Current Trends and Future Direction of Automation in Radiation Oncology

Benjamin “BJ” Sintay, Ph.D., Cone Health
Greensboro, North Carolina
Conflicts of interest

• Varian Medical Systems – travel support and honoraria for speaking & advisory board participation
Part 1
Current state of automation in radiation oncology

Hard to cover in 15 minutes
This year at AAPM annual meeting...
- 410 abstracts mention “auto”
- 56 abstracts mention “automation”
- Many focus on treatment planning and segmentation
Automation @ 2018 AAPM Meeting

• “AAPM Medical Physics Student Meeting: The Role of Automation in Clinics of the Future” (Student Meeting)
• “Automation in Radiation Therapy: Past, Present, and Future” (Edu Course)
• “Automation and Standardization of Planning, Plan Evaluation and System Testing Through Advanced Programming in Treatment Planning System” (Edu Course)
• “Intelligent Automation for Treatment Planning Workflows” (PinS) x2
• “Automation in Radiotherapy - Fasten Your Seatbelt!” (SAM Edu Course)
• “Hiding the Complexity in Treatment Planning/Automation” (SAM Sci Symposium)
• “Joint AAPM-ESTRO Symposium: Automated Treatment Planning in Clinical Practice” (SAM Edu Course)
Automation @ Annual AAPM Meeting

2016 – Washington, DC
• “Contouring and Auto-Planning” (SNAP Oral)

2017 – Denver, CO
• “Automated Planning and Image Guidance” (ePoster Discussion)
• “How to Select and Evaluate a PET Auto-segmentation Tool - Insights from AAPM TG211” (SAM Edu Course)
• “Auto-segmentation for Thoracic Radiation Treatment Planning: A Grand Challenge” (SAM Sci Symposium)
SEAAPM 2017 Scientific Meeting

“The new era of automation in medical physics”

- “Active-feedback checklists with automation” by Gregg Tracton (UNC) [workflow]
- “FMEA of manual & automated TPS commissioning” Amy Wexler (U of Missouri) [commissioning]
- “Automated calculation of multifocal SRS dose indices using ... scripting API” by Michael Trager (Duke) [plan analysis]
- “Automation of plan finalization tasks” by Lane Hayes (Cone Health) [workflow / documentation / dose calcs]
- “Scripting for the clinic” Edward Schreibmann (Emory) [workflow / planning]
- “Automation in a community setting” by David Wiant (Cone Health) [workflow / documentation]
- “Dosimetry second-checks for permanent prostate seed implants with [scripting]” by Todd Jenkins (Vidant) [dose calcs]
- “A comparison of filmless QA technologies for variable-aperture collimation in robotic radiosurgery” by Jacob Gersh [QA]
Vision 20/20: Automation and advanced computing in clinical radiation oncology

Kevin L. Moore
Department of Radiation Medicine and Applied Sciences, University of California San Diego, La Jolla, California 92035

George C. Kagalakis
Department of Medical Physics, School of Medicine, University of Patras, Rion GR 26504, Greece

Todd R. McNutt
Department of Radiation Oncology and Molecular Radiation Science, School of Medicine, Johns Hopkins University, Baltimore, Maryland 21231

Vitali Moiseenko
Department of Radiation Medicine and Applied Sciences, University of California San Diego, La Jolla, California 92035

Sasa Matic
Department of Radiation Oncology, Washington University in St. Louis, St. Louis, Missouri 63110

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This Vision 20/20 paper considers what computational advances are likely to be implemented in clinical radiation oncology in the coming years and how the adoption of these changes might alter the practice of radiotherapy. Four main areas of likely advancement are explored: cloud computing, aggregate data analyses, parallel computation, and automation. As these developments promise both new opportunities and new risks to clinicians and patients alike, the potential benefits are weighed against the hazards associated with each advance, with special considerations regarding patient safety under new computational platforms and methodologies. While the concerns of patient safety are legitimate, the authors contend that progress toward next-generation clinical informatics systems will bring about extremely valuable developments in quality improvement initiatives, clinical efficiency, outcomes analytics, data sharing, and adaptive radiotherapy. © 2014 American Association of Physicists in Medicine, [http://dx.doi.org/10.1118/1.4842515] (Key words: clinical radiation oncology, cloud computing, parallel computation, aggregate data analysis, machine learning, automation, quality improvement, data security)

1. BACKGROUND AND INTRODUCTION

While it would be impossible to envision the practice of radiation oncology in 2013 without computers, it is noteworthy that current computing infrastructures in radiation therapy are largely based around 1980s “single workstation” models. In these models individual software applications such as treatment planning systems (TPSs) and treatment management systems (TMSs) are typically connected via data transfers over a network, importing and exporting data from modules such as imaging devices, treatment machines, and ancillary software systems. Consolidated data flow from simulation to imaging of a TPS and TMS, these advances are largely accomplished by taking existing single workstation applications and transplanting them onto a server-based platform. This evolution is understandable given the needs of commercial development and the regulatory oversight of medical software. However, from the perspective of clinical users, it must be asked whether current computing infrastructures are ideal for the task of modern clinical radiotherapy.

The fundamental question that guides this Vision 2020 paper is: If radiotherapy computing systems were designed from scratch in 2013, what would they look like? We seek to identify trends in advanced computing that will shape clini-
Areas of automation

1. Workflow / care coordination
2. Contouring
3. Treatment planning / knowledge based
4. QA / commissioning
5. Chart review / metrics
6. Imaging and treatment delivery
7. Machine performance
8. Data analysis / radiomics
Automation focus

• Areas of repetition
• Tasks that are tedious
• Tasks that focus effort below “top of license”
• Tasks that involve transcription
• Increasing value

\[ VALUE = \text{Quality} + \text{EXPERIENCE} - \text{COST} \]
Vendor Solutions - Scripting and APIs

- Aria/Eclipse/Velocity – C# (ESAPI), Web Services, MS-SQL, Visual Scripting
- MOSAIQ/Monaco – Triggered Scripts, Patient Access API, SQL
- MIMVista – Java
- RayStation – Python (IronPython)
- Hospital EHRs: Epic, Cerner, etc.
- Radformation – Workflow automation tools
APIs – 21st Century Cures Act

• “... that the entity has in place data sharing programs or capabilities based on common data elements through such mechanisms as application programming interfaces without the requirement for vendor-specific interfaces;

• [...] publish application programming interfaces and associated documentation, with respect to health information within such records, for search and indexing, semantic harmonization and vocabulary translation, and user interface applications; and

• [...] demonstrate to the satisfaction of the Secretary that health information from such records are able to be exchanged, accessed, and used through the use of application programming interfaces without special effort, as authorized under applicable law.”
Hospital/clinic solutions
University of Michigan: SafetyNet

- “Streamlining and automating QA in radiotherapy”
- "A team of medical physicists and software engineers worked together to identify opportunities to streamline and automate QA."

Hadley et al.: SafetyNet: streamlining and automating QA. JACMP, 17(1), 2016
University of Michigan: SafetyNet

Fig. 3. Diagram of the Mobius Control Agent. The nine steps to perform the secondary calculation happen automatically without user interaction.

Hadley et al.: SafetyNet: streamlining and automating QA. JACMP, 17(1), 2016
Cone Health: Post-plan Automation

Plan approval by MD

0-click server

Automatic Actions

**Dose Calculation: Monitor Unit Check**

1. **G0**
   - Type: Static, Energy: 15X No Wedge, No Bolus.
   - Jaw Positions: X1: -6.8 X2: 6.8 Y1: -9.1 Y2: 8.4
   - Dose Point Location: (0.20, 0.30, 0.10) [User Coords]
   - Avg. Effective Depth: 11.23cm Avg. Equivalent Square: 13.94cm
   - Plan Dose: 84.46cGy Calc Dose: 84.46cGy Difference: -0.02%
   - Plan MU: 90.74 Calc MU: 90.72 Difference: 0.02MU
   - Calculation meets 5% or 2 MU criteria: **PASS ✓**

2. **G180**
   - Type: Static, Energy: 15X Wedges: EDW100OUT No Bolus.
   - Jaw Positions: X1: -6.8 X2: 6.8 Y1: -9.1 Y2: 8.4
   - Dose Point Location: (0.20, 0.30, 0.10) [User Coords]
   - Avg. Effective Depth: 12.32cm Avg. Equivalent Square: 13.94cm
   - Plan Dose: 85.01cGy Calc Dose: 86.47cGy Difference: 0.18%
   - Plan MU: 100.33 Calc MU: 100.51 Difference: 0.18MU
   - Calculation meets 5% or 2 MU criteria: **PASS ✓**

3. **G90**
   - Type: Static, Energy: 15X No Wedge, No Bolus.
   - Jaw Positions: X1: -4.3 X2: 7.5 Y1: -9.1 Y2: 8.4

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Total Calculations: 4

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Cone Health: Post-plan Automation
MD Anderson: Automatic Planning

- Lower rank = better plan quality
- Blinded review by 5 MDs

Quan E et al. A Comprehensive Comparison of IMRT and VMAT Plan Quality for Prostate Cancer Treatment. JROBP 83(4), 2012.
Part 2

Future of automation?
Wearable technology
Cloud computing – organizations
Smartphone
Internet of things
Siri & Alexa
Biometrics / eVisits

Images: IdentiSys Inc.
How could automation change roles?
Dosimetrist – Trainers

Simulation / Diagnostic Images
Dosimetrist – Pre-post automation

Pre-planners
Automated Prep

Post-planners
Evaluators
Dosimetrist – Daily / adaptive
Dosimetrists
Dosimetrists
Physicians

Clinical data

Input aggregation and automated analysis

Previous provider-specific decisions

AI / DL Recommendation

Human approval/correction

Shared clinical knowledge

Intervention initiation
Stage T1c N0 M0 adenocarcinoma of the prostate with a Gleason score of 4+4, and a PSA of 5.6

History of present illness
History of adenocarcinoma of the prostate originally diagnosed in November 2015, when he was found to have a Gleason score 3+3 in one core. This was involving the left apex and only 9% of the core was involved. His PSA at that time was 5.7, his prostatic volume was 34 mL. He was followed in active surveillance and underwent repeat biopsy on 01/10/2017 revealing 8 out of 12 cores involved with adenocarcinoma 1 with 3+3 Gleason score, 3 with 3+4 Gleason score, and 3 with 4+3, in one core revealing 4+4. His PSA in November 2017 was 5.86, and prior to this in May 2017 with 7.95. He has undergone metastatic workup with CT scan of the abdomen and pelvis and bone scan on 01/05/2018 which did not reveal any evidence of metastatic disease.

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Anonymous, Adam
Male
DOB: 1/1/1960

CT 2/2/2018

VMAT 91%
IMRT 7%
3D 2%

Cert. req.
Cert. req.

Potential toxicities
Rectum, bladder

Generate Consent

PTV Coverage
Bladder sparing
Rectal sparing
Femoral head sparing

Approve
Physicists

Clinical data

Input aggregation and automated analysis

Irregularity?

Yes

Human analysis

No

Next step

Global knowledge
Rapid acceptance testing of modern linac using on-board MV and kV imaging systems

Sridhar Yaddanapudi\textsuperscript{1,2} and Ein Cai\textsuperscript{3}\textsuperscript{,4}

\textsuperscript{1}Department of Radiation Oncology, Washington University School of Medicine, 4921 Parkview Place, St. Louis, MO 63110, USA

\textsuperscript{2}Taylor Harry
Department of Radiation Medicine and Applied Sciences, University of California San Diego, Moores Cancer Center, 3835 Health Sciences Dr., La Jolla, CA 92037, USA

\textsuperscript{3}Steven Dolly, Baozhou Sun, and Hua Li
Department of Radiation Oncology, Washington University School of Medicine, 4921 Parkview Place, St. Louis, MO 63110, USA

\textsuperscript{4}Keith Slenson and Camille Noel
Varian Medical Systems, 3100 Hanover Way, Palo Alto, CA 94304, USA

\textsuperscript{5}Lakshmi Santanam
Department of Radiation Oncology, Washington University School of Medicine, 4921 Parkview Place, St. Louis, MO 63110, USA

\textsuperscript{6}Todd Pawlicki
Department of Radiation Medicine and Applied Sciences, University of California San Diego, Moores Cancer Center, 3835 Health Sciences Dr., La Jolla, CA 92037, USA

\textsuperscript{7}Sasa Mutilic and S. Murty Goddu
Department of Radiation Oncology, Washington University School of Medicine, 4921 Parkview Place, St. Louis, MO 63110, USA

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Purpose: The purpose of this study was to develop a novel process for using on-board MV and kV Electronic Portal Imaging Devices (EPIDs) to perform linac acceptance testing (AT) for two reasons: (a) to standardize the assessment of new equipment performance, and (b) to reduce the time to clinical use while reducing physicist workload.

Methods and materials: In this study, Varian TrueBeam linacs equipped with amorphous silicon-based EPID (aSi:Ge) were used. The conventional set of AT tests and tolerances were used as a baseline guide. A novel methodology was developed or adopted from published literature to perform as many tests as possible using the MV and kV EPIDs. The developer mode on Varian TrueBeam linacs was used to automate the process. In the EPID-based approach, most of mechanical tests were conducted by acquiring images through a custom phantom and software tools were developed for quantitative analysis to extract different performance parameters. The embedded steel-spheres in a custom phantom were used for testing portal image resolution.
Fig. 2. Overall results for the FMEA analysis shown side by side for the ATP\textsubscript{conv} and ATP\textsubscript{EPID}. The average failure pathways and average RPN were calculated for each individual ATP\textsubscript{EPID}. The average failure pathways and average RPN were calculated for each individual ATP test then averaged over all tests. ATP test then averaged over all tests.
Physicists – Chart checks

TG-275 - “...there is likely to be an increasing reliance on automation to perform a variety of functions related to the physics plan/chart review.”

Ford et al. TG-275, 2018
Conclusions: Pretreatment physics plan review is a key safety measure and can detect a high percentage of errors. However, the majority of errors that potentially could have been detected were not detected in this study, indicating the need to improve the pretreatment physics plan review performance. Suggestions for improvement include the automation of specific physics checks performed during the pretreatment physics plan review and the standardization of the review process.
Radiation therapy timeline

Common Radiation Therapy Timeline

Consult → Schedule & Wait → Sim → Target → Plan → QA → Tx

5 – 20 days typical

Future Radiation Therapy Timeline?

Consult → Same or next day?
Outcomes Correlate to Time to Treatment Initiation (TTI)

• Study Design
  • 3.7M patients from National Cancer Database (2004-2013)
  • # days between diagnosis 1st tx for newly diagnosed w/early-stage solid-tumor cancers

• Findings
  • Median time between diag & tx (“time to treatment initiation” or TTI) has increased from 21 days in 2004 to 29 days in 2013
  • Longer delays between diag & initial tx associated with worsened overall survival for stages I and II breast, lung, renal and pancreas cancers, and stage II colorectal cancers, with increased risk of mortality of 1.2 percent to 3.2 percent per week of delay, adjusting for comorbidities and other variables
  • Prolonged TTI >6w associated w/substantially worsened survival. For example, 5y survival for stage I NSCLC for TTI <6w was 56% vs. 43% for TTI >6w; and for stage I pancreas cancer was 38% vs. 29%, respectively.

https://newsroom.clevelandclinic.org/2017/06/05/cleveland-clinic-research-shows-time-initiating-cancer-therapy-increasing-associated-worsened-survival/
"Man has to partner with machine and data science to make informed decisions. It's absolutely inevitable."

Richard Zane, MD
Chief Innovation Officer
University of Colorado Health System

https://www.astro.org/17vmpreview/
Elon Musk says he agrees that there are too many robots on the Model 3 production line

Mark Matousek  Apr. 13, 2018, 11:10 AM
Figure 5. Estimated Radiotherapy Availability Worldwide, 2013

*Countries with 100% of patients able to access radiotherapy may also include countries where radiotherapy supply is greater than demand, although disparities in access may still exist within these countries.

Thank you!