Injury, Int. J. Care Injured xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Full length article

Can the possibility of transverse iliosacral screw fixation for first sacral segment be predicted preoperatively? Results of a computational cadaveric study

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ARTICLE INFO

Keywords:
Sacrum
Pelvic ring injury
Transverse ilio-sacral screw fixation
Three-dimensional modeling

ABSTRACT

Objectives: The purpose of this study was to predict the possibility of transverse iliosacral (TIS) screw fixation into the first sacral segment (S_1) and introduce practical anatomical variables using conventional computed tomography (CT) scans.
Materials and methods: A total of 82 cadaveric sacra (42 males and 40 females) were used for continuous 1.0-mm slice CT scans, which were imported into Mimics® software to produce a three-dimensional pelvis model. The anterior height (BH) and superior width (BW) of the elevated sacral segment was measured, followed by verification of the safe zone (SZ_{S1} and SZ_{S2}) in a true lateral view. Their vertical (VD_{S1} and VD_{S2}) and horizontal (HD_{S1} and HD_{S2}) distances were measured. VD_{S1} less than 7 mm was classified as impossible sacrum, since the transverse fixation of 7.0 mm-sized IS screw could not be done safely.
Results: Fourteen models (16.7%; six females, eight males) were assigned as the impossible sacrum. There was no statistical significance regarding gender ($p = 0.626$) and height ($p = 0.419$). The average values were as follows: BW, 31.4 mm (SD 2.9); BH, 16.7 mm (SD 6.8); VD_{S1}, 13.4 mm (SD 6.1); HD_{S1}, 22.5 mm (SD 4.5); SZ_{S1}, 239.5 mm^2 (SD 137.1); VD_{S2}, 15.5 mm (SD 3.0); HD_{S2}, 18.3 mm (SD 2.9); and SZ_{S2}, 221.1 mm^2 (SD 68.5). Logistic regression analysis identified BH ($p = 0.001$) and HD_{S1} ($p = 0.02$) as the only statistically significant variables to predict the possibility. Receiver operating characteristic curve analysis established a cut-off value for BH and HD_{S1} of impossible sacrum of 20.6 mm and 18.6 mm, respectively.
Conclusion: BH and HD_{S1} could be used to predict the possibility of TIS screw fixation. If the BH exceeds 20.6 mm or HD_{S1} is less than 18.6 mm, TIS screw fixation for S_1 should not be undertaken because of narrowed SZ.

Introduction

The shape of the posterior pelvic ring structure is extremely complex with respect to percutaneous ilio-sacral (IS) screw fixation as a fluoroscopically-guided procedure. Moreover, bone overlap, obesity, poor bone quality, and bowel gas are obstacles in the identification of these relevant anatomical structures and compromise safe placement. Intraoperative interpretation of fluoroscopic images is also aggravated by the high degree of variability in the shape of the upper sacral segment [1–5]. A more elevated segment of the first sacral body, which i imprecisely described as sacral dysplasia, has been observed with an incidence of 30–54%[5–8]. The elevation can often render transverse IS screw insertion impossible because of a narrowed and angulated osseous corridors [2,8–10].

Compared with the oblique method, strict transverse placement of an IS screw could prevent the unrecognized cortex violation, especially in sacral dysplasia [2]. However, because of a smaller secured area of potential osseous corridor, preoperative recognition of the possibility of transverse IS (TIS) screw fixation should be assessed, especially in injuries including central sacral fractures, bilateral injuries, and osteoporotic fracture for complete IS joint fixation [10,11]. Although the radiological recognition of sacral dysplasia has been described [1–5,12], only two reports have addressed on the preoperative radiological marker for predicting the possibility of TIS screw fixation [9,13].

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http://dx.doi.org/10.1016/j.injury.2017.07.021
0020-1383/

The purpose of this study was to predict the possibility of TIS screw fixation into the first sacral segment and introduce the practical anatomical variables using a novel computed tomography (CT) measurement technique.

Materials and methods

Human body digital data were collected from the Korean Institute of Science and Technology Information and used with permission. We used CT data of 82 adult cadavers (42 males and 40 females), who underwent continuous 1.0-mm slice scans (Pronto, Hitachi, Japan) in the supine position. The mean age of the enrolled cadavers was 52.1 years (range, 21–60 years; SD, 9.2). The mean height was 161.3 cm (range, 146–176 cm; SD, 7.1). None of the cadavers had pelvic problems based on a review of their records. CT data in the Digital Imaging and Communications in Medicine (DICOM) format were imported into Materialise Interactive Medical Image Control System (Mimics®) software (Materialise, Antwerp, Belgium) to reconstruct three-dimensional (3D) models of the pelvis including two iliac bones and sacrum. The adjacent bones of two femurs and lumbar spine were removed to facilitate the 3D rendering.

After obtaining a 3D model of the pelvis, the transparency mode (low, medium, high, and opaque) was controlled to differentiate between the sacral canal, foramens, and cancellous bone (Fig. 1). The anteroposterior projection of the opaque sacrum can be characterized by the number of anterior foramen and lumbosacral transition vertebrae (LSTV) [13,14]. According to the LSTV [14], there were four sacralized pelvises. In the true lateral projection of the opaque sacrum, the anterior height (BH) and superior width (BW) of the elevated first sacral segment were measured by selecting the distance measurement tool of the Mimics software (Fig. 2). For clear visualization of the entire pathway of the TIS screw, the high transparency mode was used in the true lateral projection (Fig. 1). The potential osseous corridors without violation of the sacral canal and foramen of the first and second sacral segments were identified and defined as the safe zone for TIS screw fixation, which had to be in the intra-osseous position throughout the full path (Fig. 3) [6,8]. After the safe zone of the first and second sacral segments (SZ_{s1} and SZ_{s2}) was verified, based on an imaginary line aligned with the anterior border of the sacrum, the vertical distance (VD_{S1} and VD_{S2}) was measured in the mid-portion of the safe zone. For the horizontal distance (HD_{S1} and HD_{S2}), an imaginary line along the upper border of the sacrum was used in the mid-portion (Fig. 4). When the value of VD_{S1} was <7 mm, the mode was classified as impossible sacrum [3,5,14], since the transverse fixation of a 7.0 mm IS screw could not be done safely. When the value of VD_{S1} exceeded 7 mm, the model was classified as possible sacrum. To elucidate the area of SZ_{s1} and SZ_{s2} as a two-dimensional (2D) surface, 3-matic® ver. 8.0 (Materialise) was used. Once the margin of the safe zone was freely drawn (freeform patch), it was transformed to a 2D surface using the 'project mesh' option. Finally, the definitive area of the safe zone was fine-tuned and verified by an experienced surgeon (corresponding author).

For statistical analyses, descriptive statistics included the mean, minimum, and maximum. To predict the possibility of TIS screw fixation, logistic regression analyses (forward stepwise model) were performed with the anatomic variables including the BH, BW, number of foramen, VD_{S1} and VD_{S2}, and HD_{S1}, and HD_{S2}. Chi-square test and a two-sample *t*-test were used to compare the mean between the possible and impossible sacrum groups. Receiver operating characteristic (ROC) curve analysis was performed to identify the association between impossible sacrum and anatomic variables. Statistical significance was set at $p < 0.05$. The SPSS statistical software package for Windows version 23.0 (SPSS Inc., Chicago, IL, USA) and R ×64 3.1.1 (R Foundation for Statistical Computing, Vienna, Austria) were used.

Results

Among the 82 models, 14 (16.7%) were identified as impossible sacrum in the Asian cadavers (Fig. 5). Of these 14cadavers, 6 were female was 8 were male. There was no statistical significance in cadaver gender and height ($p = 0.626$ and $p = 0.419$, respectively). On the basis of the number of sacral foramens, there were two models in which the sacrum had three foramens, 69 models with four foramens, and 11 models with five foramens. Of these 11 models, 6 (54.6%) were impossible sacrum, and a two-sample *t*-test identified statistical significance based on the number of foramen ($p = 0.017$).

All measurements of the anatomic variables are summarized in Table 1. The average BW was 31.4 mm (range, 24.5-40.0 mm, SD 2.9). The average BH was 16.7 mm (range, 4.9-33.4 mm, SD 6.8). Regarding the variables related to SZ_{S1}, the average VD_{S1} was 13.4 mm (range, 1.7–26.6 mm, SD 6.1), the average HD_{S1} was 22.5 mm (range, 12.4–30.2 mm, SD 4.5), and the average SZ_{S1} was 239.5 mm^2 (range 19.2–517.7 mm^2, SD 137.1). With respect to the SZ_{S2}, the average VD_{S2} was 15.5 mm (range, 8.7–24.4 mm, SD 3.0), the average HD_{S2} was 18.3 mm (range, 12.7–26.6 mm, SD 2.9), and the average $SZ_{S2,}$ was 221.1 mm^2 (range 91.1–386.7 mm^2, SD 68.5). Among anatomic variables, BH and BW/BH were statistically significant (both $p < 0.001$). However, BW was not ($p = 0.867$). With respect to the safe zones, all variables of the first segment of

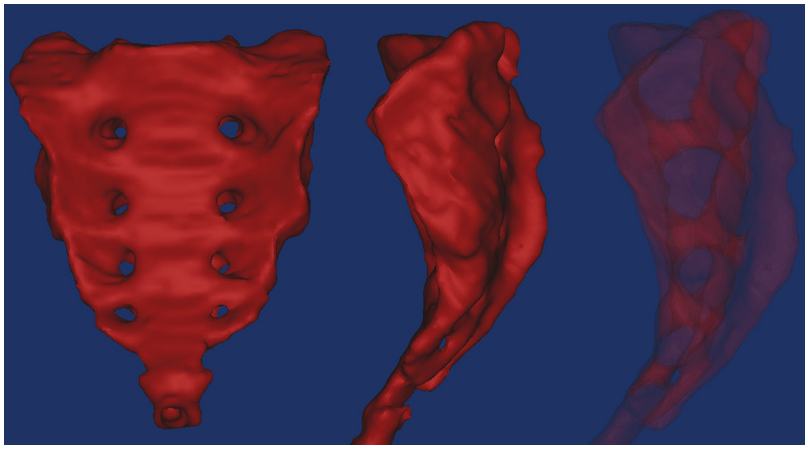

Fig. 1. Three-dimensional models of the sacrum. Mimics® software was used to reconstruct 3D models of the sacrum.

Please cite this article in press as: J.-H. Jeong, et al., Can the possibility of transverse iliosacral screw fixation for first sacral segment be predicted preoperatively? Results of a computational cadaveric study, Injury (2017), http://dx.doi.org/10.1016/j.injury.2017.07.021