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Original Report

Prospective assessment of an atlas-based intervention combined with real-time software feedback in contouring lymph node levels and organs-at-risk in the head and neck: Quantitative assessment of conformance to expert delineation

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Abstract

Purpose: A number of studies have previously assessed the role of teaching interventions to improve organ-at-risk (OAR) delineation. We present a preliminary study demonstrating the benefit of a combined atlas and real time software-based feedback intervention to aid in contouring of OARs in the head and neck.

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Conflicts of interest: Dr Fuller has served as a consultant to GE Medical Systems.

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Methods and Materials: The study consisted of a baseline evaluation, a real-time feedback intervention, atlas presentation, and a follow-up evaluation. At baseline evaluation, 8 resident observers contoured 26 OARs on a computed tomography scan without intervention or aid. They then received feedback comparing their contours both statistically and graphically to a set of atlas-based expert contours. Additionally, they received access to an atlas to contour these structures. The resident observers were then asked to contour the same 26 OARs on a separate computed tomography scan with atlas access. In addition, 6 experts (5 radiation oncologists specializing in the head and neck, and 1 neuroradiologist) contoured the 26 OARs on both scans. A simultaneous truth and performance level estimation (STAPLE) composite of the expert contours was used as a gold-standard set for analysis of OAR contouring.

Results: Of the 8 resident observers who initially participated in the study, 7 completed both phases of the study. Dice similarity coefficients were calculated for each user-drawn structure relative to the expert STAPLE composite for each structure. Mean dice similarity coefficients across all structures increased between phase 1 and phase 2 for each resident observer, demonstrating a statistically significant improvement in overall OAR-contouring ability ($P < .01$). Additionally, intervention improved contouring in 16/26 delineated organs-at-risk across resident observers at a statistically significant level ($P \leq .05$) including all otic structures and suprahyoid lymph node levels of the head and neck.

Conclusions: Our data suggest that a combined atlas and real-time feedback-based educational intervention detectably improves contouring of OARs in the head and neck.

Introduction

In order to plan for intensity modulated radiation therapy, manual segmentation (contouring) of regions of interest (ROIs), either tumors or organs-at-risk (OARs), is performed by physician observers. As these ROIs serve as the input functions for all subsequent planning steps, accurate segmentation, leading to the proper voxel assignment of both tumors and organs-at-risk, is crucial to optimize therapeutic ratio. However, data show there is a great degree of interobserver variability in manual ROI segmentation.[1] Both under- and over-contouring of tumors and OARs can have deleterious consequences, leading to local failure and normal tissue sequelae, respectively. The importance of accurate manual segmentation and the high demonstrated interobserver operator dependence of this process indicate a specific and substantial impediment to execution of multi-institutional clinical trials involving conformal radiation therapy.[2] Despite the requirement for accurate ROI delineation for radiation therapy treatment planning, instruction in target definition is often based on ad hoc instruction, with limited educational resources provided to many residents.[3] Previous cooperative group studies involving practicing physicians suggest that reference to a simple anatomic atlas can substantially standardize and improve conformality of target volumes to an expert reference.[4] Likewise, Bekelman et al[5] and Li et al[6] have demonstrated educational interventions may improve trainee target definition.

Consequently, we sought to investigate the potential gain of a standardized atlas-based, software feedback-assisted intervention to improve head and neck OAR/ROI segmentation, having developed an open source on-line segmentation analysis software.[7,8] The specific aims of the current study were the following:

(1) Estimate potential improvement in OAR/ROI manual segmentation conformance with a multi-expert composite ROI attributable to a combined atlas/visual software-feedback educational intervention.
(2) Validate utility of an open-source software solution for execution of said educational study.
(3) Hypothesize generation and sample size estimation for future prospective series.

Methods and materials

Approval and compliance

Institutional review board approval as an exempt, 45 CFR 46.101(b)(4)-compliant study was obtained, allowing collection of anonymized DICOM files. Clinical data sets were anonymized and stripped of identifiers, and fictionalized case histories were constructed for all cases.

Study design

This single-arm pilot, prospective feasibility analysis was designed to determine the requisite sample and effect size required for a planned larger atlas-based software-feedback assisted effort. The study was designed as a test-retest sequence, with comparison to a "gold-standard" multi-expert composite ROI (Fig 1).