A multimedia electronic patient record (ePR) system for image-assisted minimally invasive spinal surgery

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Abstract

Purpose This paper presents the concept of bridging the gap between diagnostic images and image-assisted surgical treatment through the development of a one-stop multimedia electronic patient record (ePR) system that manages and distributes the real-time multimodality imaging and informatics data that assists the surgeon during all clinical phases of the operation from planning Intra-Op to post-care follow-up. We present the concept of this multimedia ePR for surgery by first focusing on image-assisted minimally invasive spinal surgery as a clinical application.

Methods Three clinical phases of minimally invasive spinal surgery workflow in Pre-Op, Intra-Op, and Post-Op are discussed. The ePR architecture was developed based on the three-phased workflow, which includes the Pre-Op, Intra-Op, and Post-Op modules and four components comprising of the input integration unit, fault-tolerant gateway server, fault-tolerant ePR server, and the visualization and display. A prototype was built and deployed to a minimally invasive spinal surgery clinical site with user training and support for daily use.

Summary A step-by-step approach was introduced to develop a multimedia ePR system for imaging-assisted minimally invasive spinal surgery that includes images, clinical forms, waveforms, and textual data for planning the surgery, two real-time imaging techniques (digital fluoroscopic, DF) and endoscope video images (Endo), and more than half a dozen live vital signs of the patient during surgery. Clinical implementation experiences and challenges were also discussed.

Keywords ePR · System integration · Pre-, Intra- and Post-Op surgical workflow · Minimally invasive spinal surgery

Abbreviations

API Application program interface
BIS Bispectral index system
CO$_2$ Carbon dioxide
CR Computed radiography
CSI California Spine Institute
CSS Cascading style sheet
CT Computed tomography
DICOM Digital imaging and communications in medicine
EMG Electromyography
ePR Electronic patient record
GIF Graphics interchange format
GUI Graphical user interface
HIPAA Health Insurance Portability and Accountability Act
HIS Hospital information system
HTML Hyper text markup language
HTTP Hyper text transfer protocol
HTTPS Hyper text transfer protocol secured
ICT Information and communication technology
IA-MISS Image-assisted minimally invasive spinal surgery
IPILab Image Processing and Informatics Laboratory
IRB Institutional Review Board
IT Information technology
Introduction

Bridging the gap between diagnostic images and surgical treatment

This paper presents the concept of bridging the gap between diagnostic images and image-assisted surgical treatment through the development of a one-stop multimedia electronic patient record (ePR) system that manages and distributes the real-time multimodality imaging and informatics data that assists the surgeon during all clinical phases of the operation from planning Intra-Op to post-care follow-up. We present the concept of this multimedia ePR for surgery by first focusing on image-assisted minimally invasive spinal surgery as a clinical application. For this particular surgical procedure, in addition to images, clinical forms, waveforms, and textual data for planning the surgery, two real-time imaging techniques (digital fluoroscopic, DF) and endoscope video images (Endo), and more than half a dozen live vital signs of the patient during surgery are needed to assist and monitor the surgery. All these data have to be acquired, displayed and archived in real-time as well.

Minimally invasive spinal surgery

Back and neck pain is the price human beings pay for poor posture, prolonged sitting, lifting, repeated bending, obesity, and injury from accidents. This ailment gives the United States with a massive economic headache. Approximately 85% of inhabitants of the Western world are afflicted with some degree of back or neck pain at some point in their lives [1]. About 25% of our population has been incapacitated for 2 weeks or more due to back pain and an estimated 8 to 10 million people have a permanent disability from it [2–5]. The economic impact is obvious. In most cases, simple treatments such as bed rest, exercise, physiotherapy, and pain medication bring relief. Many sufferers are not so fortunate. If one or more of their vertebral discs ruptures and presses on nerve roots, the pain radiating from the back or neck and down the limbs can be incapacitating and severe. Until recently, the only treatment was surgical removal of part of the ruptured disc, a major operation that required general anesthesia, the dissection of muscle, removal of bone, manipulation of nerve roots, and, at times, bone fusion. In an effort to overcome the disadvantages of traditional surgical techniques, the scientific medical community began exploring the use of endoscopy (arthroscopy) for minimally invasive spinal surgery surgical operation [6,7].

An endoscope provides clear visualization and magnification of deep structures in real-time. With the advancement of scientific technology and miniaturization, including fiber optics, video imaging technology, laser treatment and experience gained through minimally invasive spinal surgery, there is a less traumatic discectomy procedure for some patients with disc problems. In the recent years, development of image-assisted surgery has improved the precision and reduced surgical tissue trauma. Figure 1 depicts the cervical, thoracic and lumbar spines on MRI before (Pre-Op) and after (Post-Op) the endoscopic-guide spinal discectomy. The lesion(s) at each spinal region is clearly cured after the surgery.

Rationale for a multimedia ePR system for image-assisted minimally invasive spinal surgery

Minimally invasive spinal surgery will be the method of choice for future spinal surgery to treat cases of herniated lumbar discs, post fusion junctional disc herniation, neural compression, osteophytes, spinal stenosis, vertebral compression fractures, spinal tumor, synovial cysts and other types of spinal traumas. Despite the overall advantageous and benefits of minimally invasive spinal surgery compared to conventional open spinal surgery, there are challenges remained in minimally invasive spinal surgery including (1) integration of Pre-, Intra-, and Post-Op surgical data from scattered data acquisition systems, (2) overcoming the difficulty of real-time data collection during the surgery, and (3) improving the efficiency of surgical workflow. An integrated real-time multimedia ePR system is an ideal solution to overcome these challenges. If successful, it will take Minimally Invasive Spinal Surgery to a higher level of excellence by combining surgical expertise in minimally invasive spinal surgery with the frontier advancements in imaging informatics.