European Journal of Radiology 82 (2013) 1366–1371

Contents lists available at SciVerse ScienceDirect

European Journal of Radiology

journal homepage: www.elsevier.com/locate/ejrad

Integration of interactive three-dimensional image post-processing software into undergraduate radiology education effectively improves diagnostic skills and visual-spatial ability

Fabian Rengier[a,*,1], Matthias F. Häfner[b,1], Roland Unterhinninghofen[c], Ralph Nawrotzki[d], Joachim Kirsch[d], Hans-Ulrich Kauczor[a], Frederik L. Giesel[d,e]

[a] University Hospital Heidelberg, Department of Diagnostic and Interventional Radiology, Im Neuenheimer Feld 110, 69120 Heidelberg, Germany
[b] University Hospital Heidelberg, Department of Radiation Oncology, Im Neuenheimer Feld 400, 69120 Heidelberg, Germany
[c] Karlsruhe Institute of Technology (KIT), Institute for Anthropomatics, Department of Informatics, Adenauerring 2, 76131 Karlsruhe, Germany
[d] University of Heidelberg, Institute of Anatomy and Cell Biology, Im Neuenheimer Feld 307, 69120 Heidelberg, Germany
[e] University Hospital Heidelberg, Department of Nuclear Medicine, Im Neuenheimer Feld 400, 69120 Heidelberg, Germany

ARTICLE INFO

Article history:
Received 10 November 2012
Accepted 18 January 2013

Keywords:
Undergraduate medical education
Radiology
Computer-assisted image processing
Teaching
Visual-spatial ability

ABSTRACT

Purpose: Integrating interactive three-dimensional post-processing software into undergraduate radiology teaching might be a promising approach to synergistically improve both visual-spatial ability and radiological skills, thereby reducing students' deficiencies in image interpretation. The purpose of this study was to test our hypothesis that a hands-on radiology course for medical students using interactive three-dimensional image post-processing software improves radiological knowledge, diagnostic skills and visual-spatial ability.

Materials and methods: A hands-on radiology course was developed using interactive three-dimensional image post-processing software. The course consisted of seven seminars held on a weekly basis. The 25 participating fourth- and fifth-year medical students learnt to systematically analyse cross-sectional imaging data and correlated the two-dimensional images with three-dimensional reconstructions. They were instructed by experienced radiologists and collegiate tutors. The improvement in radiological knowledge, diagnostic skills and visual-spatial ability was assessed immediately before and after the course by multiple-choice tests comprising 64 questions each. Wilcoxon signed rank test for paired samples was applied.

Results: The total number of correctly answered questions improved from 36.9 ± 4.8 to 49.5 ± 5.4 ($p < 0.001$) which corresponded to a mean improvement of 12.6 (95% confidence interval 9.9–15.3) or 19.8%. Radiological knowledge improved by 36.0% ($p < 0.001$), diagnostic skills for cross-sectional imaging by 38.7% ($p < 0.001$), diagnostic skills for other imaging modalities – which were not included in the course – by 14.0% ($p = 0.001$), and visual-spatial ability by 11.3% ($p < 0.001$).

Conclusion: The integration of interactive three-dimensional image post-processing software into undergraduate radiology education effectively improves radiological reasoning, diagnostic skills and visual-spatial ability, and thereby even diagnostic skills for imaging modalities not included in the course.

1. Introduction

The demand for radiological imaging and image post-processing has continuously grown in many medical disciplines due to rapid improvements, new developments and increased availability throughout the last decade [1–4]. No other specialty regularly interacts with such a wide range of different medical disciplines bringing physicians face to face with the evaluation of radiological images in every day clinical practice. Consequently, every medical student should receive profound teaching in radiology and image evaluation regardless of the intended specialty concerning future career plans. However, radiological contents still seem prevalently underrepresented in medical education programs in the United States of America as well as in Europe [5–7] leading to insufficient radiological diagnostic skills of final-year medical students [7,8].

* Corresponding author. Tel.: +49 6221 56 6410; fax: +49 6221 56 5730.
E-mail address: fabian.rengier@web.de (F. Rengier).

[1] These authors equally contributed to this manuscript and share the first authorship.

0720-048X/$ – see front matter © 2013 Elsevier Ireland Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.ejrad.2013.01.010

One of the key factors for correctly interpreting radiological images and successfully learning anatomy is visual-spatial ability [9–12]. Visual-spatial ability can be improved by special training, but also by teaching anatomy through three-dimensional (3D), tangible anatomical models [13]. It has been suggested that interacting with 3D computer visualisations as well as with 3D CT and MRI data sets also may lead to better spatial ability [14]. Therefore, integrating interactive 3D post-processing software into undergraduate radiology teaching might be a promising approach to synergistically improve both spatial ability and radiological skills thereby reducing students' deficiencies in image interpretation. To our knowledge, such an approach has only been proposed [14], but not yet been investigated regarding its effectiveness.

The purpose of this study was to test our hypothesis that a hands-on radiology course for medical students using interactive 3D image post-processing software improves radiological knowledge, diagnostic skills and visual-spatial ability.

2. Materials and methods

2.1. Hardware and software

The course was conducted in the computer lab of our institution. In short, each working place, suited for two students, consisted of one computer equipped with 3D image post-processing software (AnatomyMap Basic Edition, VitalRecon GmbH, Frankfurt, Germany) and one additional computer screen connected to a demonstration computer. Standard Digital Imaging and Communications in Medicine (DICOM) images could be transferred from the picture archiving and communication system (PACS) of our institution to all computers after anonymisation. The most important functionalities of the software were: (1) interactive viewing of source data; (2) multiplanar reformation with axial, sagittal and coronal views as well as arbitrarily adjusted double oblique views (Fig. 1); (3) 3D volume rendering with visualisation of e.g. bones or contrast-enhanced vessels (Fig. 2); (4) advanced 3D reconstructions like curved multiplanar reformations and maximum intensity projections (Fig. 2).

2.2. Course design

The course was conducted on a voluntary basis after students had completed the compulsory radiology course comprising lectures and seminars. It was developed for fourth- and fifth-year medical students, i.e. students in antepenultimate and penultimate years, to improve their radiological diagnostic skills. The course comprised seven seminars, each two hours long and held on a weekly basis, covering the following topics: musculoskeletal system, thorax, abdomen and pelvis, head and neck, central nervous system, and nuclear medicine. At the beginning students were introduced to the software. Each seminar followed a case-based approach dealing with two cases of common and important pathologies. Each case was introduced with a short clinical vignette. The students were shown how to systematically analyse cross-sectional imaging for the respective topic, and then had to systematically analyse the radiological images, generate a diagnostic report and formulate differential diagnoses. The provided imaging modalities were CT, MRI and PET-CT. Two experienced radiologists, different for each seminar, instructed the students. Five trained collegiate tutors were present for support throughout the whole course. The participants used source images and multiplanar reformations (Fig. 1), and correlated them with 3D reconstructions when helpful for diagnosis or understanding (Fig. 2). At the end of each case pathological findings were discussed with the radiologists using the demonstration computer.

2.3. Study design and effectiveness assessment

The effectiveness of the course was assessed by multiple-choice tests immediately before and after the course (pre- and post-test). Each test consisted of 64 questions. A total of 128 different single best answer questions was created by two course leaders and reviewed by an independent experienced radiologist. To test for improvements in different aspects, the questions were classified into three categories: A, radiological knowledge (24 questions); B, radiological skills (72 questions); C, visual-spatial ability (32 questions).

Category A questions (radiological knowledge) comprised technical aspects including basics of CT and MRI, contrast media and image post-processing as well as clinical aspects including radiological reasoning. All category A questions were text-based. Category B questions (radiological skills) were further subclassified into three subcategories: B1, diagnoses on CT, MRI and PET-CT images; B2, diagnoses on radiographs, ultrasound images and digital subtraction angiographies; B3, identification of anatomical structures on CT, MRI and PET-CT images. All category B questions contained one radiological image each. Category C questions (visual-spatial ability) used 3D objects from the so-called cube perspective test or "Schlauchfiguren" test [15]. This test is commonly applied to test the spatial ability of applicants for medical studies in German speaking countries and has been used in previous studies [16–18]. One question consists of two photographs of a winding tube inside a transparent cube from two different perspectives (Fig. 3). The first perspective is the view from the front. The task then was to determine whether the second perspective is the view from the back, the bottom, the top, the right or the left.

The questions for each category and sub-category were randomly divided into the two tests comprising 64 questions each. Thus, the two tests were composed of two different question sets. For each question, students could either tick one of the three provided answers or opt to tick "I don't know". A correct answer was rated with one point plus, a wrong answer with half a point minus. The "I don't know" option was rated with zero. The questions were displayed on an individual computer screen in front of every student. Students were given 35 s to answer each question before automatically moving on to the next question.

2.4. Participants and evaluation

27 students regularly attended the course. The seven seminars were conducted once for all students at intervals of one week. Two students did not attend the pre-test for personal reasons and thereby were excluded from this study. Anonymous evaluation among the participants was performed at the end of the course. A total of 9 statements were rated on a five-point Likert scale: 1 = full agreement, 2 = partial agreement, 3 = indifference, 4 = partial disagreement, 5 = full disagreement. Overall agreement was defined as the sum of full and partial agreement.

2.5. Statistical analysis

Data is given as mean ± SD. Wilcoxon signed rank test for paired samples [19] was applied to the pre- and post-test scores to assess the effectiveness of the course. For evaluation items, full agreement and overall agreement are given as a percentage of all evaluation scores. The median was calculated for all evaluation items.

A p-value of ≤ 0.05 was considered to represent statistical significance. All analyses were performed with PASW Statistics Version 17.0 (SPSS Inc., Chicago, IL, USA).