Intelligent Operating Theater: Technical Details for Information Broadcasting and Incident Detection System

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Abstract

This paper introduces an intelligent operating theater equipped with a magnetic resonance imaging (MRI) scanner and video recording and broadcasting system to enhance the quality of surgery. To reduce error, intraoperative incidents are detected and dealt with using semi-automatic computer algorithm. A multiple-channel video recording and broadcasting system was installed in an operating room and the surgical procedure was recorded. The supervising surgeon monitored the operation in real-time from outside the operating room. Information sharing via the intra-hospital network improved the work efficiency of staff. The amount of motion was estimated from recorded file size based on the principle of inter-frame video compression. A time period for which the file size significantly increased compared to those for neighboring time periods was chosen and the majority voting technique was applied to detect events using six channels of the video. A change in file size indicated a phase change of the surgical procedure. The proposed method is promising for future daily clinical procedure.

Keywords: Neurosurgery, Intraoperative magnetic resonance imaging (MRI), Surgical information, Incident detection, Video recording, Motion tracking, Digital forensics

1. Introduction

Sophisticated operating suites equipped with intraoperative imaging modalities have been introduced in a lot of hospitals. Intraoperative imaging enables in-situ visualization of the target lesion and the evaluation of surgical treatment results, allowing surgeons to modify the surgical plan in real-time in the operating room, especially in brain tumor surgery, which requires very precise resection of the target lesion. Intraoperative imaging can only optimize the surgical procedure, but total optimization of the whole surgical process can enhance the total quality of the surgery. In the operating room, surgical devices such as intraoperative imaging modalities (ultrasonography, fluoroscopy, C-arm, X-ray computed tomography, magnetic resonance imaging (MRI)) and surgical microscopes are used. Staff includes surgeons, anesthesiologists, clinical engineers, scrub nurses, and supporting nurses. Operating room and operative procedures are thus complicated.

Around 98,000 people die per year from medical errors in the United States [1]. Complicated medical care may be one of the reasons for such errors. Serious accidents and errors are investigated to find their causes to prevent future accidents. The best way to prevent medical error is the identification of potential risk factors and practical countermeasure for the risks [2]. This methodology was established for aircraft accidents [3]. Similar approaches are used in industrial companies, especially in the assembly of automobiles and ships. Assembly consists of small procedures, and can be disassembled into small pieces. If the relationship among the small pieces is clear, the complex procedure can be described using a flowchart, which facilitates the finding of the cause of error.

Surgical procedures also comprise small tasks, but they are not repetitive. A surgery, for example a brain tumor resection in the left frontal cortex, has a basic routine, but details differ depending on patient's clinical history, lesion location, operative approach, and so on. In other words, surgeons never perform the exact same operation. Only a rough flow chart of surgery can be created. The present study reviewed many clinical cases to find risk factors. As shown in Heinrich's triangle and Reason's organizational model (Swiss cheese model) [4,5], a lot of risk factors and small incidents exist behind a serious error. Such small incidents should be detected and mitigated before a serious error occurs.

Medical error is a critical issue in medical practice. A web-based adverse event reporting system for surgical patients has been developed [6] and incident analysis is conducted in the

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