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Atsushi Seichi · Susumu Nakajima · Tomoaki Kitagawa
Katsushi Takeshita · Motoshige Iwasaki
Hiroshi Kawaguchi · Hiromi Oda · Kozo Nakamura

Image-guided surgery for cervical disorders in rheumatoid arthritis

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Abstract This study demonstrated that frameless stereotaxy can be applied safely to cervical disorders caused by rheumatoid arthritis (RA). Sixteen patients with cervical instability including atlantoaxial instability due to RA underwent instrumentation surgery under an image-guidance system from February 2000 through May 2001. Neural and vascular injuries were evaluated, and postoperative computed tomography (CT) was used to determine the accuracy of screw placement. There were no neurovascular complications, and screw placement was highly accurate. Image-guidance systems are useful tools for preoperative planning and application of transarticular and pedicular screw placement in the cervical spine of patients with RA.

Key words Cervical spine · Frameless stereotaxy · Image guidance · Rheumatoid arthritis (RA)

Introduction

Cervical disorders caused by rheumatoid arthritis (RA) include atlantoaxial (C1/2) instability and subluxation in the mid- and low-cervical spine. These conditions sometimes cause myelopathy, severe pain, or both, either of which impairs the quality of life of RA patients.[1] In such cases surgery may be indicated. Posterior procedures using wiring or hook systems have been employed, but they sometimes result in loss of reduction or nonunion.[2,3] C1/2 transarticular screws have been adopted by many surgeons to achieve C1/2 stabilization, and pedicular screws have also become an option to achieve occipitocervical and intercervical stabilization.[4,5] Both techniques provide greater biomechanical stability than conventional posterior fusion methods,[6,7] but these procedures are technically demanding and pose the potential risk of neurovascular injuries.[8–10]

Frameless stereotactic technology was first designed for intracranial surgery for guidance of unseen lesions. An image guidance system for spinal surgery was developed for installation of pedicle screws in the lumbar spine. The principle of this system is that the anatomy of the patient is related precisely to the image data, making it possible to achieve preoperative surgical planning and intraoperative monitoring of the three-dimensional positioning of the surgical field in real time. Using this system we can make a preoperative surgical plan of the screw trajectory; and the intraoperative screw position can be confirmed in the virtual field on the computer screen. To improve the accuracy of screw placement in the cervical spine of patients with RA, we have adopted an image-guidance system and herein report the usefulness and the limitations of this technique.

Materials and methods

From February 2000 through May 2001 a total of 16 patients with cervical disorders due to RA were treated surgically using the image-guidance system. There were 11 women and 5 men with a mean age at the time of surgery of 62 years (range 49–74 years). The cervical disorders were atlantoaxial instability in 15 and subaxial instability in 1. All the patients had a myelopathy, and two had severe neck pain. According to the Ranawat classification,[1] the neurologic deficits were class 2 in three, class 3A in eight, and class 3B in five. Twelve patients underwent C1/2 transarticular screw fixation (Magerl's procedure)[4]; three underwent occipitocervical fusion combined with C1/2 transarticular screws using the Olerud cervical system (Nord Opedic, Askim, Sweden); and one patient underwent posterior instrumentation with pedicular screws using the Olerud cervical system at the cervicothoracic junction. All patients had autogenous iliac bone grafts. They were allowed and en-

A. Seichi (✉) · S. Nakajima · T. Kitagawa · K. Takeshita ·
M. Iwasaki · H. Kawaguchi · H. Oda · K. Nakamura
Department of Orthopaedic Surgery, Graduate School of Medicine, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-0033, Japan
Tel. +81-3-5800-8656; Fax +81-3-3818-4082
e-mail: seichi-ort@h.u-tokyo.ac.jp

couraged to stand 1 week after surgery and wore a simple cervical collar 3–4 months after surgery.

We used a frameless stereotactic image-guidance system (Stealth Station; Sofamor Danek, Memphis, TN, USA) for correct screw fixation of the cervical spine (Fig. 1). Preoperative computed tomography (CT) scans (1.25-mm axial slices) with contrast medium in the cervical spine of the patient were obtained (Light Speed QX/i; GE, Fairfield, CT, USA). The data were translated to the computer workstation of the system to reconstruct two- and three-dimensional images of the vertebrae and the vertebral artery, which was shown using contrast medium.

Fig. 1. Operative setup of the image-guidance system. The infrared camera is positioned at the cranial end of the patient (*arrow*). The probe with light-emitted diodes (*arrowhead*) is tracked by the infrared camera system, and the position of the probe is displayed on the computer monitor screen

A surgical plan in which 4 mm diameter screws were set to pass the pedicles was devised before surgery on the computer monitor image (Fig. 2). For C1/2 transarticular fixation, C2 was the planned target because the vertebral artery is located close to the course of the screwing (Fig. 3) and the intraoperative spatial relation of C1 to C2 is different in the surgical field from that in the computer field. As reported in Magerl and Seemann's original article,[4] the virtual entry point of a screw was created at the caudal edge of the C2/3 joint. The exit point from C2 was located in the dorsal half of the upper joint surface to avoid the vertebral artery. For pedicular screwing in the vertebrae below C2, a surgical plan of the screw trajectory was devised for each vertebra to which a screw was to be inserted. As Abumi et al. reported,[5] the virtual entry point was slightly lateral to the center of the articular mass and close to the inferior margin of the inferior articular process of the cranially adjacent vertebra. The insertion angle in the sagittal and coronal planes and the length of screwing were determined in the virtual field on the computer screen.

A posterior approach was employed for all cases. For C1/2 transarticular fixation, C1–4 laminae were exposed. Two small stab wounds were made at the cervicothoracic junction to provide the optimal trajectory for screw insertion, if necessary. For occipitocervical fusion, the occipital

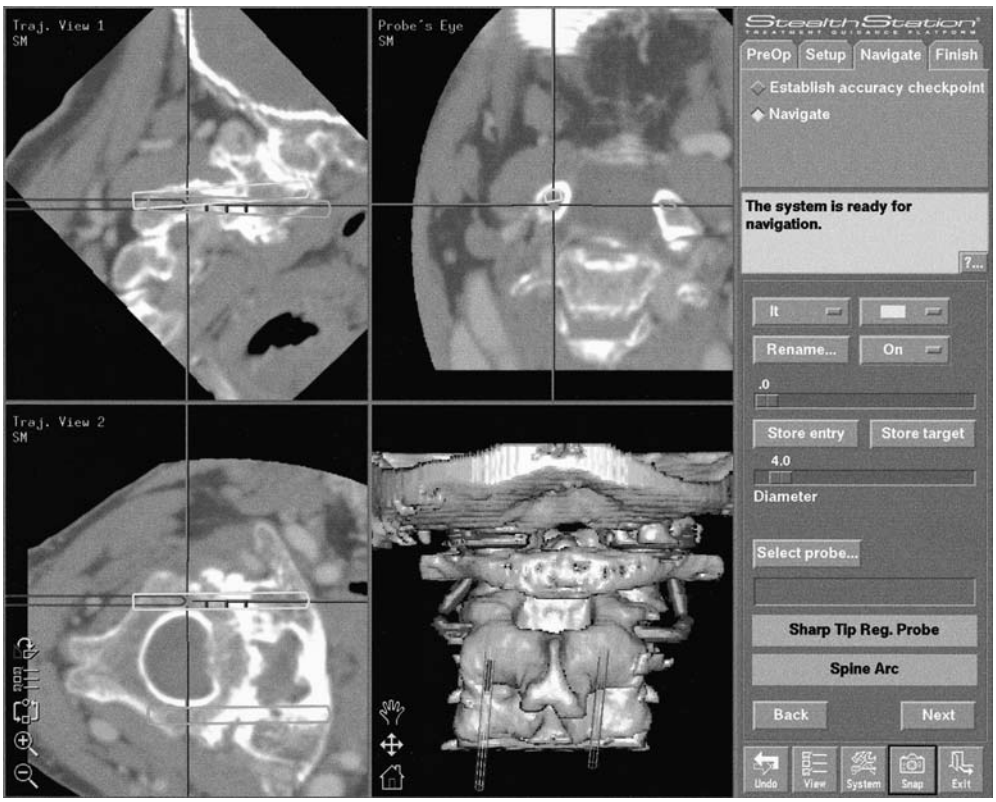

Fig. 2. Computer display shown at surgery. The position of the device and surgical plan are shown in four views. The *wide white arrow* indicates the position and direction of the device, and the *narrow gray arrow* indicates the planned screw trajectory

protuberance to the lowermost cervical fusion vertebra was exposed.

The surgical reference frame was attached intraoperatively to the spinous process of C2 for C1/2 transarticular fixation or each spinous process of the vertebra for pedicular screw insertion. Registration was performed by identifying four or five points on the vertebra in the surgical field and the corresponding points on that vertebra on the monitor. More precise matching was obtained by indicating 30 or more randomized points on the surface of the posterior elements of the vertebra with the probe (surface registration). If the considered complete accuracy calculated by this computer system was within 1 mm, registration was concluded. The system then allowed the surgeon to proceed with preparation of the pilot hole. The positions of the entrance holes for screws were made by an air drill, and the holes were deepened by a pedicle probe according to the planned screw trajectory shown by the navigation probe with light-emitting diodes on the monitor screen. For pedicular screwing below C2, a 4.0-mm self-tapping screw of appropriate length was inserted into the hole under guidance of the computer system. For transarticular fixation of C1/2, a Kirchner wire was inserted into the hole. An intraoperative X-ray image was used when this wire was inserted into the atlas, which was repositioned by manually pushing the C2 spinous process forward. The target point for this wire was the anterior arch of C1 seen on the fluoroscope screen; and the length of the screws was determined by measuring the inserted wire. Self-tapping cannulated titanium screws 4 mm in diameter were then inserted under computer guidance with simultaneous fluoroscopy.

Transverse and sagittal sections were generated to evaluate screw positions with postoperative 1.25-mm slice CT scans. Screw positions were graded into three groups: grade 1, perfectly placed screws; grade 2, partial cortical perforations lower than 2 mm; grade 3, all perforations larger than 2 mm.[11]

Fig. 3. Spatial relation of the planned screw trajectory (*white bars*) in regard to the vertebral artery, which is located close to the course of screwing at the cranial end of C2 (*arrowheads*)

Results

The mean fiducial error at the intraoperative registration ranged from 0.3 to 0.8 mm (average 0.5 mm). A total of 38 screws, including 30 C1/2 transarticular screws and 8 pedicular screws, were inserted using frameless stereotaxy. There were no neurovascular injuries. All 38 screws were exactly inserted inside the pedicles without perforating the bone cortex of the pedicles and so were evaluated as grade 1 (Fig. 4). No instrumentation failure, loss of reduction, or nonunion had occurred at the final follow-up (average 9 months; range 6–20 months). The myelopathy had been alleviated in all patients.

Discussion

Transpedicular screw fixation including C1/2 transarticular screw fixation is biomechanically superior to other conventional procedures using wiring or clamping.[4–7] Both C1/2 screw placement and pedicular screwing in the subaxial

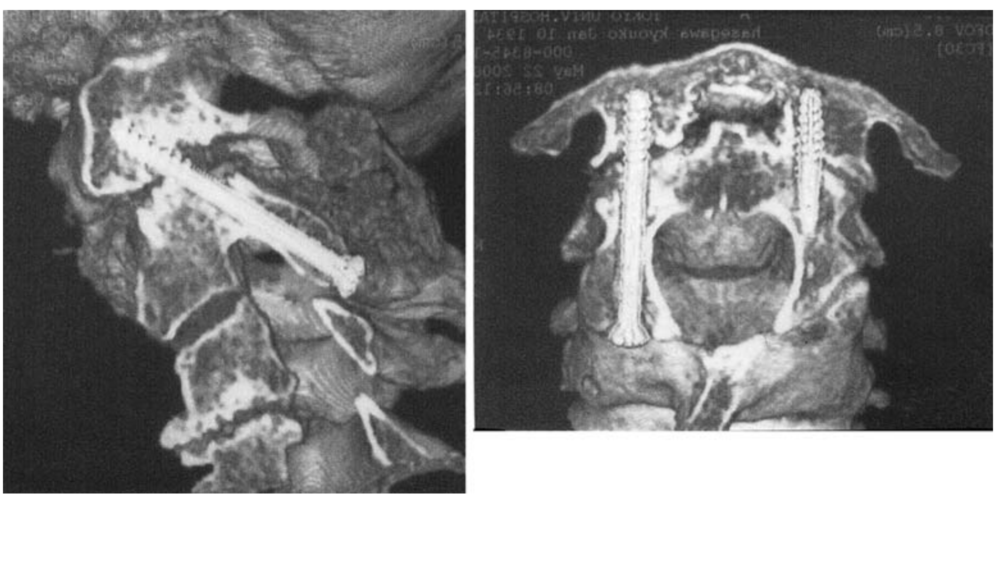

Fig. 4. Postoperative computed tomography (CT) scan of C1 and C2 in a 73-year-old man with transarticular fixation between C1 and C2. The transarticular screws correctly pass through the pedicle of C2

cervical spine depends on anatomic landmarks and intraoperative fluoroscopy. However, because anatomic landmarks are not always reliable, especially when the vertebral artery runs an abnormal course, screw placement has a potential risk of neuro-vascular injury. Clinical reports on C1/2 transarticular screw fixation have indicated that screw misplacement occurred in up to 15% of patients and injury to the vertebral artery in 2%–4%.[6–9]

It is difficult to evaluate the abnormal position of the vertebral artery by conventional two-dimensional images including CT scans, magnetic resonance imaging (MRI), and angiography. Moreover, the bony structure of the vertebrae of Japanese patients with RA is generally small and osteoporotic, and in such cases the risk of vertebral artery injury increases if fluoroscopy alone is used. One option to reduce this risk is image-guided surgery. Surgical planning with the computer-guidance system allows better recognition of the complex three-dimensional anatomy of the cervical spine in RA patients. The optimal screw trajectory can be planned on the computer screen prior to surgery; and by matching the surgical field with the virtual field on the screen, surgeons can insert screws according to the preoperatively planned optimal trajectory.

The usefulness of computer assistance for pedicle screw installation in the thoracic and lumbosacral areas has been reported.[11] The accuracy of a computer-assisted image-guidance system for correct pedicle screw fixation of the cervical spine has been confirmed in laboratory tests,[12] but its clinical results in RA patients have not yet been clarified. The current study was not large, but the results of surgery under the image-guidance system were encouraging. Use of this system in cervical instrumentation surgery for RA patients can aid in reducing the risk of screw misplacement.

At the time of preoperative CT examination, complete reduction of C1/2 subluxation by positioning is difficult. Hence the intraoperative spatial relation of C1 to C2 and possibly the course of the vertebral artery outside the C2 vertebra are different in the surgical field from that seen in the computer field. Therefore, the area of navigation during C1/2 transarticular fixation is limited to C2. Fluoroscopy is essential to confirm the position of C1. It is hoped that development of more sophisticated software will permit navigation of all mobile segments. Another limitation of the image-guidance system is that achieving perfect installation of screws according to the preoperatively planned optimal trajectory requires complete handling of hardware including a pedicle probe and motor system. Robotic surgery for screw installation may be an option in the near future.

References

1. Ranawat CS, O'Leary P, Pellici P, Tsairis P, Marchisello P, Dort L. Cervical spine fusion in rheumatoid arthritis. J Bone Joint Surg Am 1979;61:1003–10.
2. Sumi M, Kataoka O, Ikeda M, Sawamura S, Uno K, Siba R. Atlantoaxial dislocation: a follow-up study of surgical results. Spine 1997; 22:759–64.
3. Santavirta S, Konttinen Y, Laasonen E, Honkanen V, Antti-poika I, Kauppi M. Ten-year results of operations for rheumatoid cervical spine disorders. J Bone Joint Surg Br 1991;73:116–20.
4. Magerl F, Seemann PS. Stable posterior fusion of the atlas and axis by transarticular screw fixation. In: Kehr P, Weidner A, editors. Cervical spine I. Vienna: Springer-Verlag; 1987, p. 322–7.
5. Abumi K, Takada T, Shono Y, Kaneda K, Fujiya M. Posterior occipitocervical reconstruction using cervical pedicle screws and plate-rod systems. Spine 1999;24:1425–34.
6. Kotani Y, Cunningham BW, Abumi K, McAfee PC. Biomechanical analysis of cervical stabilization systems: an assessment of transpedicular screw fixation in the cervical spine. Spine 1994;19: 2529–39.
7. Grob D, Crisco JJ, Panjabi M. Biomechanical evaluation of four different posterior atlantoaxial fixation techniques. Spine 1992;17: 480–90.
8. Wright NM, Lauryssen C. Vertebral artery injury in C1–2 transarticular screw fixation: results of a survey of the AANS/CNS section on disorders of the spine and peripheral nerves: American Association of Neurological Surgeons/Congress of Neurological Surgeons. J Neurosurg 1998;88:634–40.
9. Madawi AA, Casey AT, Solanki GA, Tuite GT, Veres R, Crockard HA. Radiological and anatomical evaluation of the atlantoaxial transarticular screw fixation technique. J Neurosurg 1997;86:961–8.
10. Fuji T, Oda T, Kato Y, Fujita S, Tanaka M. Accuracy of atlanto-axial transarticular screw insertion. Spine 2000;25:1760–4.
11. Amiot LP, Lang K, Putzier M, Zippel H, Labelle H. Comparative results between conventional and computer-assisted pedicle screw installation in the thoracic, lumbar, and sacral spine. Spine 2000; 25:606–14.
12. Kamimura M, Ebara S, Itoh H, Tateiwa Y, Kinoshita T, Takaoka K. Cervical pedicle screw insertion: assessment of safety and accuracy with computer-assisted image guidance. J Spinal Disord 2000; 13:218–24.