Intraoperative Iso-C C-Arm Navigation in Cervical Spinal Surgery: Review of First 20 Cases
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INTRODUCTION: We present 20 cases that demonstrate our initial experience using intraoperative Iso-C fluoroscopy for cervical spine surgery (Fig. 1). We successfully applied this technology to complex anterior and posterior spinal procedures from the craniocervical junction to the cervicothoracic junction.

With this technique, multiple fluoroscopic images are acquired about an isocentric point in space, providing axial plane tomographic images that may be reconstructed into an accurate 3D volume. This system allows intraoperative 3D imaging without needing to reposition the patient and without restricting access to the patient. This new modality accurately correlates 3D images and the patient’s intraoperative anatomy and updates image data to support navigation. That is, traditional registration of landmarks is unnecessary.

The system functions similar to an intraoperative CT scanner but in a conventional C-arm “foot print.” The automated registration system eliminates the difficulties associated with using frameless stereotaxy during anterior spinal procedures caused by the lack of anatomic landmarks and other technical difficulties associated with manual registration of preoperative anatomic data. The Iso-C not only automates registration procedures, it also mitigates the need for postoperative imaging, a limitation of current navigational systems.

METHODS: The modified C-arm CT system (Siremobil ISO-C-3D; Siemens, Medical Solutions, Erlangen, Germany) has a 15- or 23-cm image intensifier and an orbital drive. The hardware consists of a regular C-arm computer with a hard disk and a double-processor personal computer for image processing and guidance control. The orbital motor is attached to the upper side of the hub-column housing and transports the C-arm.

During 3D-image acquisition, the motorized C-arm moves continuously around 190 degrees. During the rotation, 50 to 100 fluoro-projection images are acquired at equidistant angles. Subsequently, a high-resolution (< 0.5 mm³) 3D image data set is reconstructed using the precisely known rotation geometry. To measure and reconstruct the 3D data sets from 100 projections requires 120 s. The result of reconstruction is an image data cube of 256³ isotropic pixels with a volume of approximately 120 mm³.
The images are displayed using slice-image techniques (multiplanar reconstruction) or surface-shaded displays. The 3D images obtained in this fashion can be used to update registration or displayed as multislice images in combination with images from other modalities (e.g. soft tissue imaging using ultrasonography).

When navigating for posterior spinal procedures, the reference frame is placed on the spinous process of the adjacent vertebral body. When navigating for anterior spinal or posterior craniocervical pathology, the frame is attached to a radiolucent operating room (OR) table-mounted device.

RESULTS: This new method of imaging was successful in 20 intraoperative applications. The procedures included cervical lateral mass/pedicle screw placement (8 cases), including transarticular screw placement and C1 lateral mass/C2 pedicle screw-rod constructs (Fig. 2); anterior cervical corpectomy (4 cases); and reduction and instrumentation of the craniocervical junction (3 cases). The remaining cases involved intraoperative verification of artificial anterior cervical discs. Fifty-eight posterior screws were inserted with navigational assistance. In two corpectomies, the decompression was extended based on feedback from the intraoperative imaging. In most cases, the final 3D image obviated the need for postoperative CT.

CONCLUSION: The Iso-C is useful for most cervical spinal procedures either in conjunction with spinal navigation or as intraoperative CT to verify the extent of osseous decompression or placement of instrumentation. Half way through our cases, we stopped obtaining postoperative CT because the images obtained with the Iso-C were sufficient.

Iso-C has several advantages compared to mobile CT/MRI scanners and traditional frameless stereotaxy, including improved flexibility in patient positioning and decreased scan acquisition times. Patients may be positioned supine, lateral decubitus, or prone. Because of the system’s C-arm, patients can be positioned on traditional OR tables or affixed in radiolucent Mayfield headholders with no significant change in image quality. The cost of the Iso-C is comparable to modern 2D C-arm fluoroscopy units but significantly less than intraoperative CT or MRI suites.

The Iso-C is convenient and flexible. Data acquisition for intraoperative imaging with or without navigation is quick and seamless. The Iso-C is readily adaptable to any OR.
Figure 1. Siremobil Iso-C.

Figure 2. Intraoperatively acquired Iso-C 3D image being automatically integrated for use with Stealth image-guided navigation. The image generated is near CT quality and allows clear identification of appropriate landmarks for C1 lateral mass and C2 pedicle screw placement. Trajectory views through the C2 pedicle in (A) sagittal (B) coronal and (C) axial planes.