Why navigate in spine?

Timo Laine
ORTON Orthopaedic Hospital
Helsinki, Finland

Stereotactic principles were developed one century ago, and have been clinically used mainly for brain surgery. They were introduced to orthopaedics in the beginning of 1990´s, and the first application was for spine, probably due to the fact that vertebrae are complex structures with clearly definable anatomical points, that made registration easy.

The effectiveness of this new technique has been shown in prospective studies (1,2,3). In these studies the rate of minimal perforations of the pedicle cortex was less than 5 %, i.e. significantly lower if compared to conventional screw insertion techniques.

Despite this clear evidence, navigation systems are used routinely for spine surgery only by a few enthusiasts. Criticism is usually expressed by surgeons, who have no or only minimal experience with navigation, and no practical experience at all. The most common justifications not to use this technique are:

- ”I don´t need it”
- ”It is time consuming”
- ”It needs preoperative planning”
- ”There is too much radiation”
- ”It is unreliable”
- ”It is expensive”

It is true, that the majority of misplaced screws do not cause neurological symptoms. This may give the surgeon a wrong impression of his/her performance. It may create a sense of safety and a feeling that there is no need for improvement. The awareness and need for improving screw positioning becomes very clear, if one studies one's own accuracy with proper postoperative imaging. For the patient with nerve injury, it is of no use to explain, that nerve injuries are rare. In a North American survey study, the reported permanent nerve injury rate was 2,4 %, and the number of transient injuries and intraoperative screw related CSF leakages was three-fold (4). The rate of intraoperative detection of malplaced screws is probably underreported. Not infrequently screws are repositioned after intraoperative screw tract palpation or c-arm x-ray control. This phenomenon does not exist with navigated screws. Knowing the high rate of potentially dangerous misplaced screws, it is very difficult to understand why one should not utilise every possible means to minimise danger of causing damage to the patient.

Time is an important issue. After the learning curve of this new technique (about 30 operations), extra time needed during the operation is minimal. Let us discuss for instance a simple operation with relatively normal anatomy. With navigation it takes about three minutes to do one matching procedure, rarely more than five. The first comment of all the visitors, who have seen us navigate, has been about how fast it is, as they thought or were told otherwise. I challenge the doubting reader to measure the time he needs to do all the C-arm imaging during his next surgery, as all this time is saved with navigation. All this is true when navigation is used on a routine basis. Routine is important to keep the surgeon and other staff skilled with the system, and ready to use it with patients with difficult anatomy. Here the benefits of navigation become obvious and unquestionable. Navigation can save a lot of time e.g. in previously operated patients with distorted anatomy or smooth fusion masses, osteotomies and scoliosis patients.

C-arm based navigation does not need planning, but CT-based navigation needs. We have used different CT-based systems since 1995. Planning is usually performed the day before the operation, and it takes about 10-20 minutes. Some find this a negative factor. I think on the contrary. This time is well spent and never wasted. It leads to better understanding the

patient's individual surface, 3-D and also intraspinal anatomy. It is easier to operate, when you have already done it once the day before, virtually. Some of us even plan with the patient present. This gives an unique chance for the patient to really understand the nature of the operation he will have.

With C-arm based navigation, radiation doses are reduced. There is place for some concern in CT-based navigation. Today most of our patients are investigated preoperatively with plain x-rays and MRI, CT being a rarity. That means that the cumulative radiation dose is not as big as it used to be some years ago, when CT was a standard preoperative investigation. The modern CT imaging and image processing have reduced the amount radiation to the patient. I am concerned about this issue when navigating with a CT-based system in the "normal anatomy" patients, but I think that in deformities the benefits of navigation certainly outrun the dangers of radiation. We are always talking about the radiation for the patient, but what about the operating room personnel? With navigation, the operating room staff does not get any radiation at all.

The reliability of navigation system depends on many factors, e.g. the surgeon, the quality of the CT images or C-arm, the navigation system as a whole, especially the rigidity of instruments and the tracking camera system. The surgeon needs to understand fully the principles of stereotactic surgery and rigid body principles, and he needs training, preferably in cadaver workshops and in a centre that uses navigation routinely. The best clinical accuracy studies have been done with an active LED-based system that used the Optotrak 3020 camera. This camera outperforms all cameras used in navigation systems today, but is a retired product. Modern systems use either active (LED-based) or passive (reflecting ball-based) tracking systems. Their accuracy is one of our current study topics.

Navigation systems are expensive. Today you would probably have to invest 150-200 000 Euros. One nerve injury, that leads to a compensation through the patient insurance system, costs money to the hospital. We have not had one single patient during our thirteen year experience with navigation, who has a nerve injury due to screw malposition. For the society, the economical benefits are obvious. One single nerve injury in a patient who is working and becomes retired due to persisting pain or disability, costs the Finnish society 200-300 000 Euros, more than one navigation system. For the society, it would be cost-effective to pay for at least one navigation system yearly to any hospital doing more than fifty instrumented spines yearly. The life-span of modern systems is not known, but our very first system from 1995 is still functioning, after more than 5000 navigated screws and a couple of updates, and serves as a back-up. When the benefits of C-arm based navigation are fully understood in the orthopaedic community, with reduced x-ray exposures and operating times, not only in spine surgery but in osteotomies, any bone morphing procedures, and trauma surgery, navigation becomes cost effective also for individual hospitals. I see some possibilities in the development of navigation systems, that in the near future will reduce the price of the hardware needed for navigation, and make the systems more accessible to orthopaedic units.

New techniques, e.g. fluoroscopy in the operating theatres or exact fracture treatment with ORIF techniques had their time of opposition, but nobody questions them today. In the future, navigation will make its breakthrough also in spine surgery, to the benefit of our patients, as it has made in so many other fields of medicine. This needs new thinking and accepting the fact that surgeons are not perfect, and computer technology may help us avoid mistakes. We know that this is difficult to accept to any surgeon. One of the most important and difficult moments in my career as a spine surgeon was, when I realized where my screws were located with conventional techniques (5). The new generation of surgeons, who have grown with computers, will naturally accept computers in their operating room.

References:

1) Laine T, Lund T, Ylikoski M, Lohikoski J, Schlenzka D: Accuracy of pedicle screw insertion with and without computer assistance: a randomised controlled clinical study in 100 consecutive patients. Eur Spine J. 2000;9:235-240.

2) Laine T, Schlenzka D, Mäkitalo K, Tallroth K, Nolte L-P, Visarius H: Improved accuracy of pedicle screw insertion with computer-assisted surgery. Spine. 1997;22:1254-1258.

3) Schwarzenbach O, Berleman U, Jost B, Visarius H, Arm E, Nolte LP, et al: Accuracy of computer-assisted pedicle screw placement. An in vivo computed tomography analysis. Spine. 1997;22:452-458.

4) Esses SI, Sachs BL, Dreyzin V: Complications associated with the technique of pedicle screw fixation. A selected survey of ABS members. Spine. 1993;15:2231-2238.

5) Laine T, Mäkitalo K, Schlenzka D, Tallroth K, Poussa M, Alho A: Accuracy of pedicle screw insertion; a prospective CT study in 30 low back patients. Eur Spine J. 1997;6:402-405.