Cancer Research

LesionTracker: Extensible Open-Source Zero-Footprint Web Viewer for Cancer Imaging Research and Clinical Trials

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Abstract

Oncology clinical trials have become increasingly dependent upon image-based surrogate endpoints for determining patient eligibility and treatment efficacy. As therapeutics have evolved and multiplied in number, the tumor metrics criteria used to characterize therapeutic response have become progressively more varied and complex. The growing intricacies of image-based response evaluation, together with rising expectations for rapid and consistent results reporting, make it difficult for site radiologists to adequately address local and multicenter imaging demands. These challenges demonstrate the need for advanced cancer imaging informatics tools that can help ensure protocol-compliant image evaluation while simultaneously promoting reviewer efficiency. LesionTracker is a quantitative imaging package optimized for oncology clinical trial workflows. The goal of the project is to create an open source zero-footprint viewer for image analysis that is designed to be extensible as well as capable of being integrated into third-party systems for advanced imaging tools and clinical trials informatics platforms. *Cancer Res; 77(21); e119–22. ©2017 AACR.*

Introduction

Oncology clinical trials are widely conducted in both the academic and private sector and are commonly multicenter due to increased statistical power gained from large patient accrual at more than one site. In the context of both large multicenter trials with blinded central review and early-phase trials at a single site, criteria-specific imaging assessment is required at the site level to determine whether a patient meets enrollment criteria at baseline and continued eligibility at subsequent follow-up assessments. However, local clinical imaging infrastructures face several challenges that are difficult to address to meet these requirements (1). Tumor metrics are often needed at the time of office visit, which can place additional demands on radiologists and clinical workflow when rapid turnaround of complex assessments using varied response criteria is needed. Often times, radiology and cancer center staff struggle to balance clinical trial requirements on top of their daily clinical responsibilities and have few available resources to offset the continuously evolving needs of clinical trials. Many sites still use paper forms or extract measurements from clinical imaging reports, whereas some oncology investigators make their own measurements, raising concerns about objectivity, accuracy, and longitudinal consistency. The imaging metrics obtained in these scenarios are generally not verifiable for audits and do not easily connect back to annotated imaging records.

Moreover, studies have shown that there is significant discordance between oncologist expectations and radiology practice pattern regarding the types of imaging findings that should be included in a radiology report (2–3). For example, one study found that only 26% of radiology reports for follow-up studies in patients with solid tumors included sufficient information to determine response according to RECIST guidelines (4–5). These deficiencies may impact data access, integrity, and validation, consequently altering patient care and trial outcomes. Because of the growing workflow challenges and performance demands of clinical trials, advanced medical imaging informatics are critically needed at cancer centers and other medical centers conducting clinical trials to ensure reliable, reproducible, and protocol-compliant longitudinal imaging assessments (6).

The Tumor Imaging Metrics Core (TIMC; http://www.tumormetrics.org) was established in 2004 as a shared resource to address the needs of the Dana-Farber/Harvard Cancer Center (Boston, MA) by providing centralized imaging review services for oncology clinical trials. To promote communication between oncology and radiology teams, and enhance review and reporting processes, timeliness, and quality, the TIMC developed and implemented an informatics infrastructure, branded Precision Imaging Metrics (PIM; https://www.precisionmetrics.org). PIM provides cancer centers with a clinical trial informatics platform tailored to the specific workflow needs of site reviews and currently has been adopted by seven NCI-designated Cancer Centers

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around the country, with several other sites considering implementing this system. Architecturally, the PIM solution consists of two interconnected software applications: a web-based workflow informatics management system and an integrated desktop image analysis platform. Although the web-based system is robust and easily accessible, the desktop application must be installed on every computer where image reviews take place and must be part of the hospital network to gain direct access to the hospital's imaging archive, adding IT support requirements at each site performing image assessments. These networking requirements also restrict image reviews to predetermined workstations, reducing the efficiency for radiologists and limiting flexibility with regards to location or working hours.

Materials and Methods

LesionTracker (http://lesiontracker.ohif.org) is a quantitative imaging package that is optimized for oncology clinical trial workflows. The application is available under an open-source, commercially permissive software license (MIT) and designed with a plugin architecture that enables it to be integrated with third-party informatics applications, such as PIM. The project is funded by an NCI U24 grant for Advanced Development of Informatics Technology through the Informatics Technology for Cancer Research (ITCR) program. The goal of the LesionTracker project is to create a vendor-neutral, extensible, zero-footprint HTML5 image viewer for web browser–based display and analysis of imaging studies, optimized for oncology clinical trial workflows, and developed in accordance with HIPAA and 21 CFR Part 11 guidelines (7–8).

LesionTracker is built using Meteor (https://www.meteor.com/), a full-stack JavaScript framework for creating web applications. It is designed as a set of modular packages that can be reused in other applications that may not have an oncology focus. The core imaging components are developed with the Cornerstone (https://github.com/chafey/cornerstone) family of libraries, which provide essential functions, such as image rendering, tool support, and DICOM retrieval and interpretation. This design also allows the application to be easily extended by simply adding new packages.

The shift to a web-based system for image assessments rather than a workstation-based installed application will improve workflow efficiency, enhance accessibility, and promote collaborative image review for the radiologists at cooperating cancer centers. To achieve these design goals, the viewer and all of its functionality will be delivered to client machines exclusively through the web browser. Software products and services are increasingly being delivered in this manner due to the compelling benefits and the evolution of a more complete and mature set of client-side development tools and standards such as HTML5.

Results

The LesionTracker application supports a complete oncology imaging metrics workflow. To streamline implementation, LesionTracker was tested against various open-source DICOM servers, such as dcm4che (http://dcm4che.org/) and the lightweight Orthanc DICOM server (http://www.orthanc-server.com/). By default, measurement data is stored in MongoDB database (https://www.mongodb.com/), which comes bundled with Meteor. Developers can configure alternate data exchange mechanisms to support other databases.

LesionTracker is developed in the open on GitHub and welcomes bug reports and code improvements via pull requests (https://github.com/OHIF/Viewers). Development progress is tracked using an open JIRA instance (https://ohiforg.atlassian.net), with associated documentation managed through Confluence (Atlassian).

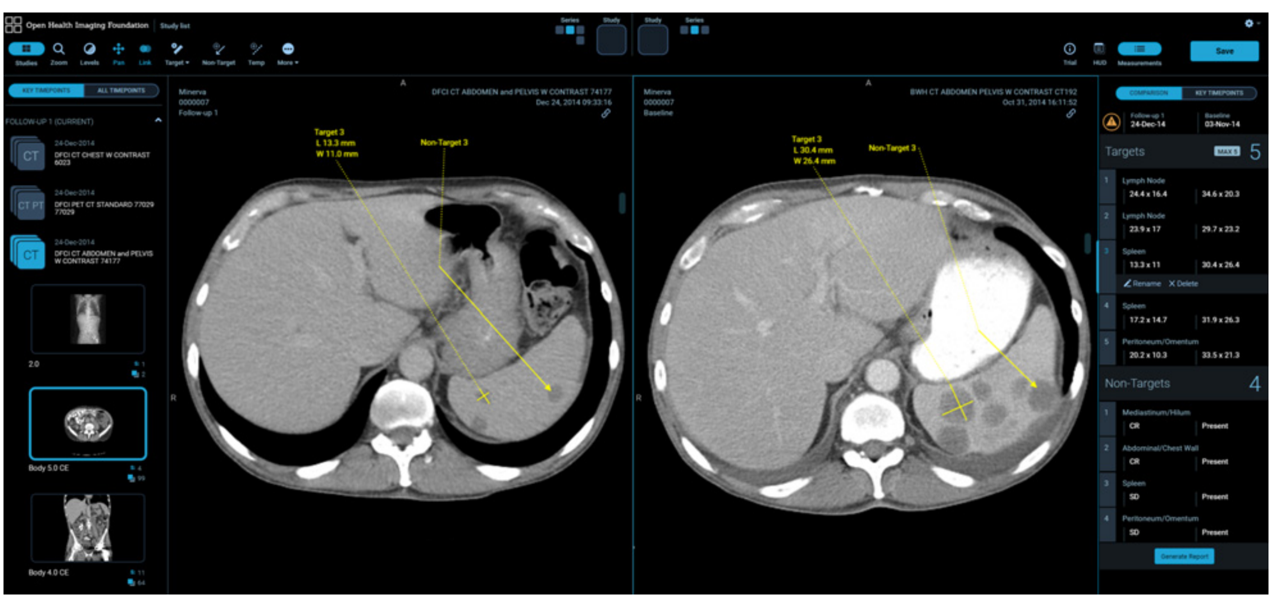

Figure 1.
The screenshot is of the web-based LesionTracker image analysis application showing side-by-side comparison of baseline and follow-up images. The study select list on the left of the screenshot is organized by time point and allows image reviewers to easily switch between studies and series. The interactive measurement lesion table on the right automatically updates in real time when measurements are changed and provides feedback regarding response criteria conformance checks. Target and nontarget lesion measurement and annotation tools are included among other standard image display tools on the top bar.

A screen capture of the LesionTracker user interface is shown in Fig. 1, and a Supplementary video and additional figures summarizing the LesionTracker workflow are provided as Supplementary Data.

LesionTracker features include:

- The ability to display and manipulate DICOM images with standard tools, including window/level, zoom, pan, and display of DICOM annotations.
- A study worklist to provide easy access to available imaging studies, searchable and sortable by patient and imaging study identifiers.
- The ability to define time points, including one or more imaging studies, and label them as baseline or follow-up.
- A user interface (UI) to label lesions based on standardized naming conventions across patients, trials, and sites.
- A bidirectional measurement tool (longest diameter and longest orthogonal diameter) to ensure that target lesions meet size criteria and are measured according to the trial's protocol.
- A nontarget annotation tool with predefined response options to provide consistent documentation of disease tracked qualitatively.
- An on-screen interactive measurement table for easy comparison of target, nontarget, and new lesions across time points. The table updates automatically as measurements are created and/or modified and also can be used to display the related lesions by clicking on table rows, which is especially useful during image review.
- Synchronized scrolling of images from multiple time points and lesion localization tools to improve review efficiencies during time point comparison.
- Built-in response criteria conformance checks (logic and UI to draw attention to protocol violations). This is provided to promote protocol compliance and is designed with the flexibility to allow response criteria to be modified or new ones to be added. RECIST 1.1 is included by default.
- Audit logs that capture all data changes and can be searched (in the UI) by type of change, who made it, and when.
- Reports showing lesion response as measured longitudinally with screen captures of the annotated images.
- The ability to upload and download imaging studies so they can be transferred to or from the user's hard disk.
- UI configuration of DICOM server, supporting both DICOM DIMSE and DICOM Web standard protocols for exchange of images and metadata.
- UI mechanisms to simplify and accelerate switching between imaging studies.
- Responsive UI that fits well on monitors of any size to ensure consistent experience across a wide range of machines and operating systems.
- Support for all major modern web browsers.

Discussion

LesionTracker fills a need for an open-source, extensible, web-based oncology clinical trials image assessment and tracking platform. The roadmap for LesionTracker includes the development of additional functionality, such as DICOM Structured Reporting, segmentation, multimodality display and analysis, study deidentification, user management, customizable user preference setting, and multi-monitor support. These enhancements will make the application more flexible and robust, creating an advanced image analysis framework and tools that could be used across sites to support and standardize image review for multicenter trials. Our team is also working with several other ITCR-funded projects to integrate and embed our web-viewer technology with other tools and applications, creating a common oncology research ecosystem, including preclinical image analysis, body composition metrics, and radiomics.

Although LesionTracker shares many functional objectives with the quantitative imaging platform, ePad (9), there are notable differences between the two applications. LesionTracker is designed to optimize image review speed and user experience for radiologists, providing standardized clinical trial reads, whereas ePad is a flexible research platform that currently provides more freedom in terms of measurement labeling and postprocessing options. Although both applications are run in web browsers, ePad is built using Java and compiled to JavaScript using Google Web Toolkit, whereas LesionTracker is written in native JavaScript.

Oncology clinical trials are increasing in their complexity, but most sites lack adequate image analysis solutions to satisfy the expectations of oncologists, radiologists, and trial sponsors. LesionTracker has the potential to minimize inconsistencies throughout the image review and reporting process and promote efficiency and collaboration across clinical teams.

Disclosure of Potential Conflicts of Interest

R. Lewis is a consultant/advisory board member for Radical Imaging LLC. Chris Hafey is the CTO at NucleusHealth, has received speakers bureau honoraria from SIIM, and has ownership interest (including patents) in NucleusHealth. G.J. Harris is the president at Open Health Imaging Foundation, has ownership interest (including patents) in Precision Imaging Metrics, LLC, and IQ Medical Imaging, LLC, and is a consultant/advisory board member for Fovia, Inc. No potential conflicts of interest were disclosed by the other authors.

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Administrative, technical, or material support (i.e., reporting or organizing data, constructing databases): T. Urban, E. Ziegler, A.D. Van den Abbeele, G.J. Harris
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