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Technical note

Implementation of a web-based, interactive polytrauma tutorial in computed tomography for radiology residents: How we do it

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ABSTRACT

Purpose: Due to the time factor in polytraumatized patients all relevant pathologies in a polytrauma computed tomography (CT) scan have to be read and communicated very quickly. During radiology residency acquisition of effective reading schemes based on typical polytrauma pathologies is very important. Thus, an online tutorial for the structured diagnosis of polytrauma CT was developed.
Materials and methods: Based on current multimedia theories like the cognitive load theory a didactic concept was developed. As a web-environment the learning management system ILIAS was chosen. CT data sets were converted into online scrollable QuickTime movies. Audiovisual tutorial movies with guided image analyses by a consultant radiologist were recorded.
Results: The polytrauma tutorial consists of chapterized text content and embedded interactive scrollable CT data sets. Selected trauma pathologies are demonstrated to the user by guiding tutor movies. Basic reading schemes are communicated with the help of detailed commented movies of normal data sets. Common and important pathologies could be explored in a self-directed manner.
Conclusions: Ambitious didactic concepts can be supported by a web based application on the basis of cognitive load theory and currently available software tools.

1. Introduction

Trauma is one of the most frequent causes of death in adults under 45 years of age in industrial nations. Following Trentz and Tschernes definition polytrauma describes simultaneously caused severe injuries in at least two body regions with at least one potentially lethal injury [1]. Disclosing potentially lethal injuries require quick and efficient diagnostic methods, which has been achieved by using whole body multi-slice computed tomography (CT) scans [2]. Still, for a quick, complete and precise report an experienced radiologist is indispensible.

In 2009, 404 polytrauma patients underwent a whole body multislice CT scan in our hospital. In our department the radiology resident on call does the first reading at the CT console immediately after the scan is finished with surgeons and anaesthesiologists attending. The radiology resident is at least a third year resident with a minimum of a six months experience in computed tomography.

In this paper we present methods and tools to establish a web-based, interactive polytrauma CT tutorial to support the residents training and to help them write a fully detailed report. The tutorial constitutes a supplementary offer for private study during or in addition to the daily routine. As an important factor in the residents' training the polytrauma tutorial should also depict the diagnostic process of an experienced radiologist reading a polytrauma CT scan. The current stage of the (German-speaking) tutorial as well as an English-speaking demo version can be accessed by www.knowledgecontainer.de.

2. Materials and methods

2.1. Didactic concept

An important factor in polytrauma diagnostics which makes the difference between a beginner and an expert is establishing an efficient reading scheme to detect all relevant pathologies in a timely manner. Consequently, knowing what a "normal" whole body CT scan (without any pathologies) looks like is indispensable and a basic requirement for assessing pathological findings, that

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can be achieved by well-founded knowledge of human anatomy and thorough training in systematic diagnostic readings of CT scans. Also typical findings of trauma pathologies have to be studied. To improve time effectiveness a standardized procedure including selection of adequate CT reconstructions planes for fast assessment of injuries is necessary. Therefore, for our tutorial a consultant radiologist defined a selection of adequate CT reconstructions planes of a head/neck and a thorax/abdomen scan to read first. Key questions for first reading at the CT console and short learning texts are based on textbooks [3] and personal experience.

Also movies with just normal findings (a whole body scan of a healthy person without any injuries) were included. The user interface design was based on year-long experience gained during CT courses at our department. There, as an additional offer, participants use an audiovisual CT case collection for training purposes.

This case collection is influenced by principles of multimedia learning theories like "Cognitive Theory of Multimedia Learning" (Richard Mayer [4]) and "Cognitive Load Theory" (originally developed by John Sweller and Paul Chandler, see also introduction and current state-of-the-art [5,6]). Cognitive load theory is concerned with the manner in which cognitive resources are focused and used during learning processes and problem solving. Many learning and problem-solving procedures encouraged by instructional formats result in students who engage in cognitive activities far remote from the ostensible goals of the task. The cognitive load generated by these irrelevant activities can impede skill acquisition.

"Cognitive Load Theory" originally refers to the human working memory and divides the whole cognitive load of a multimedia application into three parts:

- "Intrinsic cognitive load" (every exercise has its natural complexity the learner has to deal with, an individual solution must be found).
- "Extraneous cognitive load" (additional irrelevant cognitive load caused, for example, by complicated, not user-friendly interface design).
- "Germane cognitive load" (consolidating knowledge by using multiple case studies and explorative components, thus achieving an effective workload).

Concerning the polytrauma tutorial the goals are to reduce the natural complexity of a polytrauma CT scan (intrinsic cognitive load) by segmentation and structured demonstration of schematic findings. Whole body CT scans are divided into sectional CT scans with standardized reconstruction planes, which serve the pathological findings of the case. Further "irrelevant cognitive load" (inefficient learning caused by extraneous cognitive load) is reduced by a convenient user interface as well as by a guiding tutor movie. The tutor movie mirrors the situation at a workstation where the experienced radiologist demonstrates his findings and how to handle large image stacks to the residents.

There are short checklists developed by a radiology consultant with frequent and typical pathological polytrauma findings that can quickly be accessed and also short information texts below each case movie to help the resident with the main diagnosis.

The texts derive from a short textbook about polytrauma diagnostics [3].

It is also important to strengthen relevant "cognitive load" (consolidating knowledge) by application of multiple case studies and explorative components. In our case collection every main diagnosis is marked but can only be seen by the resident when he clicks on the pathology. The resident has to find the pathology himself but is supported by the tutor movie where every (main) diagnosis is explained and demonstrated by an experienced radiologist.

Images of original polytrauma CT scans with additional text information and case studies create a learning environment in which the user can get close to a real life reading situation. Case studies as well as the normal body CT scan (healthy person) are embedded as interactive scrollable original CT scans which can be explored and directed by the user, supporting an explorative learning style (Fig. 1). For support and to transfer the expert knowledge of the radiology consultant a commented movie (tutor movie) with the expert actually pointing at the pathologies and explaining his findings (visual and audible comment) was added to every case (Fig. 2). Those tutor movies represent/picture the part of trauma scan reading process where the consultant radiologist simultaneously explains his findings and demonstrates them to the resident while actually reading the case (a guided case analysis). Complementary information was added in the form of short texts and key questions for fast analysis of injuries.

2.2. Software for creating interactive CT movies and tutor movies

Based on our experience with former online tutorial creation we choose 2 different formats for movie delivery, played in web-pages by the Apple QuickTime plug-in (www.apple.com/quicktime). (1) QuickTime VR for scrollable movies of CT stacks: Original anonymized DICOM series were exported from a workstation as series of JPEG images and then converted into multi-row QuickTime VR movies (played in web pages by the QuickTime plug-in) similar to the method presented by Trelease [7]. Initially, the program VR Worx 2.6 (www.vrtoolbox.com) was used. We now use the program "Object2VR" (gardengnomesoftware.com) due to a simpler workflow and more output formats (FLASH and HTML5, see Section 4). These images are aligned by the programme to a multi-row QuickTime VR movie. The QuickTime plug-in allows scrolling of the images in a web page similar to a DICOM workstation. A how-to-do tutorial is available on our website (www.knowledgecontainer.de). (2) Tutor movies: the tutor movies including the expert interacting with a "scroll movie" are created by use of a screen recording program (Camtasia for Mac 1.2, www.techsmith.de). Camtasia allows to simultaneously record the expert's demonstration of the pathology with a mouse cursor and his spoken commentary on the trauma case. For the Camtasia audiotrack a USB headset microphone (Sennheiser M 145 USB) and a studio microphone (Shure SM 7B, www.shure.com) via FireWire audio interface (Apogee Duet, www.apogeedigital.com) is used. The tutor movies are cut with Camtasia and then exported as H.264/MPEG-4 AVC (as MPEG-4/Part 10, ISO/IEC 14496-10 standard), which is a standard movie format compatible with web browsers on PCs as well as mobile devices (tablets, some mobile phones). Installing the free Apple QuickTime plug-in (www.apple.com/quicktime) the user is able to access the movies in a web browser.

In order to create an interactive case collection and implement the didactic concept, the web-based open source learning platform "ILIAS" (www.ilias.de) is used.

Ilias is a software environment for creating, organizing, editing and sharing content consisting of text and multimedia documents. The author can manage and edit a learning environment without special programming skills. It is possible to give students personalized access to teaching materials such as lectures, schoolbooks and schedules (like we and other departments do in our Medical School).

2.3. Testing the user-interface

During the development of the polytrauma CT tutorial 5 radiology residents (1–6 years of practice) tested the user interface following the "thinking-aloud" method which was originally developed for evaluating new software regarding user-friendliness [8]. After a short introduction to the concept of the polytrauma tutorial, the residents were observed for 30–60 min and a screen movie was