediate treatment. The correct spine fracture analysis became possible in the upper cervical spine too. The development of investigation methods such as CT, followed by MRI, made the correct diagnosis in the upper cervical spine more and more precise. We now have 20 classifications to describe a traumatic lesion to the upper cervical spine to distinguish stable from unstable.

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Spinal surgeons fear of the instability in the cranio-cervical junction with the threat of sudden death. Subsequently the fracture management/treatment became the initial impetus for research and development of surgical procedures/approaches in this region. The analysis of fracture type, a timely decision on fracture stability, followed by conservative treatment with skull traction or stiff neck supports, most of them including the head in order to respect the cranio-cervical junction's special biomechanical situation: a plaster-cast (Minerva jacket) and eventually halo-vest.

The first surgical fixation method was the "Gallie fusion C1/2" with wire and bone grafting through a posterior approach in 1939. This is a very effective procedure with simple "hardware"—only a wire. Besides the treatment of odontoid fractures and traumatic instabilities in the upper cervical spine, the most common application worldwide for this surgical procedure was rheumatoid arthritis with atlantoaxial instability. The application for other instabilities followed: osteolysis in case of tumour, infections, and metastasis with instabilities in C1/2. This method underwent many modifications such as changing the direction and number of loops, changing of bone grafting (i.e. by Brooks and Jenkins in 1978), and changing the wire in a flexible cable, or dorsal clamps. Another method was developed by Magerl in 1981 with transarticular screws C1/2 plus Gallie fusion to improve the fusion rate. Subsequently, multiple posterior fusion methods were developed. A variety of screws, new possibilities of fixation to the occiput for better connection to rods, plates, directly instrumented C1 and C2 via pedicle screws, which resemble a fixateur interne. Simultaneously the development of anterior fusion techniques of upper cervical spine came up. Anterior bilateral C1/2 transarticular screws were introduced by Lesoin in 1987. Fritz Magerl reported in 1978 a case of anterior odontoid screw osteosynthesis, it was first accepted by the spine surgery community after Böhler's description in 1982.

With the development of more and better tools for surgical fusion of the upper cervical spine, the research about the fundamental biomechanics, about the diagnostic procedures (myelography, CT, MRI, and further technical investigation procedures), the knowledge about the spinal cord pathologies increased.

Nowadays we can visualise traumatic occipito-cervical junctional injuries, differentiate fracture types in the upper cervical spine, as well as degenerative and chronic diseases, tumours, metastases, and osteolytic infections.

Still, we lack good predictors for sudden death, as a result of a compressed/injured upper cervical spinal cord. We have to carefully investigate the acutely injured, surviving patient with fractures in the upper cervical spine. If there is a "dangerous instability" which can cause sudden death, there is an absolute indication for fusion. Otherwise there could be an option for conservative treatment with similar favourable outcome.

Surgical procedures in the upper cervical spine have to be performed with the utmost care, which includes both indication and surgical technique, in order to avoid catastrophic complications as high paraplegia or death.

3 Subaxial Cervical Spine: Past, Present and Future

Johannes Schröder

The subaxial part of the cervical spine is the region of most of the everyday surgery of cervical spine surgeons. Due to the biomechanical load and high mobility of the subaxial cervical spine, this is where most degenerative changes and injuries are found.

Anterior

In contrast to the lumbar spine, the anterior approach to the cervical spine is the simpler and less invasive one (Ref Chap. 11). Routinely used since the 1950s, first historical descriptions by Chipault are dating back from 1895. In 1955, Robinson and Smith [1] published their technique of disc removal and insertion of a tricortical iliac crest graft for cervical fusion, in the original technique without removal of the posterior longitudinal ligament thus with only indirect decompression (Ref Chap. 46). Cloward [2] went a step further and removed with a special half-inch twist drill both endplates including dorsal osteophytes facilitating throughout decompression of the cervical spinal canal. Fusion was achieved by a round bone dowel (Fig. 3.1).

One of the main concerns about iliac bone grafting is donor site morbidity, which led to dif-

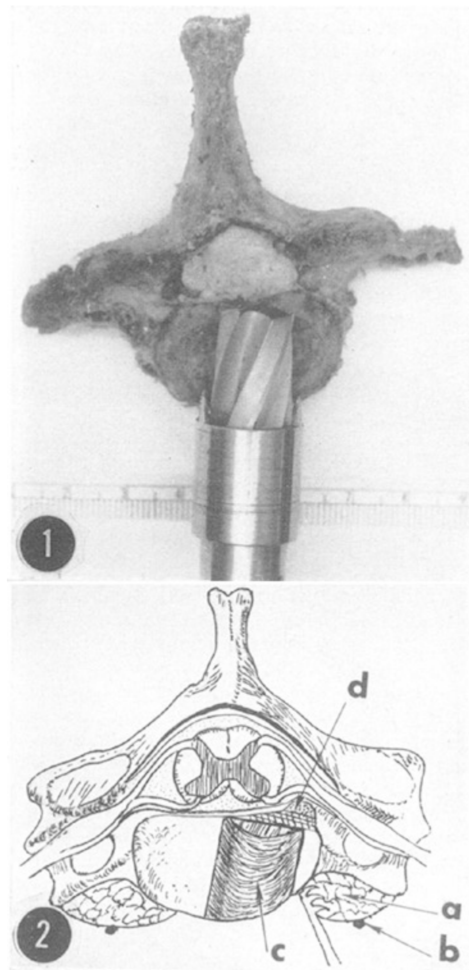

Fig. 3.1 Historical fusion technique according to Cloward [2]. Reprinted with courtesy of the Journal of Neurosurgery Publishing Group

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ferent developments of alternative graft-like implants in Europe and America.

Allografts are popular especially outside Europe avoiding a second access for bone harvesting from the iliac crest. Frozen human cadaveric bone, especially banked fibula, offers the advantage of greater strength and of versatility in the size and shape of the graft. New bone formation and revascularisation are known to be delayed compared to autograft. Therefore in many cases, a plate fixation is added.

In the late 1960s, the use of poly-methyl-methacrylate (PMMA) instead of a bone graft was published. After decompression, the disk space is filled with the still liquid material, with the dura being protected with a foam sponge. This method has been left in favour of industrially manufactured implants, making the time-consuming PMMA-component handling superfluous.

Titanium implants offer the advantage of a strong bond between the implant surface and the adjacent bone. The development went from spacers like the roughened-surface Kaden implant via hollow screws like the BAK to cage-type implants to accommodate filling materials.

Titanium cages have a high fusion rate, but are interfering with postoperative MRT investigations. Poly-ether-ether-ketone (PEEK) solved this problem but earned a bad reputation for delayed union and non-fusion of treated segments.

The anterior plates developed by Böhler [3] started a new era of implant engineering for anterior cervical spine stabilisation especially useful for trauma treatment or degenerative instability. Allograft and plate remain the gold standard outside Europe.

Interestingly, leaving the disc space empty can produce comparable results to fusion. Considerable surgical skill is required for anterior cervical root treatment leaving the disc intact. For isolated uncovertebral degeneration causing besides cervico-brachial neuralgia also cervico-encephalic symptoms, uncoforaminotomy was developed by Jung et al. [4].

Trying to preserve segmental motion, the first cervical arthroplasty devices entered the market in the 1960s. Despite the initial prospects of superior results, many designs disappeared. Only a few reasonable long-term results are available. The future has to prove if cervical disc replacement reduces adjacent segment disease, a pathology not yet scientifically proven and unknown before the advent of spinal endoprosthetics. Since moving material contact surfaces are prone to wear, one should expect long-term complications related to wear debris inflammation.

Future

The future of anterior implant technology is not clear. With PEEK although excellent for MRI follow-up, but disappointing in fusion rate, titanium cages are coming into focus again. Titanium coatings of PEEK implants can possibly combine the advantages of both materials. Trabecular metal is used as an alternative to PEEK and titanium. Resorbable cages are available but are not well investigated, yet. Lately, 3D printing technology enables individualised implant manufacturing. Artificial grafting materials are still struggling to prove their effect on quicker bone formation.

Posterior

Frykholm contributed enormously to the understanding of cervical nerve root anatomy and their dorsal decompression [5]. His foraminotomy is still widely used especially for more lateral pathologies (Ref Chap. 60). An important step to posterior stabilisation came with plate screw constructs attached to the lateral mass in the more straightforward orientation according to Roy-Camille [6] or the lateral upward orientated screws according to Magerl (Ref Chap. 70). It is interesting to know that in the absence of special implants a small fragment third tubular plate would do the trick as described in older AO trauma manuals. Polyaxial screw rod systems replaced plate screw construct nowadays entirely.

Multisegmental cervical spinal stenosis and myelopathy can be effectively treated by laminectomy (Ref Chap. 4). The subsequent posterior element weakening with development of kyphotic deformity is addressed by a wide variety of laminoplasty techniques or prevented by additional instrumentation.

Conclusions

The time for solving all subaxial spinal pathologies with one technique or one approach is over. The spine surgeon needs to know a wide variety of techniques and has to tailor the approach to the individual requirements of his or her patient. This can range from tiny decompression to 3D navigated anterior–posterior deformity corrections. It's not the tool available that decides the procedure, it's the pathology that's leading. Decades of surgical development have crystallised most effective procedures to treat subaxial pathologies. To distribute this knowledge is what this section is about.

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