curac2004
3. Jahrestagung der Deutschen Gesellschaft für Computer- und Roboterassistierte Chirurgie e.V.

Bildfreie Hüftpfannennavigation basierend auf einem statistischen Modell der Beckenoberfläche

Image-free cup navigation in THR surgery using a statistical pelvic bone surface model

Sebastian Meller[1], Willi A. Kalender[2], Ralf Petzold[3]

[1]Institut für Medizinische Physik,
Friedrich-Alexander-Universität Erlangen-Nürnberg
[2]Institut für Medizinische Physik, Friedrich-Alexander-Universität Erlangen-Nürnberg
[3]CAS innovations AG, Erlangen

Purpose

Image-free navigation systems guide the surgeon in order to place the surgical tools within the human body and, in contrast to CT-based navigation systems, they save time, costs and radiation dose induced by the 3D preoperative image acquisition. Intraoperative data such as palpated points on the bone surface tracked by an optical tracking system can provide the necessary information of the unknown individual anatomy. By using a model-based approach the whole bone surface can be reconstructed from these point coordinates and used for visualization and measurements.
The goal of this study was to develop and evaluate a component for the reconstruction of the whole pelvic bone surface from a set of intraoperatively palpated bone surface points to be used in an image-free cup navigation system for total hip replacement surgery.

Materials and methods

The component consists of a preoperative model building process and an intraoperative model fitting process.

Model building

A statistical surface model of the pelvic bone surface was generated from 20 segmented CT data sets of female patients. By applying a template-based non-rigid surface matching algorithm dense point-to-point correspondences between the surfaces were established.

The statistical model was then generated from the resulting surfaces leading to an average bone surface and a set of shape variation vectors. This shape model allows to generate a range of plausible pelvic bone surfaces controlled by a small set of parameters.

Model fitting

During a total hip replacement surgery the following points and point sets can be accessed using a pointer tracked by an optical tracking system: three points that define the pelvic coordinate system, palpated through skin, namely, the anterior superior iliac spines and the pubic symphysis and, directly on the bone surface, a point cloud of points in the acetabulum to be prepared for cup insertion. The statistical shape model can be fitted to this point set by iteratively applying a point-to-point registration and a model parameter adaptation in order to find the shape that best fits the point set.

Evaluation

For evaluation purposes on each of the segmented input surfaces the described point set was marked manually to simulate point sets acquired by an optical tracking system. Iteratively, for each of the input surfaces, a statistical model was first generated using all but this input surface, then fitted to the simulated point set and finally the approximation error was measured as the mean average distance of the known real bone surface to the reconstructed model surface.

Results

An approximation error of 1.3 +/- 1.1 mm was measured in the relevant area of the acetabulum to be prepared for cup insertion.

Discussion

This study shows that the whole pelvic bone surface can be reconstructed from a small set of points intraoperatively palpated on the bone surface when a model-based approach is used. The approximation error is in an acceptable range for application in an image-free cup navigation system for THR surgery. This way the surgeon can be provided with an individual 3D bone model without preoperative 3D imaging.