Evaluation of an Interactive Science Publishing Tool:

Toward Enabling Three-Dimensional Analysis of Medical Images

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Rationale and Objectives: Higher resolution medical imaging platforms are rapidly emerging, but there is a challenge in applying these tools in a clinically meaningful way. The purpose of the current study was to evaluate a novel three-dimensional (3D) software imaging environment, known as interactive science publishing (ISP), in appraising 3D computed tomography images and to compare this approach with traditional planar (2D) imaging in a series of lung cancer cases.

Materials and Methods: Twenty-four physician volunteers at different levels of training across multiple specialties were recruited to evaluate eight lung cancer–related clinical vignettes. The volunteers were asked to compare the performance of traditional 2D versus the ISP 3D imaging in assessing different visualization environments for diagnostic and measurement processes and to further evaluate the ISP tool in terms of general satisfaction, usability, and probable applicability.

Results: Volunteers were satisfied with both imaging methods; however, the 3D environment had significantly higher ratings. Measurement performance was comparable using both traditional 2D and 3D image evaluation. Physicians not trained in 2D measurement approaches versus those with such training demonstrated better performance with ISP and preferred working in the ISP environment.

Conclusions: Recent postgraduates with only modest self-administered training performed equally well on 3D and 2D cases. This suggests that the 3D environment has no reduction in accuracy over the conventional 2D approach, while providing the advantage of a digital environment for cross-disciplinary interaction for shared problem solving. Exploration of more effective, efficient, self-directed training could potentially result in further improvement in image evaluation proficiency and potentially decrease training costs.

Key Words: Self-directed learning; 3D imaging; lung cancer diagnosis; health care education.

Over the past decade, medical imaging has undergone exponential improvements; however, the ability to use the detailed, textured outputs of these tools requires an understanding of how to manipulate digital imaging data to ensure correct interpretation in guiding clinical management (1–3). This area of image processing is thought to be the province of radiologists, but ongoing trends suggest a greater inclusion of many medical disciplines in applying high-resolution imaging in clinical management. Yet the foundational knowledge of proper application of quantitative imaging tools in medical curriculum has not yet emerged as a major focus.

Although the technological evolution of medical imaging is moving rapidly, the integration of this new and vast source of digital data into meaningful clinical application is slow. This integration mismatch relates to a number of issues, including pressure to accelerate standard workflow and the inertial influence of shrinking reimbursement. However, the greatest current barrier to implementing image processing approaches may be that clinicians have not been educated about the potential of quantitative imaging. Thus, a knowledge gap exists in how best to apply robust imaging techniques to change the practice of medicine.

The interactive science publishing (ISP) tool was released in 2008 as a companion application that is launched by PDF reader software, making it free and easily accessible (4). ISP was designed with functionality for a wide range of imaging file formats to allow for interactive rendering, reformatting, annotation, three-dimensional (3D) measurement, animation, storage, and capture/print of volumetric and image data. The program was formally introduced in the *Optics Express* Journal in October 2008, with seven articles containing interactive data sets for 3D viewing

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along with links to obtain the ISP tool (4). Given the potential of ISP to more fully convey imaging concepts and facilitate research, it is important to assess the system to see how the potential user community perceives the value of this resource.

We designed and conducted a survey of clinician attitudes at Rush University to determine how they perceive the value of conventional versus new quantitative imaging tools. Lung cancer imaging case studies were used in the survey because imaging in lung cancer is such a dynamic area of interest (1). The survey questions assessed the level of performance in determining diagnoses and volumetric measurements of lung masses using digital imaging and communications in medicine (DICOM) files of computed tomography (CT) images presented in a conventional 2D PDF format versus a 3D environment. To enable the comparison between 2D and 3D performance, we used the ISP imaging environment, which includes both 2D and 3D visualization tools and allows clinicians to digitally manipulate and quantitatively assess medical images. The main goals of the survey were to 1) understand the prior experience of the clinicians; 2) determine clinician satisfaction with each of the data and image presentation methods; and 3) gage the general receptiveness of clinicians to use and master a representative panel of image processing tools for lung cancer clinical management.

Essentially, we describe a visualization environment designed to support the use of image analysis tools to assist in the quantitative assessment of 3D medical images. We then evaluated this environment to determine user assessment of whether these tools to better understand physicians' acceptance of these tools in allowing greater integration of image analysis into clinical management.

MATERIALS AND METHODS

We enrolled 24 uncompensated volunteers to participate in a pilot survey comparing ISP software with the more traditional 2D approach. The study was exempt from formal institutional review board process as no identifiable patient information was recorded, and all participants were physicians at Rush University. The study consisted of a survey with two primary components. The first component was a qualitative or quantitative investigation, with volunteers using the 2D PDF or 2D/3D ISP software to make judgments about eight clinical vignettes. The second component captured the participants' perception about their experience using the ISP software. Training tools were prepared as electronic instructions for the two imaging environments (2D PDF or 2D/3D ISP file structure). One research coordinator administered all evaluations.

Quantitative Evaluation Vignettes

The vignette evaluation included eight clinical cases on the basis of incidentally discovered lung nodules observed using spiral CT in patients at high risk of developing lung cancer. The eight vignettes were divided into two sets of four, with the first set focused on diagnosis (benign or malignant), and the second set focused on overall measurements of change in the size of nodules over time. Each set (four vignettes) was completed with two cases using traditional 2D PDF format and the remainder using the new interactive 2D/3D ISP software. The vignette evaluation was presented in a multiple-choice format. Each question had one correct response of five possible choices. The correct response was determined before the initiation of the survey process by two of the authors (J.L.M. and A.P.R.). Results of the analysis, which were generated by coding each correct response as 2 and each incorrect response as 1, were displayed as bar graphs representing the average performance in each condition.

Process Evaluation

Volunteers were also asked to evaluate the ISP tool by rating a series of statements concerning general satisfaction, usability, and probable application of the tool. All answers were provided using a Likert scale with "strongly disagree" rated as 1 and "strongly agree" rated as 5.

Statistical Analysis

The core analysis undertaken was an analysis of variance to determine if the imaging method (ISP vs. traditional) had a significant effect on the participants' performance in either diagnosis or measurement of lesions. A secondary mean difference test (*t* test) was undertaken to investigate the participants' relative satisfaction with the two imaging approaches.

As a result of the findings, post hoc descriptive analyses were undertaken. These analyses used a factor analysis of preference data to abstract the core characteristics of the participants' preference for either traditional or ISP imaging approaches (two factors were retained). These data were used in a cluster analysis to identify the types of participants by preference for imaging method. The characteristics of these clusters were then described to help elucidate the characteristics of physicians as they relate to imaging preference.

RESULTS

The 24 participants represented a wide variety of specialties, including internal medicine (59%), general surgery (13%), anesthesia (9%), and the rest all at 4% including cardiology, neurology, and cardiothoracic surgery (Fig 1). The participants ranged from residents to senior faculty/practitioners. Most participants were at an early stage in their career.

Quantitative Evaluation of Clinical Vignettes

Four vignettes involved analysis of diagnostic features, and the remaining four involved measurement of volume change in response to drug therapy. The primary finding was that, in