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Equivalence Evaluation of Point Registration and Intraoperative CT Registration While Using Navigation System

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Abstract

Registration of the patient body and virtual 3D plan is an initial but very fundamental procedure for accurately using the navigation system. Currently, there are two commonly used registration methods, i.e., point registration and intraoperative CT registration, which are suitable for different kinds of operative scenarios. By now, there is no literature reporting about how to choose between these two registration methods during using the navigation systems. In this study, we respectively performed 12 simulated osteotomies based on the point registration method and intraoperative registration method during using the navigation system. Two statistical tests were done based on the surgical errors of osteotomy surgeries using these two registration methods. Specifically, T-test result (p<0.001) indicated the intraoperative CT registration performed better than point registration. Besides, equivalence test of the two registration methods (Rg=1.00 mm) suggested that the two registration methods perform equivalently while using the navigation system. Moreover, we have shared the surgeons some practical suggestions about how to choose between these two registration methods during using the navigation system.

1 Introduction

Before using the navigation systems, registration is a crucial step to establish the correspondence between the real patient body and the virtual 3D plan (Fitzpatrick 1998, Qiu 2017). Generally, there are two commonly used registration methods: point registration and intraoperative CT registration (Merloz 1998, Qiu 2017). Specifically, point registration method firstly registers the patient bone and the virtual

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3D plan with the salient landmarks and then refines the registration by minimizing distances of the surface points around the registration area. While the intraoperative CT registration method establishes correspondence of the patient and navigation system through registering the intraoperatively scanned CT to the preoperatively CT.

In practice, the intraoperative CT registration method could consider more spatial information than the point registration method (CT voxels versus few landmark points), and thus could achieve relatively higher registration accuracy. However, scanning CT will inevitably radiate the patient. While point registration requires the patient to expose large bone surface to show sufficient landmark points, which might be not applicable in some complex sites and probably affect the patient's recovery.

In this study, our chief objective is to validate the equivalence of the point registration and intraoperative CT registration while using the navigation system. Besides, we want to share the surgeons some practical suggestions about the selection principle of the registration method during using the navigation system.

2 Materials and Methods

In this study, we used 4 artificial pelvises, each of which was placed a tumour on its left or right side, to simulate 4 patients. To save material, we virtually regarded the symmetric position of the tumour in each pelvis also grew a tumour. Therefore, we simulated 4+4=8 patients in total. Before performing the osteotomy surgeries, we respectively scanned the CT images (Multislice 64, Toshiba, Japan) of the four pelvises.
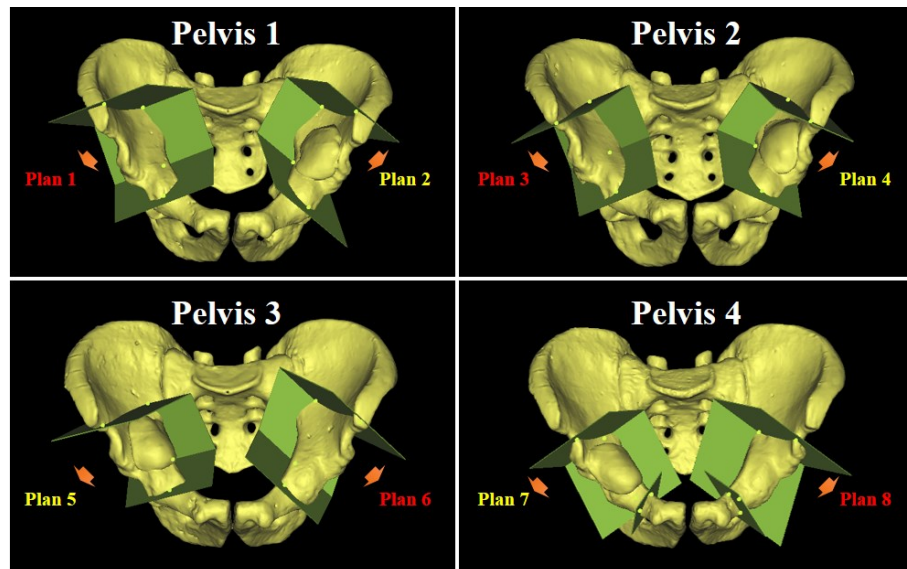

Figure 1: 8 Surgical Plans

2.1 3D Preoperative Planning

For each pelvis, we virtually segmented the simulated tumour in the Mimics software (Materialise, Leuven, Belgium), and designed 3 osteotomy planes according to the safe margin. Besides, as we regarded the healthy side of each pelvis also grew a tumour, thus we symmetrically imposed 3

osteotomy planes on the symmetric positions of osteotomy planes in the tumour side. Therefore, we totally designed 8 surgical plans, each of which contained 3 osteotomy planes, as shown in Figure 1.

2.2   Operative Procedure and Navigation

Afterwards, each surgery plan was converted into the DICOM format and then imported into our navigation system (3D OrthoMap, Stryker, Freiburg, Germany). Furthermore, we respectively utilized the intraoperative CT (Arcadis Orbic 3D, Siemens Medical, Munich, Germany) registration method and point registration method to register the tumour side and the healthy side to the virtual 3D plan in the navigation system. Next, we followed each surgical plan to perform the osteotomies with a freehand saw.

2.3   Error Measurement with Surgical Specimen

Once osteotomies were performed, the specimen was scanned to CT and reconstructed with the same protocol for the 3D preoperative planning.

The 3D virtual specimen was firstly superposed on the 3D preoperative plan. Then, we sampled the surface points on each specimen and computed their distances to the corresponding osteotomy plane as the osteotomy errors.

2.4   Statistics

A total of 24 osteotomies were obtained and analysed in 2 groups according to the type of the registration methods: intraoperative CT registration (n=12) and point registration (n=12).

The distances between the planned and performed osteotomies through imposing the sectioned specimen for the two registration methods were respectively calculated, where we adopted ICP algorithm to automatically align the sectioned specimen to the 3D planning. Afterwards, a t-test was performed to compare the osteotomy errors of the two registration methods at all sampling points. Specifically, the null hypothesis of the t-test was that the absolute mean errors of the intraoperative CT registration and point registration were equal, and its alternative was the absolute mean error of intraoperative CT registration was less than that of the point registration. More importantly, the difference between the two registration methods was evaluated by a test of equivalence (Tryon 2008, Ritacco 2013). The test of equivalence firstly built 95% confidence interval (CI) of each registration method, and then calculated the total range of their CIs (Rg). If Rg is less than or equal to the empirical value (1 mm), then the compared methods are equivalent.

3   Results

According to the statistics, the absolute mean error of the point registration method was 1.97 mm, which was greater than 1.5 mm for the intraoperative CT registration. Besides, the t-test rejected the null hypothesis at the 1% significance level (p<0.001), which indicated the intraoperative CT registration performed better than point registration. As for the equivalence of the point registration method and the intraoperative CT registration method, difference in 95% CI were 1.66 to 2.28 mm for the point registration method and 1.29 to 1.72 mm for the intraoperative CT registration method, thus the total range of CI (Rg) was equal to 1.00 mm. Since Rg was equal to the empirical indifference range (1 mm), thus the results suggested the two registration methods were equivalent.

4 Discussions

Registration of the patient body and virtual 3D plan is an initial but very fundamental procedure for the accurate usage of the navigation systems. The two registration methods, point registration and intraoperative CT registration, respectively have their own characteristics: intraoperative CT registration could be applied in various operation sites but would radiate the patient, while point registration is very simple but could only be applied in the operation sites that could be exposed to show sufficient landmarks.

Previously, some literatures evaluated the accuracy of the compute-aided surgeries (Cartiaux 2010, Ritacco 2013) and assessed the registration accuracy using the intraoperative CT (Stoll 2015), but no one has ever explored the equivalence of the two commonly used registration methods. Thus, in this study, we verified the equivalence of point registration and intraoperative CT registration while using the navigation system. Moreover, according to our evaluations, we want to share the surgeons some suggestions about the reasonable selection between the two registration methods:

(1) If the operation site could be easily exposed and contain enough landmarks, then we suggest the surgeons to conduct point registration;

(2) If only small surface could be exposed or the landmarks are rare, then we suggest the surgeons to adopt intraoperative CT registration;

(3) If the surgeons want to pursuit more precision, we suggest them to use intraoperative CT registration.

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Disclosures