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High-end imaging in spinal surgery

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In this supplement

Imaging in spinal surgery

Minimally invasive approaches to spinal surgery can lead to less blood loss, faster rehabilitation and a reduction in patient scarring. However, these procedures may also lead to increased procedure times, higher doses of radiation and less surgical precision. The Artis zeego fixed C-arm from Siemens Healthineers is designed with these challenges in mind, to facilitate fast, precise minimally invasive surgery with less need for repetition.

Since the introduction of the first mobile C-arm in 1955, the technology has become a mainstay of spinal surgery. The live, high-resolution images produced by C-arms can allow for immediate corrections and facilitate minimally invasive procedures. While the image quality and radiation dosage associated with their use have improved through many years of development, mobile C-arms are still limited in a number of ways.

Downsides of the traditional mobile C-arm include the inability to replicate a previous position exactly, the limited field of view available and the inability to perform sufficiently high-quality control imaging immediately after surgery. Utilizing a hybrid operating room (Hybrid OR), with a high-end, fixed C-arm, can solve all of these problems.

The multi-axis Artis zeego uses robotic technology to automatically return to previously recorded positions. The system automatically recalls stored projections, helping to save time and reduce unnecessary fluoroscopic images. The Artis zeego can also be safely parked away from the table when not in use with the press of a button. The Artis zeego features an extended field of view, offering anatomical coverage of up to 10 vertebral bodies in both 2D and 3D. The integration of syngo DynaCT enables the acquisition of 3D images in seconds, allowing for intraoperative quality control; eliminating the need for next-day postoperative computed tomography (CT).

These improvements are transforming the practice of screw placement worldwide. Leading institutions have reported a 50% average reduction in OR time, ultra-low complication rates of less than 0.2%, and zero postoperative revisions since the adoption of the Artis zeego. "Initially, it took us eight hours or more to perform scoliosis surgery. Now, since we have implemented Artis zeego, it takes only four hours", says Sohei Ebara, director of the Spine and Scoliosis Center at Tokushukai Hospital, Fujisawa, Japan.

These benefits, ultimately offering the potential for lower complication rates and fewer repeated surgical procedures, underline the ability of the Artis zeego to better support surgeons in handling complex cases. Its high-resolution visualization is crucial to ensuring accuracy in hard-to-image areas, such as the spinal junctions, as well as appropriate tissue penetration in obese patients. The smallest fracture fragments can be visualized with syngo DynaCT Micro's spatial resolution capacity of 0.1mm.

The accurate placement of pedicle screws could not be more important for safe and effective spinal surgery. As populations age and obesity rates rise, ensuring that patients can receive the benefits of minimally invasive surgery may be challenging. Mobile C-arms continue to have an important place in spinal surgery, but fixed C-arms like the Artis zeego can offer significant benefits in many cases for patients and physicians. The Hybrid OR can be used by multiple specialities, such as neurosurgery and cardiothoracic, vascular and urological surgeries, allowing physicians to perform combined and complex procedures which were previously impossible. This can translate into an expanded range of treatment, an ability to deal with more complex cases and, above all, an improved quality of care for patients.

> ***"Leading institutions have reported a 50% average reduction in OR time, ultra-low complication rates of less than 0.2%, and zero postoperative revisions since the adoption of the Artis zeego."***

Pioneering orthopedic and trauma surgery in the Hybrid OR:

Interview with Prof. Dr. Florian Gebhard and Dr. Peter Richter

Medical Director of the Trauma, Hand, Plastic and Reconstructive Surgery Department, Prof. Dr. Florian Gebhard, and Dr. Peter Richter (both at University Hospital, Ulm, Germany) have been using the Artis zeego fixed C-arm in a Hybrid OR since 2012. They discuss the importance of accurate screw placement in the thriving field of minimally invasive spinal surgery.

Prof. Dr. Florian Gebhard

Dr. Peter Richter

What benefits can minimally invasive surgery bring to the spinal field?

Peter Richter: Most importantly, we can reduce the damage we do to our patients' soft tissue. Unlike the large incisions of open surgery, minimally invasive surgery's smaller incisions can preserve muscle function, which is a huge advantage for patients.

How can a fixed C-arm like the Artis zeego facilitate minimally invasive surgery?

Florian Gebhard: Firstly, the Artis zeego can travel precisely from a park position to the previous acquisition position, enabling a direct comparison of pre- and post-images. When you want to return to a position, the Artis zeego will drive exactly into place, giving you the X-ray you want to achieve. With a classic mobile C-arm it can be difficult to obtain anteroposterior and lateral images, for example. As we can save the C-arm's positions, we can switch easily and quickly between the anteroposterior and lateral images; you just push the button and the Artis zeego goes to the position you want.

A second advantage is that the fixed C-arm uses a more powerful X-ray tube and detector, leading to higher image quality and a bigger field of view. This helps us to better visualize bone, which is necessary for minimally invasive screw placement.

How has the Hybrid OR affected spinal surgery at your hospital?

Florian Gebhard: Trends are leading more and more towards minimally invasive surgery which, especially in the high thoracic area and the cervical-thoracic junction, is always difficult to visualize with a mobile C-arm; there are the shoulders, or a lot of soft tissue and bone. But, a fixed C-arm helps us to visualize these tricky areas of the spine.

Furthermore, it is possible to do a syngo DynaCT intraoperative 3D scan—which is about CT quality—to see right away if our Kirschner wires or screws are positioned correctly, or if they need adjusting. Before, we would place the screws and do a postoperative CT, where we would see any misplaced screws. Now, we no longer need to perform separate revision surgeries.

The 3D scan also allows us to plan screws in combination with our navigation system. The system itself gives us the ability to plan a trajectory which can be visualized later on.

The Artis zeego does a 3D scan in five seconds, 360 degrees around the patient. Looking at the records for our first 100 cases, we have not seen any more infections in the wounds imaged by the Artis zeego.

What benefits can fixed C-arms bring outside of screw placement surgery?

Peter Richter: For a large tumor resection, for example, we can use the system to visualize soft tissue as well. This minimises our resection of healthy tissue, because we know exactly where tumors are.

What kind of procedures will predominantly be done with mobile C-arms like the CIOS Alpha?

Peter Richter: In a lot of surgeries, we do not need the Artis zeego's 3D function. We still want great image quality, of course, and so the CIOS Alpha is very good in these instances. We use our CIOS Alpha, for example, for fracture treatment. The system gives us the ability to use stored programs to reduce image quality variation. We have special programs to ensure good image quality for obese patients, for example. We can also activate a program for pediatric surgery which can reduce radiation dosage significantly, whilst still giving us a great image quality. Almost as big as the Artis zeego´s, the CIOS Alpha has a wide field of view, which is larger than a typical mobile C-arm.

What other areas of surgery benefit from the Hybrid OR, and how does the hospital benefit from this?

Florian Gebhard: At our hospital, we wanted a system to ensure that different disciplines could work in the operating room together and independently to optimize our usage of the Hybrid OR. We convinced our chief executive officer with the promise that the room would be used very frequently, and that it would offer advantages to other departments, along with the benefits it offers us.

The Artis zeego has developed from an angioplasty-focused device to an interdisciplinary intraoperative imaging system. The ability to perform intraoperative angiographies is especially helpful. At our hospital, we have vascular surgeons using it for abdominal aorta stent placements, cardiac surgeons for TAVI and valve implantations and neurosurgeons using it for the treatment of intracerebral aneurysms.

Clinical experiences in the Hybrid OR

A report published in *Injury* documents the first year's experience of Prof. Florian Gebhard and his team with the Artis zeego in the orthopedic trauma unit at Ulm University, Germany.[1] This Hybrid OR—comprised of the Artis zeego fixed C-arm and Brainlab's Curve navigation platform—is one of the first of its kind. The authors note that the system produced a surgeon-friendly environment and allowed fast and high-quality imaging to aid physician confidence and accuracy.

The Hybrid OR measures 58.6m^2, with a 10.79m^2 server room and a 12.32m^2 technical support room, incorporating a viewing window. It is shared by the orthopedic trauma, neurosurgery, cardiothoracic and vascular surgery departments. For spinal procedures, patients are placed with their heads towards the C-arm, in order to optimize cervical and thoracic visualization. To facilitate movement of the C-arm, anesthetists are positioned at the foot of the table, equipped with long monitoring wires and ventilator tubing. Gebhard *et al* note that this positioning was unproblematic. A cocoon was created by the circumferential draping of sterile film around the patient, ensuring hygienic access to the Artis zeego.

Of the 92 cases featuring in the report, over half (53) involved the posterior stabilization of the spine. Sacroiliac screw placement was the next most common surgery recorded, with 12 procedures performed in the year. Biopsies, tumour resections and vertebroplasties were among some of the other procedures reported to have taken place in the Hybrid OR. The authors reinforce the usefulness of the system, particularly for orthopedic oncologic surgery, due to its capacity to fuse different image sources. Enabling the high-quality visualization of soft tissue and bone, the Artis zeego can aid in the complete resection of tumors. "With a contrast resolution of up to 3–5 HU, compared to a conventional computed tomography scanner with a resolution of up to 1 HU, the Artis zeego system enables great soft-tissue visualization," the experts state. Over half (47) of the cases observed used navigation alongside implant placement, whilst 46.7% (43) procedures were performed minimally invasively. The rate of adverse events was reported to be normal.

The surgeons note that the Hybrid OR offers major benefits in its large field of view and the superior quality of images produced. The intraoperative 3D image in Figure 1 has captured seven thoracic vertebrae with one scan. Taking only six seconds at most, this was not considered to lengthen procedure times significantly.

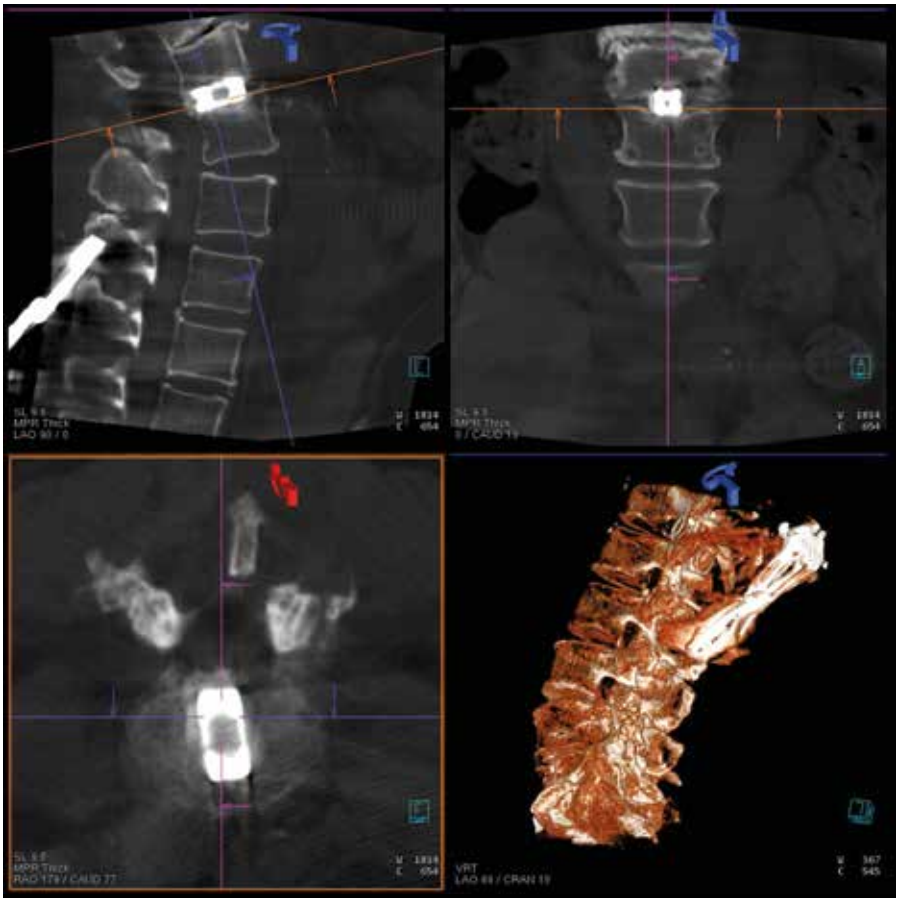


Figure 1. Seven thoracic vertebrae are visualized following one intraoperative 3D scan[1]

The system's storage of C-arm positions eliminated the need to use a radiology technician. The sterile control panel is operated by the surgeons themselves, whose selections are automatically and precisely carried out by the robot-assisted C-arm, avoiding the trial-and-error associated with traditional mobile C-arms.

The system enables extensive storage of anteroposterior and lateral images, whose collimation can be individually adapted for optimal image quality. "This improved imaging and ability to collimate result in increased surgeon confidence regarding accurate implant placement," the authors note. The efficiency of image-gathering—which is vital to enable a reduction in fluoroscopy shots—can be further enhanced by the use of a laser crosshair. This line appears on the display screen following the capture of an image, and can be moved to center the next shot as required.

The 3D scans were integrated with navigation technologies quickly and easily, taking the navigation system interface less than one minute to complete registration.

The doctors note that there was a learning curve for optimal positioning,

> ***"The surgeons note that the hybrid operating room offers major benefits in its large field of view and the superior quality of images produced."***

but that they were able to adapt to the new technology fairly easily. By using a thin mat on the operating table and adjusting the position of the patient, the surgeons were able to visualize the posterior spine even in the case of severe thoracic kyphosis. Within nine months, the authors recorded significantly reduced procedural times. Recommending that the Hybrid OR first be used in routine cases, the authors assert that, with some practice, surgical staff should be able to exploit the large field of view and high image quality to particularly benefit difficult procedures.

The experienced team claims that the costs of the system can likely be justified in the case of larger, interdisciplinary institutions. With regards to the potential financial savings of the system, the authors report, "This system may obviate the need to pay for radiology technicians, and we have found no need to obtain or pay for interpretation of postoperative CT scans since the intraoperative imaging quality is so high in image quality. Further, intraoperative imaging allows malpositioning to be addressed in the same surgical setting, and avoids the cost of revision surgery."

The doctors affirm that, particularly when complex cases require difficult imaging and an interdisciplinary approach, the Hybrid OR offers an advantage for surgeons. Surgeons in this orthopedic trauma department were afforded a higher degree of confidence with the Artis zeego. The quality of images and large field of view ensured optimal patient care, even in obese and osteopenic patients.

Figure 2. The Hybrid OR at Ulm University featuring the Artis zeego

"We anticipate continued success and progress with this system, as it has greatly enhanced orthopedic surgery at our institution," the authors conclude.

Reference

1. Peter H Richter *et al*. *Injury, Int. J. Care Injured* 2015; 46S4: S129–S134.

Case reports

Figure 3. Stabilization of C1-C2 vertebrae in a 51-year-old[1]

The C1 vertebra of a 51-year-old male was broken in a mountain-biking accident. Surgeons performed a stabilization of C1-C2 (Figure 3), noting fracture instability and displacement. A large amount of bleeding followed the placement of the first screw. The patient can be kept in the same place, while neurosurgeons perform an immediate intraoperative angiography to access and treat vascular injury.

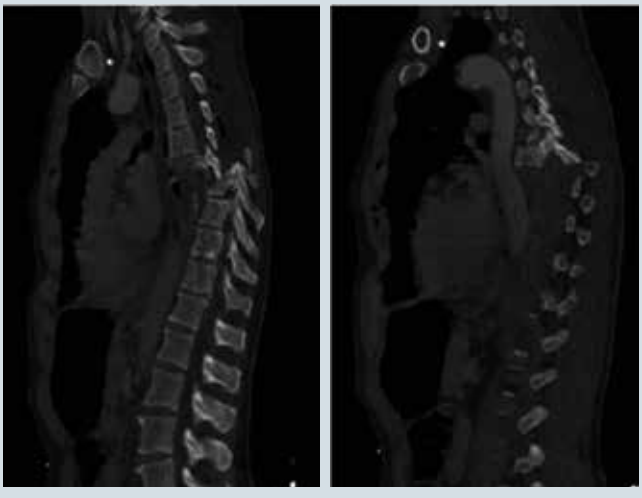


Figure 4. Proximal spine compromises aortic flow in 52-year-old male[1]

Presenting complete disruption of the thoracic spine, a 52-year old male was transferred to the hybrid OR following a CT scan and initial resuscitation efforts. The proximal portion of the patient's spine was compromising aortic blood flow (Figure 4). The vascular surgeon could operate on the patient without the need to relocate, following severe bleeding after fracture reduction.

"An incredible achievement"

Prof. Dr. Stefan Zausinger, a neurosurgeon from University Hospital Grosshadern (Munich, Germany) talks to *Spinal News International* about his experience using the SOMATOM Sliding Gantry CT scanner.

Prof. Dr. Stefan Zausinger

How long have you been using the SOMATOM Sliding Gantry CT?

Our first system was installed in 2006. We have used it for imaging during cranial operations, and routinely for spinal operations. For the last year-and-a-half we have had the newest version of the Sliding Gantry CT scanner—the SOMATOM Definition AS—in our surgical centre. This creates a two-room solution, where the CT scanner can slide between two adjoining ORs. Currently, we use the intraoperative CT predominantly for stereotactic neurosurgery. This means that we can plan our stereotactic operations—biopsies and so on—with aid of the intraoperative scanner, while at the same time in the neighbouring room we can use it for imaging in parallel operations, such as spinal procedures.

How do you use the system during a screw placement surgery?

This is a simple four-step procedure:

1. **Definition of the table position:** The patient is placed on the table, which is then lifted to locate the optimal position for the procedure. Defining the table position is a very important step, because it eliminates the danger of a collision between the sliding gantry and the patient, and can help to save time during the procedure. Once defined, the table position is stored. This is absolutely crucial.
2. **Registration of the navigation system:** After sterile draping, we then begin the operation. We place a linear incision directly above the desired verterbrae and carefully expand the surgical field until the spinous processes are exposed. We then place our neuronavigation reference star on the spinous process of the vertebrae.
3. **Intraoperative reference scan for the navigation system:** A real-time scan inside the OR is performed to provide up-to-date images of the patient in the operating position. This first scan yields images for the intraoperative navigation system, providing higher precision. The placement of screws can then take place.
4. **Intraoperative control scan:** After placing all of the screws, we perform a control scan. This scan allows us to regulate the position of each screw exactly, whilst the patient is still inside the OR. In the case of misplacement, we can correct immediately.

In standard stabilization procedures, patients would normally receive a low-dose CT scan before an operation to generate images for neuronavigation, and a second postoperative scan for control of screw placement position. Performing these scans intraoperatively with the Sliding Gantry CT eliminates the need for pre- and postoperative scans, meaning that the patient receives a normal radiation dose.

What benefits have you experienced since adopting this system?

I have noticed significant benefits. First of all, the initial CT images are generated in the final surgical position, meaning you have very precise images for neuronavigation. Normally, the diagnostic images are made preoperatively in a supine position, which can differ dramatically from the surgical positioning. This always leads to changes in the position of the vertebrae. With the SOMATOM Sliding Gantry CT, the images reflect the way the patient is set up on the surgical table exactly; the anatomy is then scanned as it will be seen during surgery. With this, we can achieve higher precision, which is especially important when you have to achieve a very difficult placement of the screws. For example, when you are working in very small or narrow places like the cervical spine, you need very highly precise placement to avoid any damage to the neighbouring nerves or vessels. With the Sliding Gantry CT you have the advantage of the generation of images in the final surgical position.

Another important benefit is the production of intraoperative control images. This means you can react immediately if any implants or screws are malpositioned. Reoperations due to implant malpositions can be avoided. We published a retrospective analysis of our centre in *Spine*,[1] comparing reoperation rates due to screw malposition before and after we had the SOMATOM Sliding Gantry CT. Before, the revision rate for new placement of screws was about 5% for our patients, which is in keeping with the numbers found in other high-end spine centres worldwide. Now, with assistance from the images provided by the SOMATOM Sliding Gantry CT, we have lowered our revision rate for new screw placement to 0%. This is an incredible achievement. We sometimes perform revision surgeries because of infected wounds, for example, but not a single patient has required reoperation to replace malpositioned implants.

"With assistance from the images provided by the SOMATOM system, we have lowered our revision rate for new screw placement to 0%. This is an incredible achievement...not a single patient has required reoperation to replace malpositioned implants."

The intraoperative CT also allows us to acquire high definition soft tissue images, with which we can control, for example, for intracranial hemorrhaging. The ability to see high resolution images of soft tissue within the head brings higher diagnostic safety for neurosurgical procedures, as well as for spinal surgeries.

What sets the SOMATOM Sliding Gantry CT apart from other intraoperative imaging systems?

The SOMATOM Sliding Gantry CT's high quality images of both bones and soft tissue enable us to produce special image protocols like perfusion studies, which are crucial for stroke patients, for example. The system also has special tools for reconstruction of implants, and provides us with a high level of detail that we did not have before inside our OR. It features very high imaging quality, with all tools of a high-end CT scanner, but with the advantage of being inside the OR.

Has the system proved cost-effective in your hospital?

Whilst I have no precise numbers for my hospital, the images produced from the system has helped us to avoid those 5% of revisions caused by malpositioned screws for our stabilization patients.

The SOMATOM Sliding Gantry CT has widened the surgical indications of our hospital. Since we acquired the SOMATOM Sliding Gantry CT, we now offer a wider range of neurosurgical treatments than we could offer

before. As an example for spinal surgery, the stabilization of the upper cervical spine requires very high precision, which we could not ensure before we acquired this system. It has given us the imaging support necessary to perform such operations with the required safety.

The SOMATOM Sliding Gantry CT moves between two ORs at your center. How is this two-room solution been beneficial to your hospital?

The two-room solution at our hospital comprises an operating room, the SOMATOM Sliding Gantry CT and another operating room. The Sliding Gantry CT has long rails, allowing for a longer range of scanning in both rooms. We have a very high—nearly daily—demand for stereotactic operations, where it is crucial to generate high-quality images. We have an equally high demand for intracranial surgeries and spinal stabilizations. With the two-room solution, we can do both kinds of surgery in parallel. With special training for our radiology staff to coordinate the two operating rooms, we can be much more flexible when we generate our operating room schedule. The SOMATOM Sliding Gantry CT is usually used from eight in the morning to late in the afternoon every day. It is only possible to coordinate the dates for these parallel surgeries with our two-room solution.

Reference

1. Zausinger *et al. Spine (Phil Pa 1976)* 2009; 34 (26): 2919-26).

The statements by Siemens Healthineers' customers described herein are based on results that were achieved in the customer's unique setting. Since there is no "typical" hospital and many variables exist (e.g. hospital size, case mix, level of IT adoption) there can be no guarantee that other customers will achieve the same results.

Siemens product portfolio

Artis zeego

- Artis zeego, with its 30 x 40 flat detector, allows a field of view of up to 10 vertebral bodies.
- Robot-supported C-arm easily and quickly moves into stored predefined positions using the Automap function, significantly speeding up spinal procedures.
- Intraoperative 3D imaging for quality control makes postoperative CT obsolete.
- CARE & CLEAR is the free dose-reduction protocol that comes with Artis zeego for low-dose, high-quality imaging for the spine.

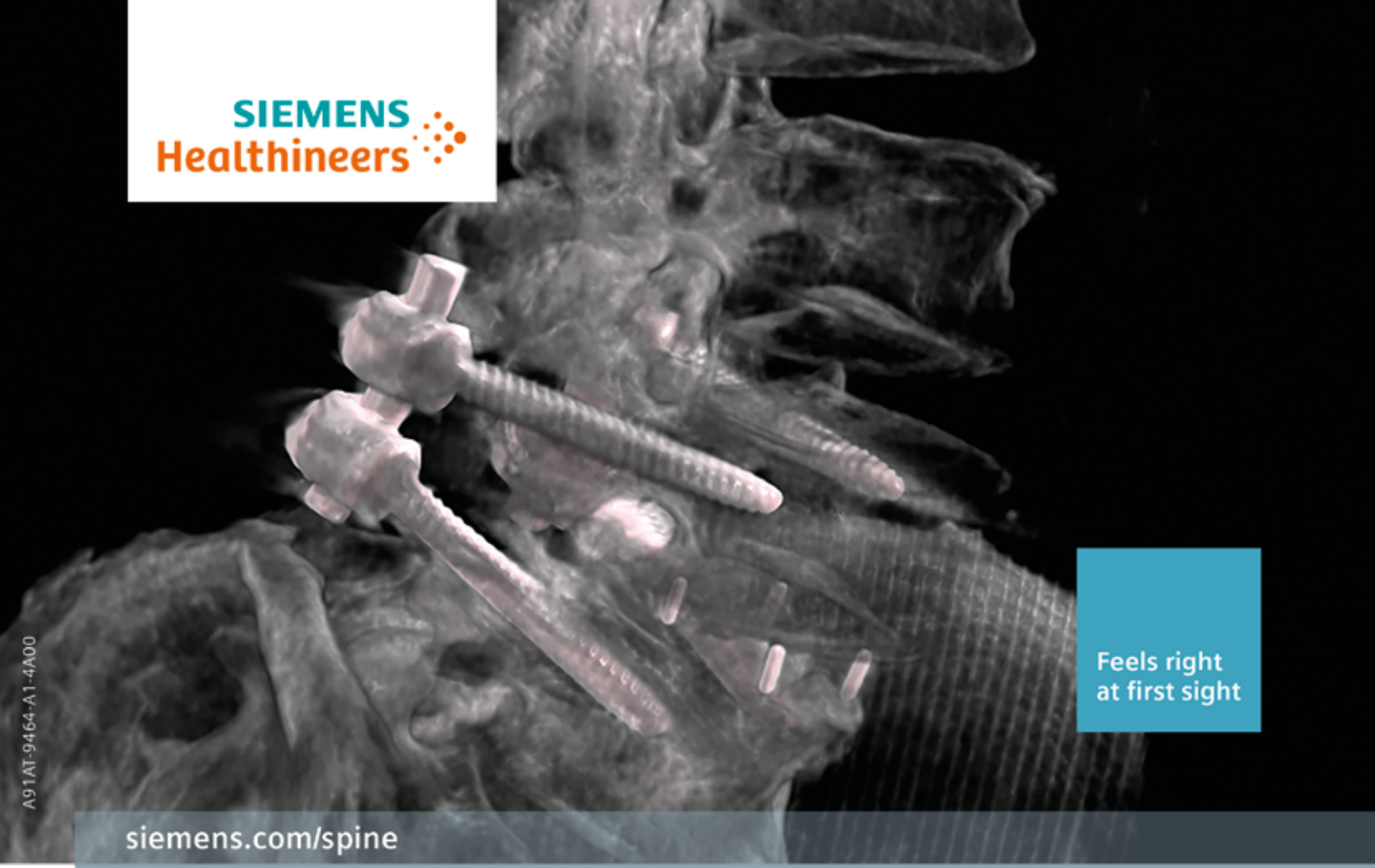
Mobile C-arm

- Mobile C-arm with a 30 x 30 flat detector to see up to seven thoracic vertebrae, and a smart collimation system providing up to 25% more coverage even during image rotation.
- Easy control of the system during spinal surgery due to touchscreen table-side control.
- Its high-power 25kW generator offers excellent image quality and visualization of the spine.
- The Intelligence Dose Efficiency Algorithm (IDEAL) supports optimal radiation dose management and image quality, even in obese patients.

SOMATOM Sliding Gantry CT

- SOMATOM Definition AS and Edge Sliding Gantry can image the entire spine in a few seconds, and can be set up to be used parallel in two ORs.
- Easy and automatic labeling of the entire spine provides quick anatomical guidance.
- The 80cm gantry opening is ideal to fit even obese patients, and the full gantry tilt provides easy patient access during the entire surgery.
- CARE Dose 4D automatically adapts the kV and radiation dose, adjusting to the uniqueness of each spinal area: cervical, thoracic and lumbar.

SIEMENS Healthineers



Feels right at first sight

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Speed. Precision. Less repetition.

High-end Imaging in Spine Surgery.

Almost all discussions of modern spinal surgery will at some point lead to the concept of improved quality management in open and minimally invasive approaches. The common goal of institutions and surgeons as well as patients is the best achievable outcome along with short OR times and reduced hospital stay.

Minimal invasiveness is a trend that is increasingly finding its way into spinal surgery. It can lead to less blood loss, faster rehabilitation as well as less pain and scarring. However, it may also mean longer OR time, more radiation dose, and less precision. What is needed are the skills and the technology to do it right. That way, minimally invasive procedures can be fast, precise, and reduce the amount of complications and readmissions. The right imaging technology can speed up workflows and enable procedures that simply were not possible before – and that's true both for minimally invasive and open approaches.

Siemens Healthineers supports you with technology that feels right at first sight, adapting the highly successful concept of the hybrid OR to spinal surgery: a powerful working environment with a fixed C-arm that offers the best possible support. From integration of pre-operative data to intra-operative guidance and quality control, the robot-supported imaging system Artis zeego offers high-resolution 2D and 3D imaging, ultrafast image acquisition, an extra large Field of View, and navigation integration – all in one room and at low dose.

Make your decisions with confidence and handle complex or difficult cases while increasing patient safety and reducing the number of secondary surgeries. And that is spine surgery done right.

Siemens Healthineers –
High-end Imaging in Spine Surgery.