Target Contour Testing/Instructional Computer Software (TaCTICS):

A Novel Training and Quantitative Evaluation Software Platform for Radiotherapy Target Delineation


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Introduction

- Modern radiotherapy affords exceptional conformality of dose delivery, such that steep dose gradients may be implemented between target and non-target tissue.

- However, dose delivery is limited, among others, by 2 major factors:
  - Target volume delineation error (input error)
  - Spatial alignment of target volumes with plan isocenter (set-up error)
The Impact of Gross Tumor Volume (GTV) and Clinical Target Volume (CTV) Definition on the Total Accuracy in Radiotherapy

Theoretical Aspects and Practical Experiences

Elisabeth Weiss, Clemens F. Hess

From the magnitude of recorded uncertainties it appears that for many tumor locations, variabilities in target volume delineation might have a greater impact on the accuracy of dose delivery than errors in treatment setup and organ motion [10, 19, 43].
Target delineation process

• Time intensive (1-2 hours per case for experienced users)
• User dependent/Unstandardized
• Low reproducibility
Anatomic sites

- Different sites, different issues
- Imaging modality differentials (GTV)
- Subclinical dissemination differences (CTV)
- Motion (not considered here-PTV)
**Dosimetric impact on rectal dose due to variations in prostate clinical target volume (CTV) delineation**

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Table 2
Percentage rectal dose difference for a single patient that was delineated twice by ten physicians. Rectal maximum and mean doses were normalized to the 3mm PTV.

<table>
<thead>
<tr>
<th>Physician</th>
<th>5mm</th>
<th>10mm</th>
<th>5mm</th>
<th>10mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Max Dose</td>
<td>Mean Dose</td>
<td>Max Dose</td>
<td>Mean Dose</td>
</tr>
<tr>
<td>1</td>
<td>3.2</td>
<td>9.2</td>
<td>0.5</td>
<td>24.9</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
<td>8.6</td>
<td>2.8</td>
<td>24.2</td>
</tr>
<tr>
<td>3*</td>
<td>0.7</td>
<td>7.5</td>
<td>4.6</td>
<td>26.0</td>
</tr>
<tr>
<td>4</td>
<td>3.5</td>
<td>8.8</td>
<td>6.4</td>
<td>26.5</td>
</tr>
<tr>
<td>5</td>
<td>1.0</td>
<td>8.4</td>
<td>3.4</td>
<td>25.4</td>
</tr>
<tr>
<td>6*</td>
<td>1.5</td>
<td>6.5</td>
<td>4.5</td>
<td>24.0</td>
</tr>
<tr>
<td>7</td>
<td>0.5</td>
<td>9.3</td>
<td>0.9</td>
<td>32.4</td>
</tr>
<tr>
<td>8</td>
<td>1.0</td>
<td>13.9</td>
<td>3.2</td>
<td>39.7</td>
</tr>
<tr>
<td>9</td>
<td>0.3</td>
<td>8.5</td>
<td>2.1</td>
<td>36.2</td>
</tr>
<tr>
<td>10</td>
<td>2.4</td>
<td>8.9</td>
<td>0.1</td>
<td>27.6</td>
</tr>
<tr>
<td>Mean ±SD</td>
<td>1.5±1.2</td>
<td><strong>9.0±1.9</strong></td>
<td>2.8±2.0</td>
<td><strong>28.7±5.5</strong></td>
</tr>
</tbody>
</table>

* = Expert
Pre- and Postinduction Chemotherapy Target Volume Delineation in Head and Neck Cancer: Preliminary Results from an Expert Panel

D.I. Rosenthal¹, C.D. Fuller², K.K. Ang¹, D.M. Brizel³, A. Eisbruch¹, Q.T. Le⁴, N.Y. Lee⁵, B. O’Sullivan⁶, J. Duppen⁷ and C.R.N. Rasch⁸

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Figure 4: Boxplot distribution of inter-observer common/encircling ratio (e.g. the volume covered by both users divided by total contour volume contoured by either user), by structure.
#1 question

• "So, how did I do?"
Purpose

• The purpose of this effort is to develop a software application which will allow users to delineate target structure regions of interest (ROIs) in DICOM-RT compatible formats, followed by automated comparison and scoring of user-derived with ROIs defined by reference sets derived from expert users.
Methods

The steps in creating TaCTICS consisted of:

1. Collecting a set of more than 400 structure contours from a variety of expert and nonexpert users for at least four anatomical sites.
2. Identifying a set of meaningful quantitative metrics that can be used to compare three dimensional volumes.
3. Creating a web-site and software tools that enable user to upload a DICOM-RT file containing the structures for comparison with expert derived structures when queried.
Dataset A

- Dataset A consists of DICOM-RT ROIs derived from a double-blind, randomized hypothesis generating pilot study designed to test the impact of instructional modification of user-generated contours for a standardized T3N0M0 rectal cancer case twice.
  - 15 radiation oncologist observers (experts and non-experts),
  - 94 distinct ROI structures available for analysis.

**Clinical Investigation**

PROSPECTIVE RANDOMIZED DOUBLE-BLIND PILOT STUDY OF SITE-SPECIFIC CONSENSUS ATLAS IMPLEMENTATION FOR RECTAL CANCER TARGET VOLUME DELINEATION IN THE COOPERATIVE GROUP SETTING
Dataset B

• Dataset B consists of a series of DICOM-RT files derived from a study of human-computer user interface device (UID) modification on target volume delineation efficiency.
• Four anatomical sites
  – prostate, brain, lung, and head and neck case presentation
• A total of 21 observers
• >400 collected ROI TV structures.
Metrics I

- Volumetric
  - Volume difference
    - where $V_a$ is the volume of the user-derived contour and $V_g$ is the volume of the “gold standard” (or the expert-derived contour)
    - then:
      \[ VD = \frac{V_a - V_g}{V_g} \times 100 \]

- Dice/Jaccard
  - where $A$ is the user contour and $G$ is the gold standard

  \[ D = \frac{2|A \cap G|}{|A| + |G|} \times 100 \]
  \[ J = \frac{|A \cap G|}{|A \cup G|} \times 100 \]
Metrics II

- Hausdorff distance (H)
  - The H between A and G, $h(A,G)$ is the maximum distance from any point in A to a point in G and is defined as:

  $$h(A, G) = \max_{a \in A} d(a, G)$$

  and

  $$d(a, G) = \min_{G \subseteq G} \| a - g \|$$

  then

  $$H(A, G) = \max(h(A, G), h(G, A))$$

\[\begin{align*}
\delta(C,D) &= \max(a,b)
\end{align*}\]
Warfield’s Simultaneous Truth and Performance Level Estimation (STAPLE)

- STAPLE is an expectation-maximization algorithm
- Computes a probabilistic estimate of true segmentation given a set of manual contours.
- In addition to the expert derived contours we have created an additional set of “ground truth” contours using this algorithm.
- Currently in beta version (not online)
Design

System
- Collection of CT studies and contours from multiple sites for expert users
  - Convert RT structures to masks
  - Create zipped studies without contours for download
- Calculate overlap measures
- Update Statistics of Overlap Measures

User
- Register/get password
  - Download DICOM CT slices
  - Contour using usual TP software
  - Upload RSTRUCT file containing structures and choose expert/STAPLE
- Receive Report
The website was built using a Ruby on Rails framework.
The ruby-dicom gem was used for parsing the DICOM files.
A PostgreSQL database was used to store the user information,
information about the studies (including location of the CT slices),
ROI information extracted from the DICOM header (including ROI
 names, volumes and slice information), and the metrics derived
from all users.
The main processing of the structures and calculation of the
metrics was performed in C++ using the ITK toolkit.
These procedures were wrapped in Ruby and called from the
website to generate the report.
http://skynet.ohsu.edu/tactics/

Target Contour Testing/Instructional Computer Software (TaCTICS)

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Submission Site
Comparisons
Publications

Enter your email address:
Your e-mail:
Find Uploaded DICOM-RT Files
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Target Contour Testing/Instructional Computer Software (TaCTICS)

Please register here:

First name:

Last (Family) name:

Your organization:

Your primary area of research:

How did you learn about TaCTICS?

Please select one of the following.

Your website (optional):

Your email address:

Register
Download files to TPS

Target Contour Testing/Instructional Computer Software (TaCTICS)

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Download DICOM images
SWOG
Prostate
Lung
Head and Neck
Delineate
Target Contour Testing/Instructional Computer Software (TaCTICS)

Submit file

Please submit your RTSTRUCT file here:

Your e-mail:

`test@test.com`

What anatomical site are you uploading data for?

`SWOG`

File to Upload:

- Choose File
- no file selected
- Upload
Report

Target Contour Testing/Instructional Computer Software (TaCTICS)
Conclusion

- We have demonstrated that a web-based interactive analysis/scoring software can be implemented.
- We hope that by constructing a GUI that allows users to analyze target volume ROIs and gain meaningful "scores" regarding their performance over time, exposure to training software might become a viable tool for longitudinal examination and improvement of trainee performance.
Future directions

• Completion of STAPLE analytic module (in beta)
• Prospective longitudinal educational study current accruing
• Axial slice report with ROI overlap
• Composite volume capability for consensus development
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