Fully functional MR-compatible flexible operating table resolves the neurosurgeon's dilemma over use of intraoperative MRI

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(Received January 25, 2008; Accepted February 27, 2008)

In February 2006, our hospital officially opened the Magnetic Resonance / X-ray / Operation (MRXO) suite, which is the first hybrid neurosurgical procedure suite to combine magnetic resonance imaging (MRI), computed tomography and angiography with a neurosurgical operating room. For this suite, we have developed a specially designed fully functional magnetic resonance (MR)-compatible *flexible* operating table. Here, we describe the details of this operating table and discuss its advantages. Its MR-compatible tabletop can be bent during surgery. The specially designed MR-compatible *flexible* operating table for the MRXO suite reduces limitations on neurosurgeons during standard neurosurgical procedures. Also, it does not give rise to imaging artifacts on MRI. The specially designed MR-compatible *flexible* operating table resolves the neurosurgeon's dilemma over use of intraoperative MRI.

Key words: image-guided therapy, intraoperative MRI, operation table, interventional procedure

INTRODUCTION

Today, intraoperative magnetic resonance imaging (MRI) is widely used in neurosurgical field. Operations can be performed near or in the aperture of a magnetic resonance (MR) magnet, so that high-resolution intraoperative MR images can be obtained. However, neurosurgeons experience a dilemma over use of intraoperative MRI with currently available MR-compatible operating tables, which can not be bent during the surgical procedure. MR-compatible operating tables generally have an *inflexible* flat tabletop. Such *inflexible* flat tabletops can cause problems with the surgical procedure, including insufficient cerebrospinal and venous drainage, and narrowing of the microsurgical field.

In February 2006, our hospital officially opened the Magnetic Resonance / X-ray / Operation suite (MRXO) suite, which is the world's first interventional surgical suite to combine MRI, computed tomography and angiography with a neurosurgical operating room. The MRXO suite represents a major advance in the field of neurosurgery, and details of the MRXO suite have previously been reported[1]. We have developed a fully functional MR-compatible *flexible* operating table that can be bent to change a patient's position during surgery; it was specially designed for use with the MRXO suite. This *flexible* operating table is a great help in meeting the need for MRI during surgery. In this paper, the authors give a detailed description of this newly developed fully functional MR-compatible *flexible* operating table, and discuss its advantages.

MATERIALS AND METHODS

Flexible operating table with MR-compatible tabletop

Our newly developed fully functional *flexible* operating table (MST-7201BX; Mizuho Ikakogyo Co. Tokyo, Japan) (Figure 1) has a special MR-compatible tabletop. The possible positions of the table base range from trendelenburg (maximum, 20 degrees) to reverse trendelenburg (maximum, 45 degrees); the patient can be rotated right or left (maximum, 30 degrees); the feet can be tilted up and down; the head can be tilted to an elevated position (maximum, 45 degrees) or a lowered position (maximum, 30 degrees); and the possible heights of the table base range from a minimum of 480 mm to a maximum of 1100 mm above the floor. This working range is the same as that of standard neurosurgical operating tables currently used in neurosurgical operating room. Figure 2 shows special MR-compatible tabletop that is divided into 3 segments. The specially designed MR-compatible tabletop is made of fabric-reinforced phenol resin. During surgery, the operating table base and MR-compatible tabletop are locked to each other. The 3 parts of the MR-compatible tabletop are connected to each other by 2 MR-compatible joints at which the tabletop can bend. Each joint is made of Titanium-6Aluminium-4Vanadium. During surgery, if the surgeon wishes to take an intraoperative MR image, the MR-compatible tabletop is placed in a flat position and a spacer is inserted into each of the 2 tabletop joints (Figure 2). The spacers tightly lock the 3 parts of the MR-compatible tabletop together. At this point, the *flexible* MR-compatible tabletop is flat and *inflexible*. Next, the

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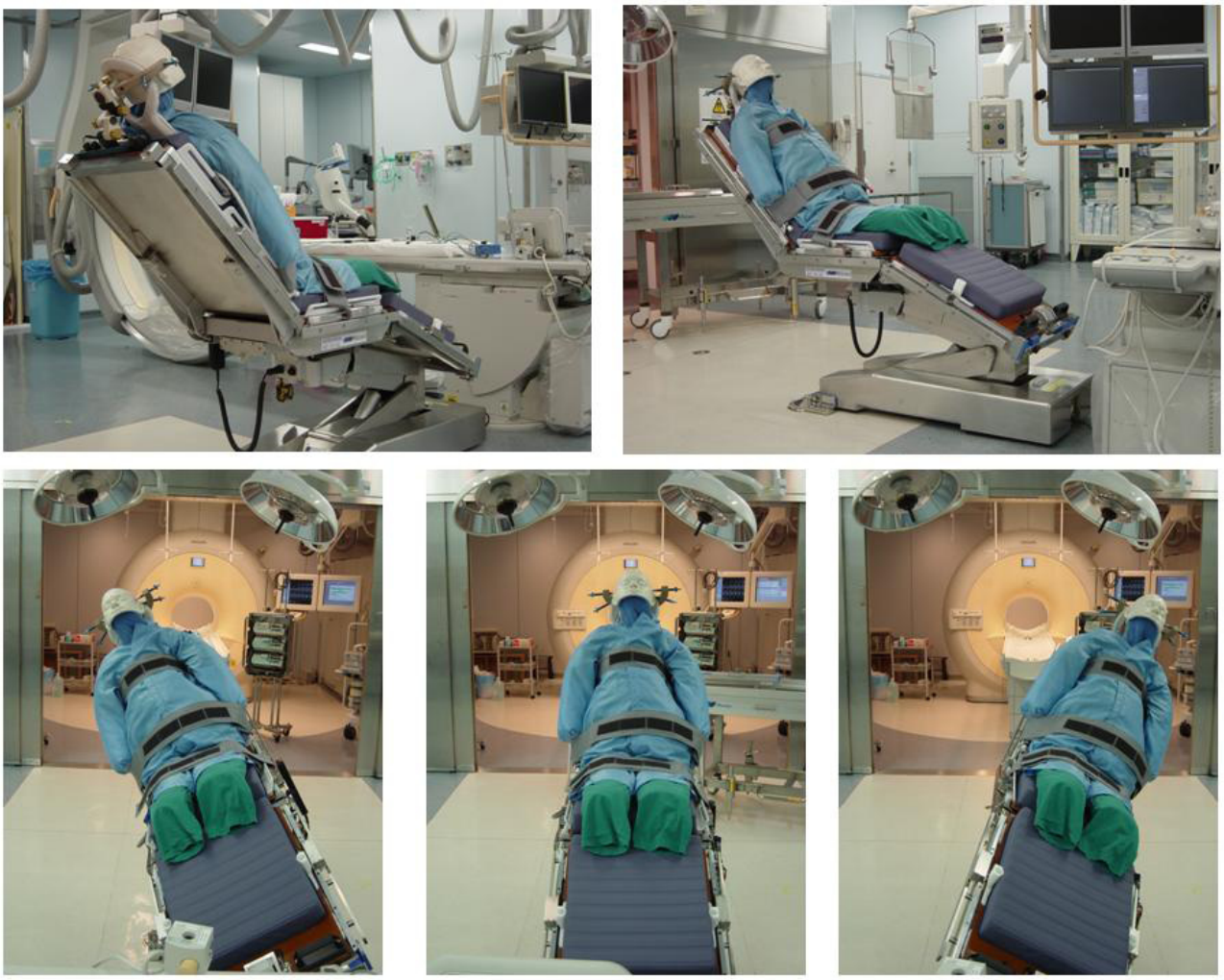

Fig. 1. The MR-compatible tabletop is mounted on the mobile surgical operating table. This operating table allows the surgeon to position the patient in trendelenburg or reverse trendelenburg, rotate the patient to the right or left, allow the feet hang down, tilt the head to an elevated or lowered position, and position the patient at a high or low height above the floor.

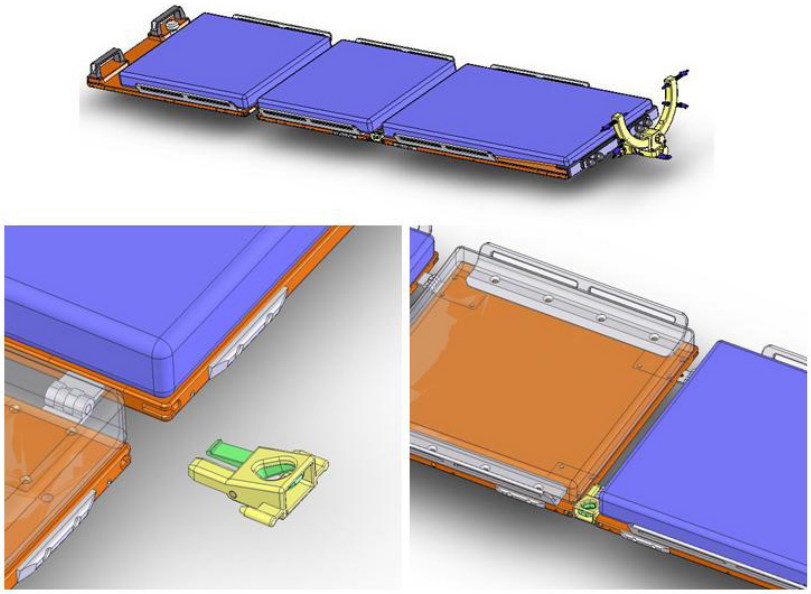

Fig. 2. The newly developed fully functional MR-compatible *flexible* operating table has a special MR-compatible tabletop, which is divided into 3 parts. When the surgeon wishes to take a MR image, the tabletop is placed in a flat position and a spacer is inserted into each of the 2 tabletop joints. The spacers tightly lock the 3 parts of the tabletop together.

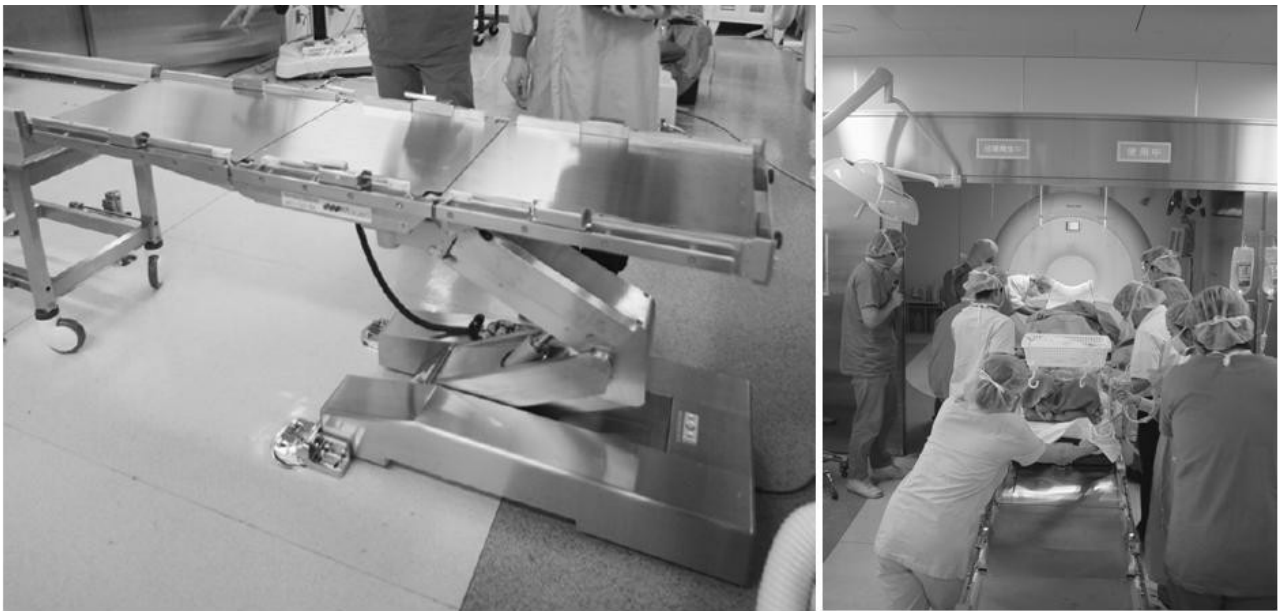

Fig. 3. Left: Operating bay (MST-7201BX; Mizuho Ikakogyo Co., Tokyo, Japan) after the patient has been sent to the MR equipment on the MR-compatible tabletop.
Right: The patient, on the movable MR-compatible tabletop, can be smoothly transferred between the operating table and the MR equipment.

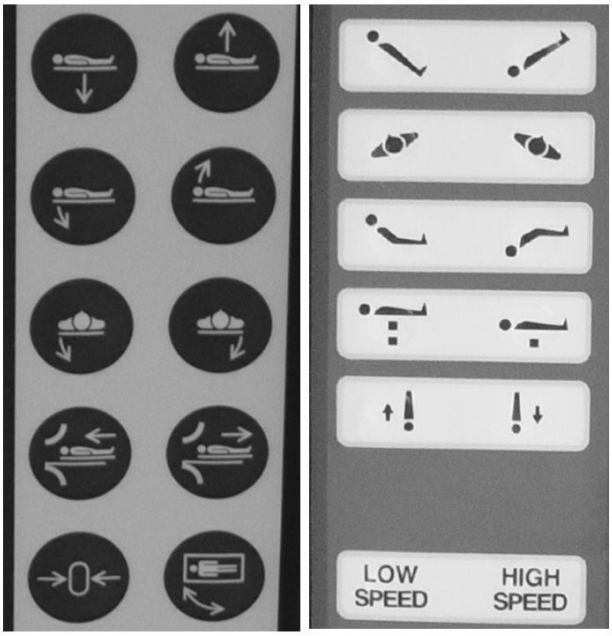

Fig. 4. Left: Controller for a conventional operating table. Right: Controller for the newly developed *flexible* operating table. With both tables, the patient can be positioned in trendelenburg or reverse trendelenburg, rotated to the right or left, and elevated or lowered. Note that the controller for the newly developed *flexible* operating table includes buttons than are used to bend the table, which is not possible with the *inflexible* operating table (left).

locking system that locks the MR-compatible tabletop to the table base is released. When the MR-compatible tabletop and table base have been unlocked, the MR-compatible tabletop and patient can easily be slid into the MR bay (Figure 3). Figure 4 shows the controller for a widely used standard MR-compatible *inflexible* operating table (left), and the controller for our newly developed MR-compatible table (right); the controller for the MR-compatible *flexible* operating table includes buttons than are used to bend the table.

RESULTS

The present MR-compatible *flexible* operating table allows the surgeon to position the patient in trendelenburg or reverse trendelenburg, rotate the patient to the right or left, let the feet hang down, tilt the head to an elevated or lowered position, and position the patient at a high or low height above the floor. Use of this newly developed fully functional MR-compatible *flexible* operating table helps prevent surgical problems such as brain swelling, uncomfortable surgeon's position,

and narrowing of the microsurgical view. Moreover, changing the patient's position during surgery using this MR-compatible *flexible* operating table is less likely to adversely affect vital signs than is the case with conventional MR-compatible *inflexible* operating tables. The MR-compatible *flexible* tabletop bears the patient's weight well during changes in position. The spacers can be smoothly inserted into the joints between the segments of the MR-compatible *flexible* tabletop, tightly locking them in position during transfer of the patient between the operating table and MR equipment. During the first 12 months since the introduction of the MRXO suite and the MR-compatible *flexible* tabletop, we used them to treat 1 or 2 cases per week. During that time, we did not experience any problems during intraoperative MRI. Also, the MR-compatible *flexible* tabletop did not create any imaging artifacts on MR images.

DISCUSSION

When performing microsurgical techniques, neurosurgeons frequently change the direction of the microscope light. Consequently, in order to optimize the microsurgical view, it is often very helpful to change aspects of the table position such as head elevation, descent, and rotation right or left. Also, neurosurgery and anesthesia require sufficient cerebrospinal and venous drainage from the skull. Currently available MR-compatible operating tables have a limited range of movement. In particular, *inflexible* MR-compatible operating tables can not be bent[2,3,4,5,6]. It is important that a patient's position does not change during transfer between the operating table and MR equipment. Also, it has generally not been feasible to use joints to divide a MR-compatible tabletop into segments, because the materials generally available for hinges are not safe for use with MRI scanners or they give rise to artifacts on the resulting images. The currently available *inflexible* MR-compatible tabletops cause many limitations and dilemmas in use of MRI during microsurgery, thus limiting the usefulness of intraoperative MRI in microsurgery. To resolve these dilemmas, we designed an MR-compatible table top that is divided into 3 parts by 2 MR-compatible joints, using MR-safe, imaging-compatible materials. This newly designed operating table with a *flexible* MR-compatible tabletop can be bent during neurosurgery. It produces no artifacts on MR images, and it allows safe transfer of the patient between units of the MRXO suite. Moreover, this *flexible* operating table provides a comfortable surgeon's position, and allows sufficient cerebrospinal and venous drainage from the skull. Thus, the fully MR-compatible *flexible* operating tabletop of the MRXO suite improves the effectiveness of intraoperative MRI.

CONCLUSIONS

The specially designed *flexible* MR-compatible operating tabletop for the MRXO suite provides clear advantages for neurosurgeons over current *inflexible* MR-compatible operating tabletops. It resolves the common dilemma that neurosurgeons face over use of intraoperative MRI, with its consequent limitations on their surgical actions and/or use of intraoperative MRI. Thus, the MRI-compatible *flexible* operating table allows neurosurgeons to combine microsurgery with intraoperative MRI more effectively than conventional *inflexible* MR-compatible operating tabletops.

ACKNOWLEDGMENTS

We wish to thank Mr. Noriaki Nemoto, Mr. Toshimi Shiun, Dr. Daisaku Ikeda, Mr. Yasushi Kojima, Mr. Yoshihiro Sakata, and Mr. Yoshiaki Kono (Mizuho Ikakogyo Co., Ltd., Tokyo, Japan), who built the MR-compatible operating table and its accessories.

DISCLAIMER

None of the authors received financial support for this study. No author has an interest in any of the companies mentioned.

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