ACCURACY OF PEDICLE SCREW INSERTION USING A NEW INTRAOPERATIVE CONE-BEAM CT IMAGING TECHNIQUE: RETROSPECTIVE ANALYSIS OF 586 SCREWS

Virginie Cordemans[1], Ludovic Kaminski MD[2], Xavier Banse MD PhD[2], Nadia Irda MD[2], Bernard Francq PhD[3], Olivier Cartiaux PhD[1,*]

[1,*] University of Louvain, Laboratory for Computer Assisted and Robotic Surgery, Brussels, B-1200, Belgium, olivier.cartiaux@uclouvain.be

[2] Saint-Luc University Hospital, Department of Orthopaedic Surgery, Brussels, B-1200, Belgium

[3] University of Glasgow, Robertson Centre for Biostatistics, Glasgow, G12 8QQ, Scotland

INTRODUCTION

Pedicle screw placement is a widely used procedure for the treatment of spine pathologies including trauma, scoliotic deformities, infection, degenerative and malignant diseases. Inaccurate screw placement with a pedicle breach can lead to spinal cord, visceral and vascular injuries, with complications in terms of patient survival. Clinical studies have demonstrated the feasibility of achieving clinically accurate placement of pedicle screws with the aid of assistive technologies including intraoperative imaging systems, navigation systems, robots, and 3D-printed mechanical guides (Tian 2011).

Assessment of pedicle screw placement accuracy is usually carried out in postoperative CT scans (Motiei-Langroudi 2015), thereby making it impossible to detect pedicle breach intraoperatively. New techniques have been adapted to detect pedicle breach intraoperatively and to allow for direct re-positioning of these misplaced screws (Santos 2012), thereby helping to reduce the radiation dose by eliminating the need for postoperative CT scans. This retrospective study aims to assess accuracy of pedicle screw placement using a new intra-operative cone-beam CT (CBCT) imaging technique, and to compare the efficacy of this technique with conventional postoperative CT scans for pedicle breach detection.

MATERIALS AND METHODS

In 102 patients, 586 pedicle screws were inserted over a 21 month period. The new intraoperative CBCT imaging technique consisted of a robotic interventional angiography system (Artis Zeego, Siemens Healthcare, Forchheim, Germany) equipped with CBCT software applications (DynaCT, Siemens Healthcare, Forchheim, Germany) which has been recently adapted for spine surgeries. In all patients, intraoperative CBCT scans (Fig. 1) were acquired after all screws were inserted, and retrospectively reviewed by the orthopaedic surgeons for pedicle breach detection and grading. Of the 586 inserted screws, placement assessment of 239 screws were also carried out in conventional postoperative CT scans using the same grading system. Reliability tests computing Cohen's Kappa coefficient and Gwet's coefficient were performed to compare the CBCT imaging technique with the conventional postoperative CT scans for assessing screw placement accuracy and detecting pedicle breach. Sensitivity, specificity, positive and negative predictive values of the CBCT imaging technique to assess screw placement accuracy were measured, assuming that postoperative CT scans are the gold standard for assessing such accuracy.

RESULTS

Of the 586 inserted pedicle screws (Fig. 2), 496 (84.6%) were placed within the pedicle without any breach, 24 (4.1%) were in-out-in screws with a lateral breach but with the screw tip inside the vertebral body, 21 (3.6%) had a medial breach <2 mm, 10 (1.7%) had a medial breach between 2 and 4 mm, 4 (0.7%) had a medial breach of >4 mm, 5 (0.9%) had a lateral breach, and 26 (4.4%) had an anterior breach. Seventeen screws (2.9%) were revised intraoperatively. Kappa and Gwet's coefficients on screw placement assessment carried out in intraoperative CBCT and in conventional postoperative CT scans were 0.80 and 0.93, respectively. Sensitivity and specificity of the intraoperative CBCT imaging technique, considering that the postoperative CT imaging is the gold standard, were 0.77 and 0.98, respectively. Positive and negative predictive values were 0.91 and 0.96, respectively.

DISCUSSION

This study is the first to assess accuracy of pedicle screw placement using the new intraoperative Artis Zeego CBCT imaging system. Screws placed within the pedicle without any breach were considered accurate. In-out-in screws with a lateral breach but with the screw tip inside the vertebral body can also be considered accurate thanks to relevant mechanical stability (Husted 2004). The cumulative rate of "accurate" screws in the present study is consistent with the findings of clinical and cadaveric studies that investigated the accuracy of pedicle screw placement with the aid of various assistive technologies, including 3D fluoroscopy-based navigation (Ling 2014), intraoperative CT-based navigation (Scheufler 2011), robotic guidance (Kantelhardt 2011), among others.

This study also compared the efficacy of the Artis Zeego CBCT imaging system with that of conventional postoperative CT scans for pedicle breach determination. Intraoperative CBCT as performed in the present study seems to allow for accurate assessment of pedicle screw placement and might render postoperative CT imaging unnecessary. Nonetheless, collection of the CBCT data which are presented here consisted in the retrospective reviewing of the CBCT scans which were acquired intraoperatively. The results observed here, in terms of sensitivity and specificity, suggest that surgeons should take the necessary time intraoperatively to carefully review the CBCT scans and reduce the risk of not detecting a pedicle breach intraoperatively. As an illustration of such a potential risk, two screws with a medial breach of more than 4 mm were not detected intraoperatively on the CBCT scans, while they were properly graded during the retrospective reviewing of the same CBCT scans.

Further studies should be performed to account for complementary factors that may impact the overall quality of spine surgeries using the Artis Zeego CBCT imaging system: radiation dose, image quality, operating time, use of navigation system, learning curve, among others.

REFERENCES

- Husted DS, Haims AH, Fairchild TA, Kershaw TS, Yue JJ, Morphometric comparison of the pedicle rib unit to pedicles in the thoracic spine, Spine (Phila Pa 1976), 29(2), pp:139–146, 2004.
- Kantelhardt SR, Martinez R, Baerwinkel S, Burger R, Giese A, Rohde V, Perioperative course and accuracy of screw positioning in conventional, open robotic-guided and percutaneous robotic-guided, pedicle screw placement, Eur Spine J, 20(6), pp: 860–868, 2011.
- Ling JM, Dinesh SK, Pang BC, et al, Routine spinal navigation for thoraco-lumbar pedicle screw insertion using the O-arm three-dimensional imaging system improves placement accuracy, J Clin Neurosci, 21(3), pp: 493–498, 2013.

- Motiei-Langroudi R, Sadeghian H, Assessment of pedicle screw placement accuracy in thoracolumbosacral spine using freehand technique aided by lateral fluoroscopy: results of postoperative computed tomography in 114 patients, Spine J, 15(4), pp: 700–704, 2015.
- Santos ER, Ledonio CG, Castro CA, Truong WH, Sembrano JN, The accuracy of intraoperative O-arm images for the assessment of pedicle screw position, Spine (Phila Pa 1976), 37(2), pp: E119–E125, 2012.
- Scheufler KM, Franke J, Eckardt A, Dohmen H, Accuracy of image-guided pedicle screw placement using intraoperative computed tomography-based navigation with automated referencing, Part II: thoracolumbar spine, Neurosurgery, 69(6), pp: 1307–1316, 2011.
- Tian NF, Huang QS, Zhou P, et al, Pedicle screw insertion accuracy with different assisted methods: a systematic review and meta-analysis of comparative studies, Eur Spine J, 20(6), pp: 846–859, 2011.

DISCLOSURES

Ms Cordemans has received funding from Siemens for this investigation regarding Zeego imaging system. Dr Banse is consultant for Siemens. Dr Cartiaux is funded by the Brussels Capital Region-Innoviris (research grant BB2B-2012-1-05). Drs Kaminski, Irda and Francq declare that they have no conflict of interest.

Figure 1: Illustrations of the CBCT imaging system (Artis Zeego, Siemens, Forchheim, Germany).

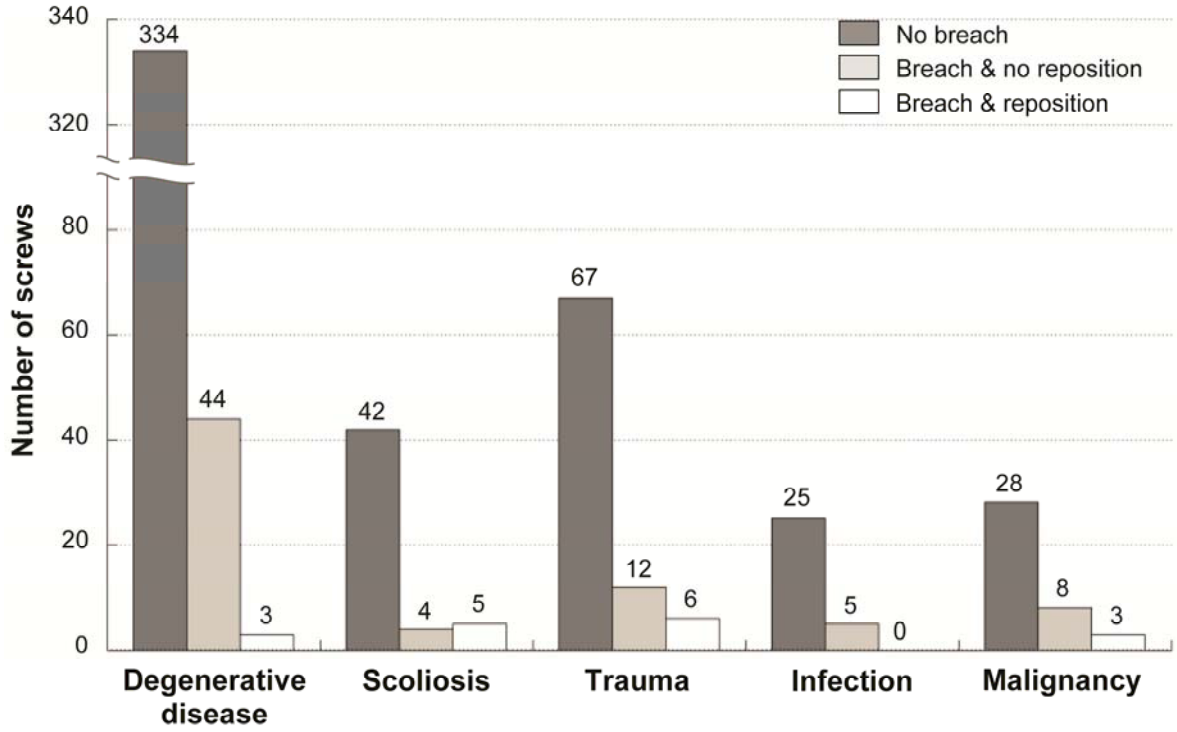

Figure 2: Numbers of screws for each surgical indication.