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Synframe: a preliminary report

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Abstract Both endoscopic lumbar spinal surgery and the non-standardized and unstable retractor systems for the lumbar spine presently on the market have disadvantages and limitations in relation to the minimally invasive surgical concept, which have been gradually recognized in the last few years. In an attempt to resolve some of these issues, we have developed a highly versatile retractor system, which allows access to and surgery at the lumbar, thoracic and even cervical spine. This retractor system – Synframe – is based on a ring concept allowing 360° access to a surgical opening in anterior as well as posterior surgery. The ring is concentrically laid over the surgical opening for the approach and is used as a carrier for retractor arms, which are instrumented with either different sizes or types of blades and/or different sizes of Hohmann hooks. In posterior surgery, nerve root retractors

can also be installed. This ring also functions as a carrier for fiberoptic illumination devices and different sizes of endoscopes, used to transmit the surgical procedure out of the depth of the surgical exposure for both teaching purposes and for the surgical team when it has no longer direct visual access to the procedure. The ring is stable, being fixed onto the operating table, allowing precise minimally open approaches and surgical procedures under direct vision with optimal illumination. This ring system also opens perspectives for an integrated minimally open surgical concept, where the ring may be used as a reference platform in computer-navigated surgery.

Key words Minimally invasive surgery · Spine surgery · Laparoscopy · Lumbar spinal fusion · Lumbar disc surgery

Introduction

The concept of MISS – minimally invasive spine surgery – has significantly evolved in the last five to ten years. There are three major elements to this surgical concept, which are crucial for its further development and its survival in practical surgery:

1. Access technology
2. Implant technology
3. Bone graft or substitute technology

The *access technologies* compromise endoscopic procedures [2, 3, 6], necessitating optical tools, image-guided navigation or computer-assisted spine surgery [4], minimally open procedures with specific retractor systems [1,5], robot-aided surgery and combinations of these technologies (hybrid technologies).

In this paper we will focus on a specific access technology consisting of a unique *retractor system*. Other articles in this issue will deal with the other two technologies.

Access technology is primarily necessary in anterior surgery, in particular lumbar and thoracic spine surgery,

because the spine is located in the depth of the operating field and a major part of the surgery is to create a space that allows sufficient access to the spine and enough room for the necessary manipulations, e.g. for a stabilizing or fusion procedure.

Where a retroperitoneal access is chosen to the lumbar spine, there is no preformed cavity, which would allow the necessary space for the mentioned procedures, and it must therefore be created artificially. While the peritoneal and thoracic cavity are natural spaces where laparoscopic and thoracoscopic accesses offer major advantages, the lumbar and thoracolumbar areas of the spine are literally hidden behind these spaces and are therefore not ideal for a laparoscopic or thoracoscopic approach. Gas insufflation techniques are not helpful in spine surgery, and that is why other methods needed to be developed to get proper access to this area of the spine. The retractor system is crucial for the access to the lumbar and thoracolumbar spine, be it applied by additional ports in an endoscopic procedure or be it a retractor system that maintains a miniaturized surgical approach open without fail.

Retractor systems that can maintain a laparotomy or thoracotomy open have long been available, and these kinds of retractors have also been adjusted to fit the requirements of ALIF surgery [1]. These systems, however, are not fixed to the table. A rectangular or square frame is laid over the incision, and the maintaining of the surgical opening acts on the principle that retractor blades, which are fixed on this frame, pull in two opposite direction pairs, thus keeping the retractor system balanced in place.

While these systems may be sufficient for specific procedures, they do not allow a universal approach concept and they do not provide the stability of the operating field that is necessary for standardized minimally open procedures on the spine.

That is the reason why we were looking for a different concept that (1) enables spine surgeons to apply surgical techniques with which they are familiar from performing regular wide open spine surgery, (2) allows direct vision and does not need indirect recognition through an endoscope, and (3) offers nevertheless optimal illumination and high versatility in its surgical application.

Concept of the Synframe

The retractor system is built on a ring, which is stable, being fixed by two adjustable arms onto the operating table. The ring is laid over the surgical exposure and allows access from any point of the 360° of the ring. There are therefore no predetermined locations on the ring where, e.g., retractors need to be fixed, and there is complete freedom regarding where to position a retractor blade or other tool needed for the surgery. The free assembly of the ring through adjustable clamps and arms tolerates a high degree of versatility and adaptation of the ring position

over the patient, not only for the anterior approach to the lumbar spine but also for the approach to the anterior thoracic and cervical spine as well as for all posterior approaches (Fig. 1).

The ring acts as a carrier for surgical tools and instruments. The basic instruments are either the retractor blades or the modified Hohmann levers, which can be clicked onto the ring (Fig. 2). With either of them alone or in combination the surgical exposure can be maintained minimally open and a standardized surgical procedure can be executed. The connection of the blades and Hohmann levers to the ring is guaranteed by a clamp, which allows the adjustment of the retractor elements in all six degrees of freedom (Fig. 3). Each blade can be adjusted individually and tilted in the sagittal plane in order to hold back the tissue, particularly in the depth of the exposure, and exchanged according to the needs of the blade lengths (Fig. 4).

The ring can also be used to carry a fiberoptic adjustable light source, with which the depth of the operating field can be illuminated perfectly well. In the same way, endoscopes of different angulations and sizes can be mounted on the ring, and allow visualization of the procedure in the narrow space in the depth of the operating field. This allows those not directly involved in the surgery to follow the surgery on the video screen, therefore supporting an important teaching mission by visualizing the details of the procedure. The stable, precise illumination and the use of loup glasses by the surgeon make this procedure as good as microscopic spinal surgery, but most probably faster and more straightforward. The original concept of the ring was to use it as a carrier of retracting, optical imaging and illumination systems and it was first applied for anterior surgery of the lumbar, thoracolumbar and thoracic spine. It quickly became obvious that there was also an application in anterior cervical spine surgery, cervical plexus surgery and, more importantly, in minimally invasive as well as conventional posterior spine surgery. Microdiscectomies with the Synframe carrying a light source, a miniendoscope for transmission to the screen and, e.g., a modified root retractor, has become very standardized and a simple one-surgeon operation (Fig. 5).

Recognizing the great potential of the Synframe as an instrument and tool carrier, it started to be used also in orthopedic procedures other than spine surgery.

In the following, we will describe the technique of application of the Synframe in the presently most established indications.

Indications

Transperitoneal minilaparotomy

The patient, with his bowels prepared for abdominal surgery, is positioned as for conventional surgery on a radi-

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Fig.1 The Synframe ring with the different components for assembling. The distal end of the retractor arm is mobile and can be tilted by a hexagonal screwdriver in flexion and extension and finally tightened in the preferred position (1 ring, which can be separated into two half rings, 2 retracter arms, which are fixed with 3 special clamps, 4 different sizes of blades, which fit into the distal end of the retractor arms)

Fig.2 The ring mounted on the table and on the patient with blade retractors, demonstrating the size of the exposure in relation to the ring

Fig.3 Special clamp, which is clicked on to the ring and holds the retractor arms or the fiberoptic light source. The clamps can be

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moved along the ring and rotated on the ring tube, which allows rotation of the retractor arms in the horizontal plane, thus tolerating movements in all three planes

Fig.4 Retractor arm with mounted blade demonstrating the possibility of tilting the blade in the sagittal plane with the help of the lever arm of a hexagonal screwdriver

Fig.5 Ring mounted in a case of L4/5 microdiscectomy. (1 Hohmann retractor fixed to the ring and located at the outer side of the left L4/5 facet joint, 2 6-mm miniendoscope inserted through a separate stab wound and transmitting the surgical procedure out of the depth to a video screen, 3 fiberoptic light source mounted on the ring and delivering perfect illumination in the depth of the wound)

Fig. 6 Anterior approach to the lumbar spine with mounted ring and inserted retractors and the light source (L.S.)

Fig. 7A–C Exposure of the L4/5 level by a minimally invasive anterior approach and the use of Hohmann retractors to keep the small wound open. The Hohmann retractors are inserted in L4 and L5, keeping the L4/5 disc stable, open and easily accessible. **A** Opening at the skin level, **B** disc visible and well illuminated in the depth, **C** disc seen through the laparoscope transmitted to the video screen (Hoh. Hohmann retractor, L.S. light source, Per.par. peritoneum parietale, Retr. B. retractor blade, A.I. arteria iliaca, c. communis, e. externa, i. interna)

olucant kidney table, which allows hyperextension of the lumbar spine and the lumbosacral junction. The projection of the segment L5/S1 and/or L4/5 to the skin of the abdominal wall in the midline and the flank on one side is marked with the image intensifier. A mini-Pfannenstiel incision is made (4–6 cm, depending on the size of the fat layer), followed by a longitudinal midline incision through the fascial sheets between the two rectus abdominis muscles. The visceral peritoneum is opened between two stay sutures, which facilitates closure after the intervention. At this point 2–4 blades are introduced into each handle, which are then positioned onto the Synframe and into the wound, using their capabilities to be adjusted

in all three planes of the space. This allows for sufficient opening of the abdominal cavity to identify, by blunt dissection either by the surgeon's fingers or by a mounted sponge, the promontorium of the os sacrum by mobilizing as best as possible the emptied bowel slings cranially out of the way. The bowels may be retracted with an abdominal pad held by one of the retractors positioned at 12 o'clock and one each at 9 and 3 o'clock of the Synframe. A long retractor blade is mounted on the handle at 6 o'clock, retracting over a sponge the bladder out of the way. The parietal peritoneum is incised sagittally over the promontorium and possibly the bifurcation of the iliac vessels. By repositioning the retractors with longer and at the tip angulated blunt blades underneath the borders of the parietal peritoneum, the lumbosacral disc can now be exposed. Depending on the type of surgery to be performed, some small posteriorly oriented vessels of the iliac artery, and more so of the vein and the median sacral vessels, may need ligation or clipping in order to mobilize the bifurcation. Depending on the requirements, the common iliac artery and vein on both sides or only the external or internal one may be slung temporarily on a vessel loop to allow for optimal exposure of L5/S1 and/or L4/L5 vertebrae.

This surgery does basically not differ from a conventional approach, except that it is performed through a smaller, though completely stable, incision and with a standardized retractor system and optimal illumination (Fig. 6). In order to increase the precision and stability of the operating field, today we use mostly Hohmann retractors, which are linked with flexible handles to the Synframe (Fig. 7 A–C). After the exposure is satisfactory and its level again confirmed, if necessary, by an image intensifier, the surgery related directly to the spine can now be performed.

Retroperitoneal L1/2–L5/S1 mini approach

The bowel-prepared patient is positioned supine with the side of the approach elevated and with sandbags under the pelvis and rib cage, allowing a slight tilting of the patient to the opposite side.

Again, the spinal level of the planned surgery can be identified by an image intensifier, and projection to the skin is marked anteriorly on the abdominal wall and laterally on the flank. The incision is horizontal, starting medially from the left lateral rectus muscle sheath and going about 4–6 cm laterally, depending on the size of the patient. The incision can also be made obliquely, depending on how many segments need to be addressed.

The obliquus externus and internus fascia, and the corresponding muscles, are divided along its fibers. So is the transverse fascia and muscle, before one reaches the visceral peritoneum, which is bluntly dissected from underneath the transversus muscle-fascia to mobilize the peritoneal sack away from the posterior muscle wall and leaving behind the retroperitoneal space. This space can now be maintained, with properly placed retractors mounted on the ring. The process of dissection is done either bluntly with the finger or with a mounted sponge on a stick, or it can be done with a disposable Visiport from the laparoscopic equipment until the psoas muscle is reached, and from there, access can be gained to the lumbar spine, using the psoas muscle as a guide. The established channel of approach is now maintained and gradually widened with the retractor blades, and segmental vessels are ligated, or clipped if necessary, to have full access exposure to the anterior surface of a specific lumbar spine level(s). The ultimate operating field again is optimally exposed with either the retractor blades or the more precise Hohmann retractors. The endoscope and the illumination source are similarly mounted on the ring, providing focused illumination of the operating field and excellent visualization on the video screen, clearly outperforming conventional illumination or even that of a microscope (Fig. 8).

Fig. 8 Exposure of the L4/5 disc seen through the laparoscope

Thoraco-lumbar junction

The thoraco-lumbar junction can be reached in part from a small incision through the retroperitoneal space at the level of L2, pushing it to the edge by the leverage power of the Hohmann retractors, which can be anchored in L1. At the same time, the left crus of the diaphragm can be dissected from the spine to get access to L1, and through a small mini-thoracotomy and a splitting along the fibers of the diaphragm, the T11–12–L1 transitional zone can be visualized and the two accesses can be joined. This is a very small double access instead of using a conventional wide thoraco-phrenico-lumbotomy. In this procedure, the use of very precisely placed Hohmann retractors clicked onto the Synframe is an extremely helpful tool. Usually, the placement of maximally four Hohmann retractors on the ring are sufficient and the Hohmann retractors can be exchanged with the retractor blades.

Mini-thoracotomy

The thoracic spine has been identified as relatively easy for a gas-free endoscopic approach specifically for an anterior release in scoliosis surgery, but also for very localized thoracic disc or vertebral body surgery, using most of the time at least four ports and unilateral lung collapse. However, this area of the spine can probably be approached more easily by the Synframe technology through a small incision.

An incision of 4 cm is made at the level of the upper rib belonging to a vertebral segment or to that above, from the left or right side, between the anterior and posterior axillary line, with the patient in lateral position. The thoracotomy is made through a window in the rib, which is created by a double osteotomy of the this rib (4–6 cm),

Fig. 9 Minithoracotomy for multilevel anterior release in scoliosis surgery. Exposure with Hohmann retractors and view through the laparoscope (D disc)

which allows a relatively wide spreading of this small incision, again by specially designed thoracic retractor blades or by the Hohmann retractors. Again the light source, the endoscope, etc. can be placed on the Synframe and provides an excellent view (Fig. 9).

Posterior surgery

The Synframe is equally suitable for posterior surgery, since the retractor blades or customised short Hohmann retractors allow for a very focused and particularly stable exposure of the posterior elements of the spine in conventional posterior spine surgery.

Microdiscectomy can be handled very elegantly by the Synframe application, through a 2- to 3-cm skin incision, a one-side fascial incision and subperiosteal exposure of the unilateral lamina and the interlaminar space, by placing a customised fine Hohmann retractor on the outside of the facet joint (along the outside of the inferior facet of the superior vertebra). This once-off surgical maneuver leads to a sufficient exposure, allowing the resection of the ligamentum flavum, limited laminotomy and exposure of the dural sac at the level of the supposed disc. The soft tissue trauma around the access opening is minimal, the illumination and the mini-endoscope, together with the loupes of the surgeon, create an excellent view of inside the canal and the exposure. The retraction of a specific nerve root with a root retractor, which can be mounted on the ring for stability, adds further to this concept, which allows this kind of surgery to be easily performed without any other medical assistance (Fig. 5).

In the process of gaining experience with this mini-discectomy, it became obvious that the same very limited approach could be chosen for a PLIF (posterior lumbar in-

terbody fusion) procedure, even when combined with a semi-percutaneous translaminar screw fixation (see article in this supplementum, page 71). Both sides of the posterior elements can be sequentially approached via a very limited access, making a combined posterior instrumented PLIF procedure a small operation as regards the patient's recovery.

Other applications

This retractor system can be very useful in cervical spine surgery, and dispenses with the need for assistants retracting the surgical wound for a variable time length. The system, has also been used in shoulder and pelvic surgery for trauma, and has met with a lot of enthusiasm from non-spine surgeons. We may describe these new techniques later, when we have certain evidence that the system is really advantageous for those applications.

It is obvious that all the above procedures can be executed with the same technology, equipment and tools, making this system extremely versatile and cost effective in comparison with endoscopic technology, with all its disposals and the expensive special instruments required for endoscopic surgery in the retroperitoneum.

The ring, which, being fixed to the table, is stable, including in relation to the patient, may also open a perspective for the integration of different new technologies, like computer-navigated surgery, where the ring could act as a stable reference platform for a computer-guided surgical procedure.

Preliminary results

In the last 2 years we have increasingly used the Synframe in any conceivable indication for spinal, and recently also pelvic, hip and shoulder, surgery. Originally designed for anterior lumbar spine surgery to overcome the difficulties with endoscopic surgery, it quickly proved itself very useful in minimal surgical approaches as well as in conventional posterior lumbar and thoracic spine surgery and also in anterior and antero-lateral transthoracic spine surgery. The Synframe has been used in over 250 posterior and in more than 100 anterior lumbar, thoraco-lumbar and thoracic spine surgeries. There was one single complication noted that was directly related to the use of Synframe components. In a tumor case of L2, where the neoplastic process grew around and in between the big vessels, one Hohmann retractor was placed incidentally into the aorta abdominalis. Massive bleeding ensued when the retractor was removed. It was quickly decided to have a better overview of the operating field by enlarging the access incision. This could be done easily with the Synframe in place; in fact it was a big help in reaching an optimal exposure and liberating hands which were needed to com-

press manually the aorta and to suture the leak. The ring was therefore not at all in the way for the enlarged approach, but rather facilitated it.

We are not yet able to submit prospectively collected hard data on the possible beneficial effect of the less traumatic surgery in terms of less postoperative pain, leading to less postoperative pain medication; earlier mobilization and shortening of the hospitalization time; and earlier return to work and daily activities. However, we are assessing them. Trendwise, we can predict that there may be a strong correlation between these parameters.

Conclusion and discussion

We present the possibilities, indications and surgical techniques of a ring retractor system in spine surgery, which

allows minimally open surgery through a stable standardized exposure with either sophisticated retractor arms and blades or specialized Hohmann retractors mounted on a flexible retractor arm. This ring, called Synframe, is basically the carrier of those different retractor devices as well as of the fiberoptic illumination tube and the endoscope, both providing excellent illumination and visualization of the operating field. This retractor system can be used universally and with a great deal of versatility, for minimally invasive as well as conventional anterior and posterior lumbar, thoracic and cervical spine surgery and other orthopedic surgical locations. The results in terms of benefit for the patient, like postoperative pain medication, earlier mobilization, shorter hospitalization and shorter rehabilitation time appear to be quite promising, though not yet proven.

References

1. Mayer HM (1997) A new microsurgical technique for minimally invasive anterior lumbar interbody fusion. *Spine* 22: 691–700
2. McAfee PC, Regan JR, Zdeblick T, et al (1995) The incidence of complications in endoscopic anterior thoracolumbar spinal reconstructive surgery. *Spine* 20: 1623–1632
3. Nibu K, Panjabi MM, Oxland T, Cholewicki J (1998) Intervertebral disc distraction with a laparoscopic anterior spinal fusion system. *Eur Spine J* 7: 142–147
4. Nolte L-P, Zamorano L, Jiang Z, Wang Q, Langlotz F, Berlemann U. (1995) Image-guided insertion of transpedicular screws: a laboratory set-up. *Spine* 20: 497–500
5. Onimus M (1998) Minimal invasive anterior lower lumbar spine fusion. Presented at the Fifth Annual Meeting of the Society for the Study of Surgical Technique for Spine and Spinal Nerves, 5,6 September 1998, Tokyo
6. Zucherman JF, Zdeblick TA, Bailey SA, Mahvi D, Hsu KY, Kohrs D (1995) Instrumented laparoscopic spinal fusion. *Spine* 20: 2029–2035