Introduction

Since the description of transpedicle fixation of posterior spinal implants by Roy-Camille et al. [18], this procedure has gained general acceptance for rigid segmental fixation. Correct implantation of the screws without perforation of the pedicle is difficult and requires detailed anatomic knowledge and good surgical skills. The identification of the correct entry point for the pedicle screw and the correct angle of inclination in the sagittal and transverse planes are crucial. A standard technique for pedicle screw insertion is done with an image intensifier in the lateral and anteroposterior (a.p.) views. In osteolytic tumors identification of anatomical landmarks is difficult and intraoperative imaging can be impossible due to increased radio translucent vertebrae.

Computed-tomography (CT)-controlled studies have had significant rates of incorrect placement of lumbar transpedicle screws [5, 8, 25] and implant-related and neurologic complications also have been reported [6, 26]. The central implant placement in the thoracic pedicle is a more difficult procedure [28], and an increasing rate of misplacement can be expected in this region.

Within the past years, computer-aided systems for CT-based freehand navigation have been introduced [15, 24]. With this technique, a preoperative CT scan (CT dataset) is superimposed onto the intraoperative rigid body (the spinal vertebra). As long as the navigated vertebra is non-deformable, online visualization of the instruments within the preoperative data set is possible. In addition, it is important to have intact posterior structures for stable fixation of the data reference base (DRB).

Using these new techniques, experimental [1, 4, 16] and initial clinical [12, 14] results have shown significantly reduced misplacement rates in the lumbar spine pedicle and a decrease in neurologic complications [2].

Depending on the extent of the disease, the main goals of tumor surgery of the spine are tumor reduction, decompression of the neural structures and stable fixation of a malignancy-induced destabilized spine. As tumor localization in the spine is predominantly in the anterior column, posterior treatment is palliative only, or is done as a first step in a double intervention approach. In corpectomies of tumors of the cervical [17, 23] and thoracic spine [23], initial clinical studies have shown possible applications of image-guided surgery using an anterior approach. No clinical studies have been published regarding posterior treatment of the thoracic spine so far.

Another disadvantage in standard spine tumor surgery is that the extension of the tumor cannot be accurately determined intraoperatively, and therefore, the surgeon cannot do procedures such as neural decompression, hemilaminectomy, or laminectomy in complete safety. However, accurate visualization of the tumor can be obtained preoperatively using CT or magnetic resonance imaging (MRI) scans, which can provide safer surgery for the patient.

The aim of this clinical feasibility study was to investigate the efficacy of a computer-aided visualization technique during neural decompression and transpedicle stabilization in patients who require tumor-related surgery of the spine.

Materials and Methods

Since August 1999, an optoelectronic navigation system (SurgiGATE, Medivision, Oberdorf, Switzerland) has been used by the authors. The navigable data sets have been generated on a four-gantry spiral CT (MX 8000, Marconi, Hofheim-Wallau, Germany).

12 patients with tumors of the spine and acute instability or myelopathy underwent posterior decompression...
and stabilization using the navigation system. In 5 patients two or more vertebrae were involved and in 7 patients the tumor was located in one vertebra only. Ten tumors were in the thoracic level, 2 in the lumbar area (see Fig. 69-5). In all patients advanced metastatic disease was diagnosed, therefore, surgical intervention was palliative and no anterior procedure followed the posterior intervention.

In all patients navigated posterior decompression and computer-guided pedicle screw implantations were planned.

After footside installation of the navigation camera and the navigation computer with the screen, correct fluoroscopic identification of the involved spinal region in the lateral and a.p. views were ensured in all patients.

Positioning, covering and the surgical approach corresponded to the standard technique in each patient. To achieve computer guidance, matching of the CT dataset and the patient was done. Having fixed the DRB, the paired point matching procedure was done using four points and a surface matching was added. After achieving an acceptable matching result, verification was done to recheck the accuracy of registration of the CT dataset and the vertebra on the posterior laminar surfaces of the registered vertebra.

Transpedicle instrumentation of the matched vertebra was done with a tracked pedicle awl to have access to the pedicle followed by a tracked pedicle probe to generate the screw hole, in which the 5-mm Schanz screws were implanted with a tracked T handle. After instrumentation of one vertebra, the same procedure was done for the next vertebra.

The second step of the operation consisted of decompression. Therefore, a third matching was done for metastatic vertebrae after fixation of the dynamic reference base to its spinal process, if the latter was intact (n=8). In 4 cases the DRB was fixed at the cranial or caudal neighbor vertebra. Then a small piece of the mediocranial edge of the left or right lamina was resected by an Hayek dissector with intermittent application of the pedicle awl in the guidance or real-time mode of the navigation system. On the screen of the navigation system, the real-time position of the tracked pedicle awl was observed in relation to the tumor on the CT dataset. Complete posterior decompression can be controlled and ensured by the surgeon.

The following data were recorded for each patient:
1. the time required for data transfer and planning the intervention;
2. the time required for intraoperative installation of the computer system;
3. the time required for vertebral matching and instrumentation;
4. the subjective (surgeon) and objective (history mode) performance of the navigation system.

Postoperatively, a CT-based analysis of localization of the pedicle screws and the status of decompression in each patient were confirmed by two independent observers (radiologist and trauma surgeon). Correct pedicle screw insertion was reported in all cases where the patient had a successful intrasosseous implant, or where patients experienced perforation less than a screw thread in the case of a pedicle breadth that was smaller than the implant diameter. To evaluate the quality of decompression, in the transverse scans the original vertebral tumor extension was identified in the spinal canal. The rim of the tumor, intruding into the canal was marked and translated posteriorly by graphics software (volume matching, MX-view, Marconi, Hofheim-Wallau, Germany). This was implemented into sagittal and frontal reconstructions and consecutive observation showed if the posterior laminar structures were resected completely, referring to the anterior tumor extension.

Results

Inclusion criteria in this study was palliative posterior tumor treatment of the spine and intraoperative CT-based navigation.

One patient with extensive disease that extended to the posterior spinal structures (not listed above) was excluded from the study before surgery, because a rigid connection between the affected vertebra and the data reference base was not possible due to instability of the spinous process. Six thoracic screws had to be placed in standard technique, because no successful matching procedure could be achieved.

The aim of computer-aided decompression and hemilaminectomy was realized in all patients. The average time of data transfer was 11 min (range, 8–15 min), and the average planning time for the operation was 35 min (range, 13–90 min). Intraoperative installation of the system took approximately 5 min and the final matching