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Application of an innovative computerized virtual planning system in acetabular fracture surgery: A feasibility study

Huixiang Wang[a], Fang Wang[a], Simon Newman[b], Yanping Lin[c], Xiaojun Chen[c], Lu Xu[c], Qiugen Wang[a,*]

[a] Orthopaedic Traumatology, Trauma Center, Shanghai General Hospital, School of Medicine, Shanghai Jiao Tong University, Shanghai, PR China
[b] MSk Lab, Imperial College London, Charing Cross Hospital, London, UK
[c] School of Mechanical Engineering, Shanghai Jiao Tong University, Shanghai, PR China

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ABSTRACT

Introduction: Acetabular fracture surgery is amongst the most challenging tasks in the field of trauma surgery and careful preoperative planning is crucial for success. The aim of this paper is to describe the preliminary outcome of the utilization of an innovative computerized virtual planning system for acetabular fractures.

Methods: 3D models of acetabular fractures and surrounding soft tissues from six patients were constructed from preoperative CT scans. A novel highly-automatic segmentation technique was performed on the 3D model to separate each fracture fragment, then 3D virtual reduction was performed. Additionally, the models were used to assess potential surgical approaches with reference to both the fracture and the surrounding soft tissues. The time required for virtual planning was recorded. After surgery, the virtual plan was compared to the real surgery with respect to surgical approach and reduction sequence. A Likert scale questionnaire was completed by the surgeons to evaluate their satisfaction with the system.

Results: Virtual planning was successfully completed in all cases. The planned surgical approach was followed in all cases with the planned reduction sequence followed completely in five cases and partially in one. The mean time required for virtual planning was 38.7 min (range 21–57, SD = 15.5). The mean time required for planning of B-type fractures was 25.0 min (range 21–30, SD = 4.6), of C-type fracture 52.3 min (range 49–57, SD = 4.2). The results of the questionnaire demonstrated a high level of satisfaction with the planning system.

Conclusion: This study demonstrates that the virtual planning system is feasible in clinical settings with high satisfaction and acceptability from the surgeons. It provides a viable option for the planning of acetabular fracture surgery.

Introduction

Acetabular fractures are amongst the most challenging fractures in the field of trauma surgery. The goal of acetabular fracture surgery is to achieve an anatomic reconstruction of the articular surface [1]. Achieving this goal is very difficult due to the complexity of pelvic anatomy, the choice of correct surgical approach and the limited exposure and visualization of the fracture. Letournel and Judet [2] stated that the treatment of an acetabular fracture should not be commenced until complete comprehension of the fracture is achieved. A meticulous preoperative plan is crucial for success [3].

In recent years, advances in image processing and computer technology have permitted the preoperative virtual planning of orthopaedic procedures [4–11]. However, in previous publications on virtual planning for acetabular fracture surgery, two dimensional (2D) manual segmentation of fracture fragments was required [4,7,8], which is a time consuming process especially with comminuted fractures. Furthermore these studies do not include the visualization of adjacent soft tissue structures, which may be beneficial in planning the surgical approach, reduction and fixation maneuvers.

Consequently we have developed a new computer-assisted virtual surgical planning procedure that facilitates understanding of the three dimensional (3D) nature of acetabular fractures and

* Corresponding author.
E-mail address: wangqiugen@outlook.com (Q. Wang).

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enables virtual planning of surgical approach and reduction steps. Compared to previously reported tools, the system features a highly efficient and automatic bone fragment segmentation function and facilitates high-resolution 3D visualization of both bone and soft tissue structures, which to the best of our knowledge, is the first report of a system of this nature for the planning of acetabular fracture surgery. The purpose of the present study is to evaluate its feasibility and value in clinical practice.

Patients and methods

Patients

Six adult patients with a mean age of 52.7 years (range: 37–65 years) with acetabular fractures were recruited. The study was approved by our institutional ethics committee. Informed consent was obtained from all patients. Each patient underwent CT scans of the pelvis (GE Light speed 64CT machine, USA) before the surgery. The six fractures were classified according to the AO classification with three B type fractures and three C type fractures (Table 1).

Virtual planning procedure

Six orthopaedic surgeons experienced in acetabular surgery participated in our study and personally performed the virtual planning process. The CT data in DICOM (Digital Imaging and Communications in Medicine) format was loaded into M-3D software (Forward Algorithm Company, Shanghai, China). The appropriate threshold (in Hounsfield units) for bone was determined and a surface rendered 3D model of the pelvic surface was reconstructed.

An innovative 3D segmentation method was used to separate fracture fragments. When defining two contiguous fragments as separate parts, the surgeon approximately marked the boundary of the two parts on the 3D model using the cursor before a software algorithm automatically defined the fragment border precisely. A different colour was assigned to each fragment to aid the observer in identifying different fragments (Fig. 1). After segmentation of all bone fragments, individual fragments were manipulated three-dimensionally to plan the steps involved in fracture reduction (Fig. 2).

A volume rendered 3D model that included the pelvis and adjacent soft tissues was constructed from the DICOM data (Fig. 3). By varying the transparency of the tissue layers and rotating the model, the surgeon could determine different layers of tissues to be visualized and view the fracture through and in relation to the surrounding soft tissues from different perspectives. Through this process, the surgeon selected the optimal surgical approach.

Evaluation of the system

After surgery, the virtual plan was compared to the surgical outcome with respect to surgical approach and reduction sequence. Additionally, the time for the segmentation and model

Table 1
Patient data and comparison between virtual planning and real surgery.

Case	Age (years) /Gender	Fracture type (AO classification)	Time required (minutes)	Virtual planning		Real surgery compared with virtual planning	
				Approach	Reduction sequence	Approach	Reduction sequence
1	51/male	Transverse/posterior wall fracture (B1)	21	Kocher-Langenbeck approach	Transverse fracture, posterior wall	Identical	Identical
2	37/ male	T shaped fracture (B2)	24	Kocher-Langenbeck approach	Posterior column, anterior column	Identical	Identical
3	65/ female	T shaped fracture (B2)	30	Kocher-Langenbeck approach	Posterior column, posterior wall, anterior column	Identical	Identical
4	49/ male	Double column fracture (C1)	57	Combined posterior and anterior approach	Crest iliac, anterior column, posterior column	Identical	Identical
5	60/ male	Double column fracture (C1)	51	Combined posterior and anterior approach	Crest iliac, anterior wall, anterior column, posterior column, posterior wall	Identical	Minor change
6	54/ male	Double column fracture (C2)	49	Combined posterior and anterior approach	Crest iliac, anterior column, posterior column	Identical	Identical

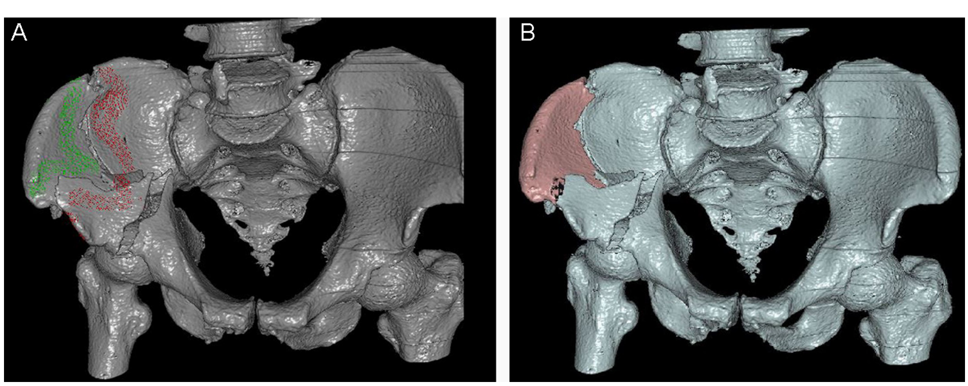

Fig 1. 3D segmentation of bone fragments: (A) Approximate marking (red and green lines) of the boundary of two fragments on the 3D model. (B) Then the software automatically defines the fragment borders precisely with different colour assigned to separate parts. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)