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CT-based Navigation THA using CT-fluoro Matching Registration

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Abstract

CT-fluoro matching (CFM) registration is one of the registrations for CT-based navigation developed by Brainlab company, in which the contours of the intraoperative fluoroscopic 2D X-ray images were matched to the contours of 3D pelvic and femoral models created based on the preoperative CT images. Brainlab company stopped to provide CT-based navigation and shifted to imageless navigation for THA. Therefore, clinical efficacy of this CFM registration is not well known. We analyzed the accuracy of implant position and postoperative complications after CT-based navigation assisted THA of 45 cases (43 females, 2 males, average age: 72.7 y.o.) using CFM registration and cementless implants (SQRUM cups and J-Taper high offset stems [Kyocera, Japan]). The differences (average ± standard deviation of absolute values, [95% confidence interval]) between the pre- and post-operative angles of cup inclination, anteversion, and stem antetorsion were 2.2 ± 1.5º, [1.8~2.6º], 3.7 ± 3.1º, [2.9~4.6º], 5.9 ± 4.5º, [4.6~7.1º], respectively. The differences (average ± standard deviation of absolute values, [95% confidence interval]) between the intra- and post-operative angles of cup inclination, anteversion, and stem antetorsion were 2.2 ± 1.7º, [1.7~2.6º], 2.3 ± 2.1º, [1.7~2.8º],4.6 ± 3.0º, [3.7~5.4º], respectively. These values were clinically acceptable when we compared with the previous accuracy studies of CT-based navigation using surface matching registration. There was no dislocation after THA in this study. From these results, CFM registration is useful for THA. However, this CT-based navigation with CFM registration will be discontinued in near future. Novel CT-based navigation systems should be developed based on this CFM registration procedure.

1 Introduction

CT-based navigation is believed to be most accurate for THA. However, this system has been replaced by imageless or portable navigations, even though CT-based navigation has been still popular in spinal surgeries [Terrence T. Kim, 2016]. We can clinically use 2 kinds of registrations; "surface matching (SM)" and "CT-fluoro matching (CFM)" registrations in CT-based navigation for THA. SM registration is popular in Japanese hip surgeons who use CT-based navigation with excellent registration accuracy in not only primary THA, but also revision THA [Nobuhiko Sugano, 2012] [Iwana D, 2013] [Nobuo Nakamura, 2013]. SM registration is also used in the robotic surgery using MAKO Plasty

(Stryker, US). SM registration requires more than 30 of reference points on the bone surfaces and there are learning curves to master this procedure. In CFM registration, the contours of 2 shots of intraoperative 2D fluoroscopic X-ray images were matched semi-automatically to the contours of 3D pelvic and femoral models created according to the preoperative CT images. CFM registration requires only 3 reference points on iliac crest for pelvis and 2 points on bilateral epichondyles for femur. Because Brainlab company has stopped to provide CT-based navigation and shifted to develop image-less navigation for THA, only few surgeons have used this CFM registration and its usefulness is not well known. The aim of this study is to reveal accuracy of CFM registration with single surgeon and single kind of acetabular and femoral implants.

2 Patients and Methods

Fifty two hips of 45 cases (43 females, 2 males, average age: 72.7 y.o., follow up: 2~36 months [average18.1 months]) were subjected to this study. All procedures were performed by single surgeon (KT) through modified Watson-Jones approach in lateral decubitus position [Bertin KC, 2004]. Cementless acetabular cups; SQRUM cups (Kyocera Medical, Japan), and cementless femoral stems; J-Taper high offset (HO) stems (Kyocera Medical, Japan) were used with a CT-based navigation system, Vector Vision Hip version 3.5 (Brainlab, Germany). For acetabular reaming and cup impaction, Brainlab's universal acetabular reamer and cup impactor were used. Because the navigation program was originally made for another cementless femoral stems; PerFix stems (Kyocera, Japan), we created rasp holders and a stem impactor for J-Taper stem by setting a tracker attachment on the same geometry as the tools for PerFix stems which enabled us to navigate broaching and stem insertion of J-Taper stems just like as PerFix stems.

The cup inclination, anteversion and stem antetorsion angles in postoperative CT images were measured using 3D image analyzing software, ZedHip (LEXI, Japan), in which the contours of cups and stems were sharpened using the metal halation reduction software and digitally reconstruction radiographs. Superimposed views between the postoperative implants and the 3D CAD of implants were confirmed in multiplanar images to achieve accurate angle measurements. Because the Vector Vision Hip software used operative definition [DW, 1993] for cup angles in the anterior pelvic plane, we used the same definition and coordinate. For femoral measurements, the Vector Vision Hip software uses the long axis of femoral shaft as Z axis in femoral coordinate, however, it is impossible to reproduce the same long axis in ZedHip analysis with postoperative CT images. So, we used table top plane as the femoral coordinate, which was created by connecting the most posterior points of the proximal femur and the bilateral posterior epicondyles. The Z-axis was defined as a projection of the line between the trochanteric fossa and the center of the knee joint on the table top plane. We also investigated the differences between the pre- and post-operative implant sizes, operative times, intraoperative blood loss, and post-operative complications.

3 Result

The differences (average ± standard deviation of absolute values, [95% confidence interval]) between the pre- and post-operative angles of cup inclination, anteversion, and stem antetorsion were 2.2 ± 1.5º, [1.8~2.6º], 3.7 ± 3.1º, [2.9~4.6º], 5.9 ± 4.5º, [4.6~7.1º], respectively. The differences (average ± standard deviation of absolute values, [95% confidence interval]) between the intra- and post-operative angles of cup inclination, anteversion, and stem antetorsion were 2.2 ± 1.7º, [1.7~2.6º], 2.3 ± 2.1º, [1.7~2.8º], 4.6 ± 3.0º, [3.7~5.4º], respectively.

The postoperative cup sizes were same as the preoperative planning cup sizes except for 2 hips which required smaller sizes. Only one hip required larger head size than the preoperative planning. However, there were 11 hips whose stem sizes were different from the preoperative planning. We had to change the neck length in 23 hips out of 52 hips to manage soft tissue tension or leg length discrepancy.

The average of operative time and intraoperative blood loss were 96.2±12.1min and 258.7±170.8 mL, respectively. There was no dislocation after THA in this study.

4 Discussion

The accuracy of both cup and stem angles in current study were worse than the previous accuracy study of CT-based navigation using SM registration [Iwana D, 2013] [Nobuo Nakamura, 2013]. However, these were better than our previous accuracy measurements of SM and CFM. Especially errors of stem antetorsion were smaller than those with SM using Stryker Hip Navigation system (the average ± standard deviation [95% confidence interval] of absolute values of differences in pre- and post-operative and intra- and post-operative antetorsion were 6.8 ± 5.0º [6.3~7.3º] and 7.1 ± 5.0º [6.6~7.6º]). From these results, CFM registration was useful for THA when we used SQRUM cups and J-Taper stems. We had to change the stem sizes in 11 hips out of 52 hips, indicating that the preoperative judgements of femoral shapes and bone qualities were insufficient. Soft tissues play an important role for hip stability after THA [van Arkel RJ, 2015]. Because the current CT-based navigations provided only geometrical information without soft tissue balance or tension, we had to change neck lengths in half cases.

The first limitation of this study was small numbers of subjects. To reveal the accuracy of CFM registration, we selected the cases with single kind of implants, so we measured only 52 hips. The second limitation was the definition of stem antetorsion. We could not reproduce the femoral Z-axis in Vector Vision Hip, and we chose table top plane as the femoral coordinate to measure the femoral antetorsion. Therefore, some errors of femoral antetorsion might be due to this measurement procedures. So far, there was no dislocation in this study, indicating CFM registration was useful for THA.

5 Conclusion

CT-based navigation assisted THA using CFM registration showed acceptable accuracy of cup and stem replacement for THA. This registration is simple and easier than SM registration. However, CFM registration will be discontinued by Brainlab company in the near future. CT-based navigation systems should be developed for THA based on this CFM technology.

6 Disclosure

There was no conflict of interest in this study.

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