Current Trends and Future Direction of Automation in Radiation Oncology

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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 mintues

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]

WORKFLOW
QA
PLAN ANALYSIS
COMMISSIONING
PLANNING
DOCUMENTATION
DOSE CALCS

Vision 20/20: Automation and advanced computing in clinical radiation oncology

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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 analyses, data sharing, and adaptive radiotherapy. [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

ing 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 20/20 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 clin-

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 =

$$\frac{\text{Quality} + \text{EXPERIENCE}}{\$\downarrow \text{ COST } \$\uparrow}$$

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."

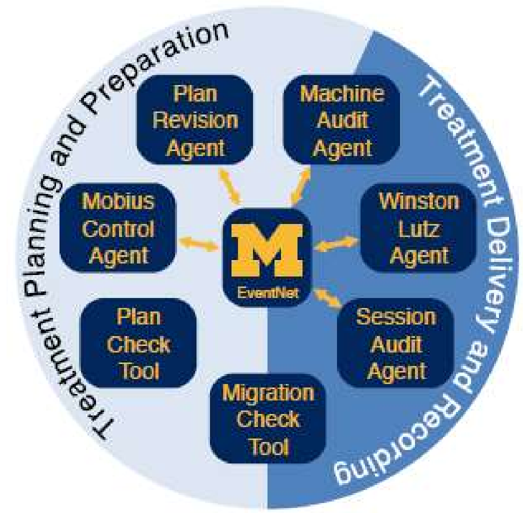


FIG. 1. Overview of SafetyNet system. EventNet is central to the operation of the software agents, which receive events to activate QA and send messages notifying of results.

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

University of Michigan: SafetyNet

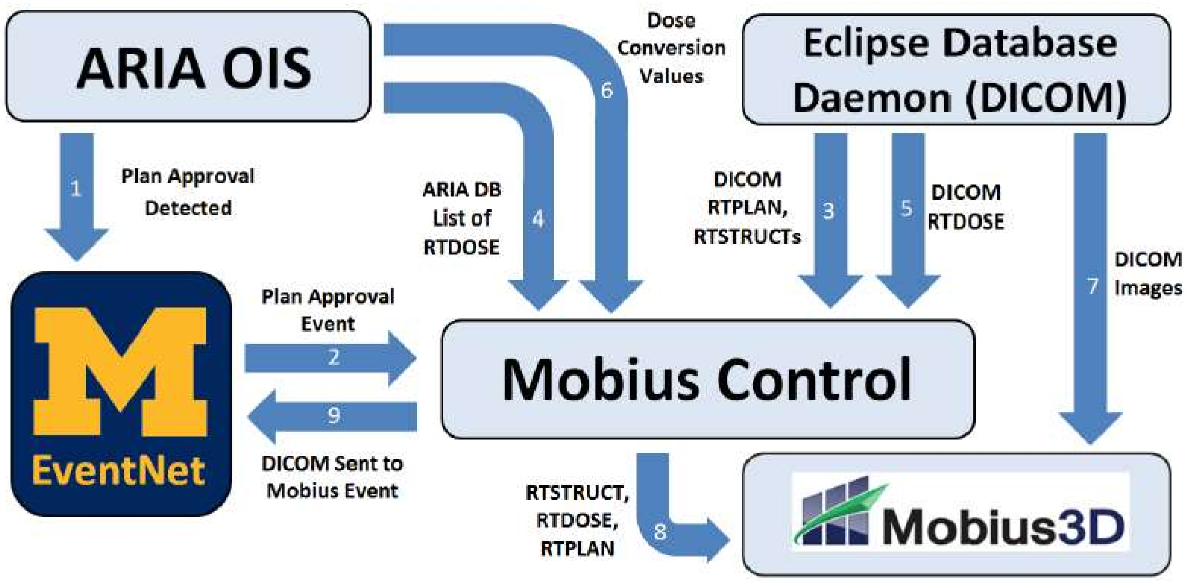
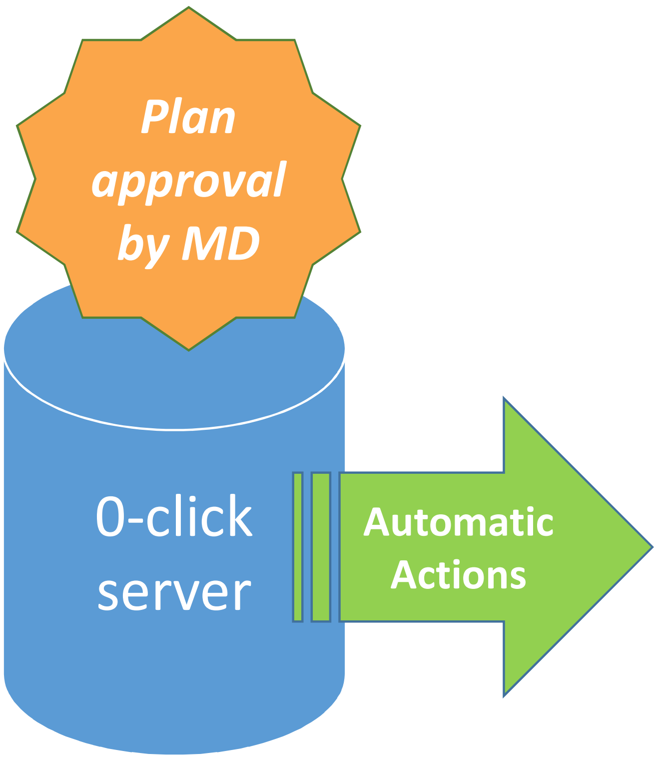
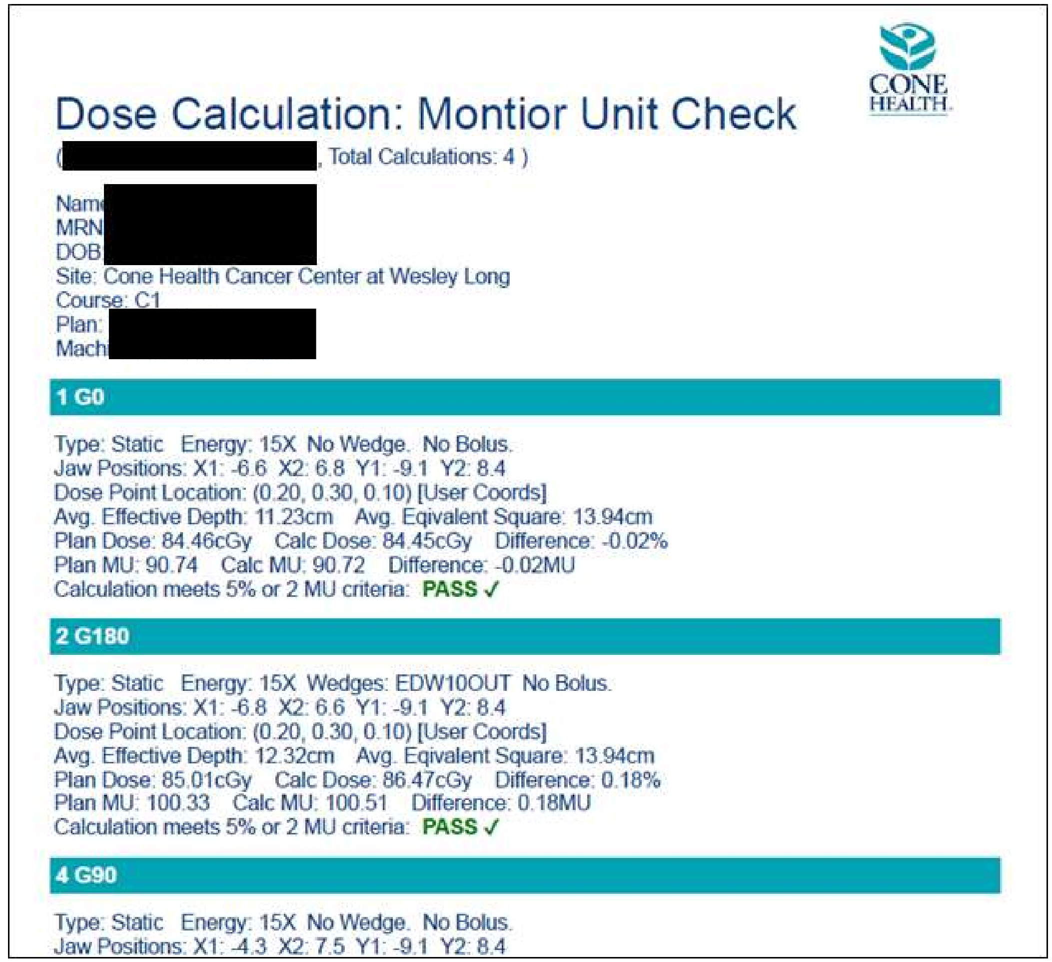


FIG. 3. Diagram of the Mobius Control Agent. The nine steps to perform the secondary calculation happen automatically without user interaction.

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

Cone Health: Post-plan Automation





CONE HEALTH

Dose Calculation: Montior Unit Check

([redacted], Total Calculations: 4)

Nam[redacted]
MRN
DOB
Site: Cone Health Cancer Center at Wesley Long
Course: C1
Plan: [redacted]
Mach[redacted]

1 G0

Type: Static Energy: 15X No Wedge. No Bolus.
Jaw Positions: X1: -6.6 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. Eqivalent Square: 13.94cm
Plan Dose: 84.46cGy Calc Dose: 84.45cGy Difference: -0.02%
Plan MU: 90.74 Calc MU: 90.72 Difference: -0.02MU
Calculation meets 5% or 2 MU criteria: **PASS ✓**

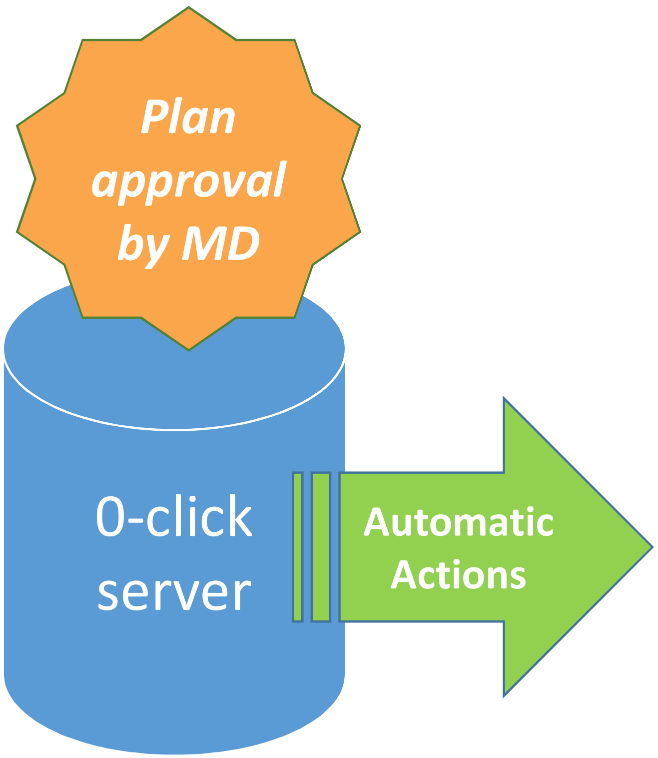
2 G180

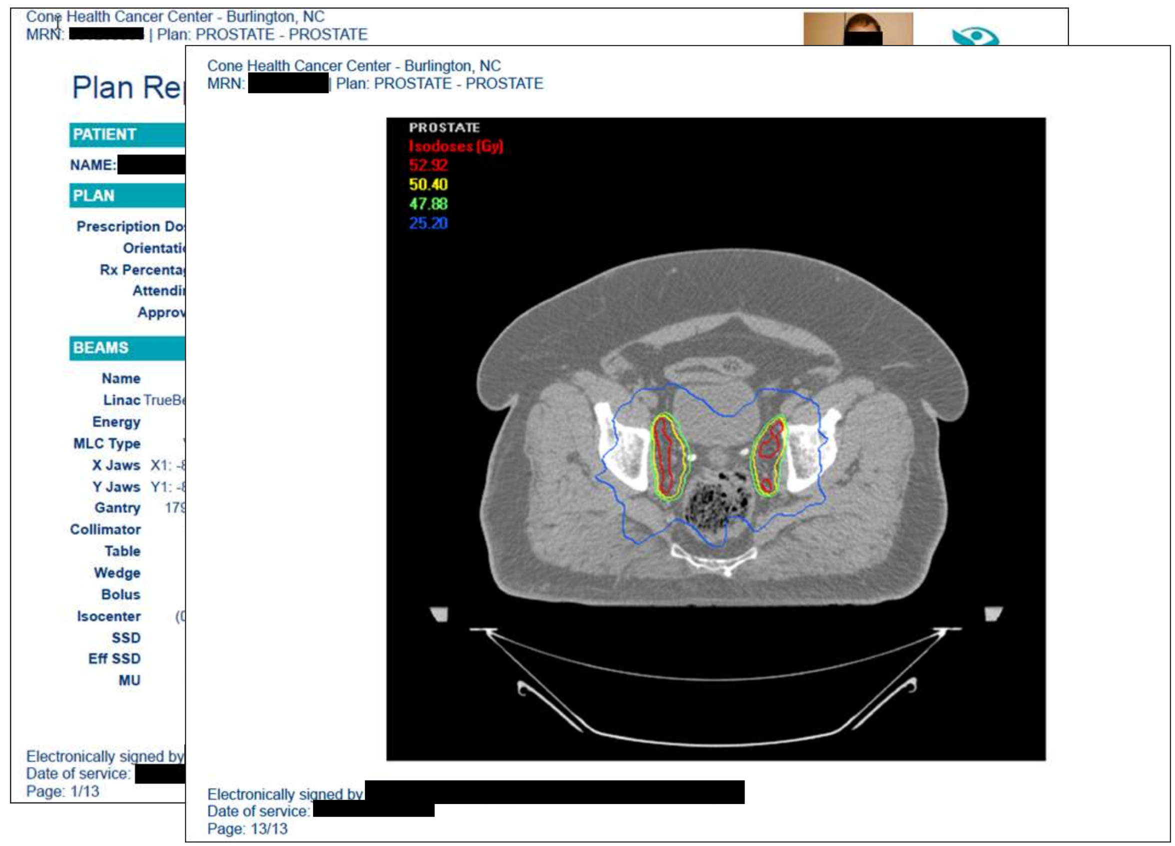
Type: Static Energy: 15X Wedges: EDW10OUT No Bolus.
Jaw Positions: X1: -6.8 X2: 6.6 Y1: -9.1 Y2: 8.4
Dose Point Location: (0.20, 0.30, 0.10) [User Coords]
Avg. Effective Depth: 12.32cm Avg. Eqivalent Square: 13.94cm
Plan Dose: 85.01cGy Calc Dose: 86.47cGy Difference: 0.18%
Plan MU: 100.33 Calc MU: 100.51 Difference: 0.18MU
Calculation meets 5% or 2 MU criteria: **PASS ✓**

4 G90

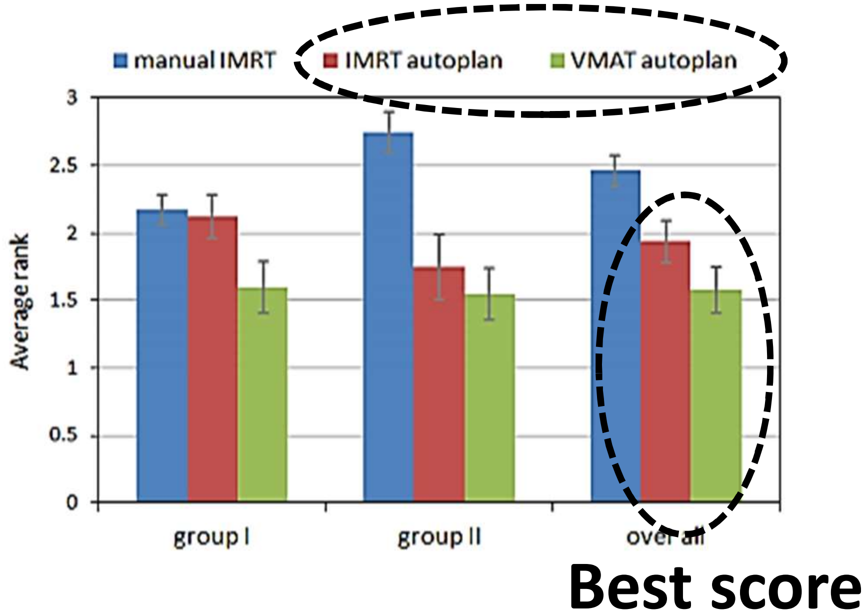
Type: Static Energy: 15X No Wedge. No Bolus.
Jaw Positions: X1: -4.3 X2: 7.5 Y1: -9.1 Y2: 8.4

Cone Health: Post-plan Automation





MD Anderson: Automatic Planning



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

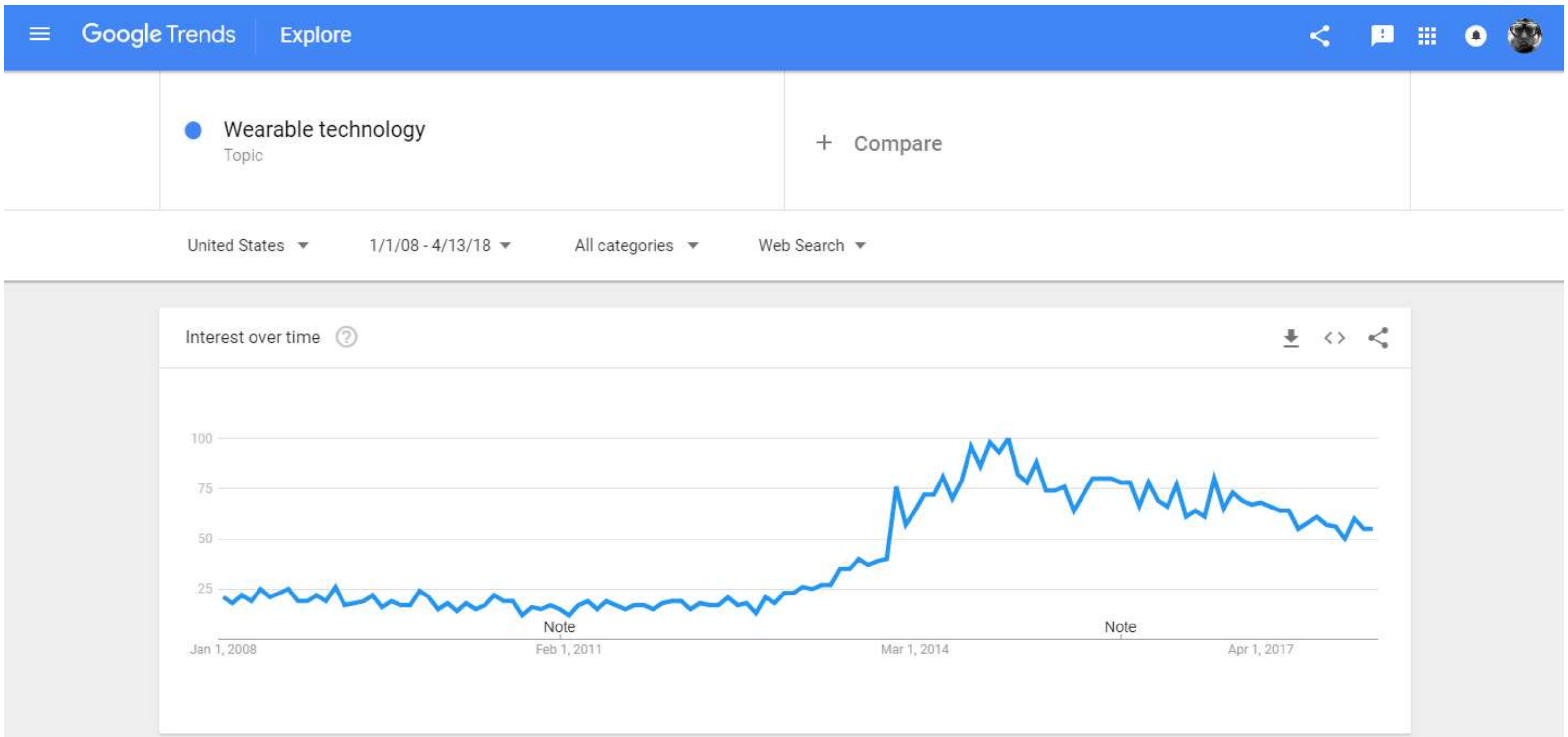
- Group 1: direct competition
- Group 2: replan of previously accepted clinical plan

Quan E et al. Automated Volumetric Modulated Arc Therapy Treatment Planning for Stage III Lung Cancer: How Does It Compare With Intensity-Modulated Radiotherapy? IJROBP 84(1), 2012.
Quan E et al. A Comprehensive Comparison of IMRT and VMAT Plan Quality for Prostate Cancer Treatment. IJROBP 83(4), 2012.
Zhang X et al. A methodology for automatic intensity-modulated radiation treatment planning for lung cancer. Phys Med. Bio. 56(13), 2011.

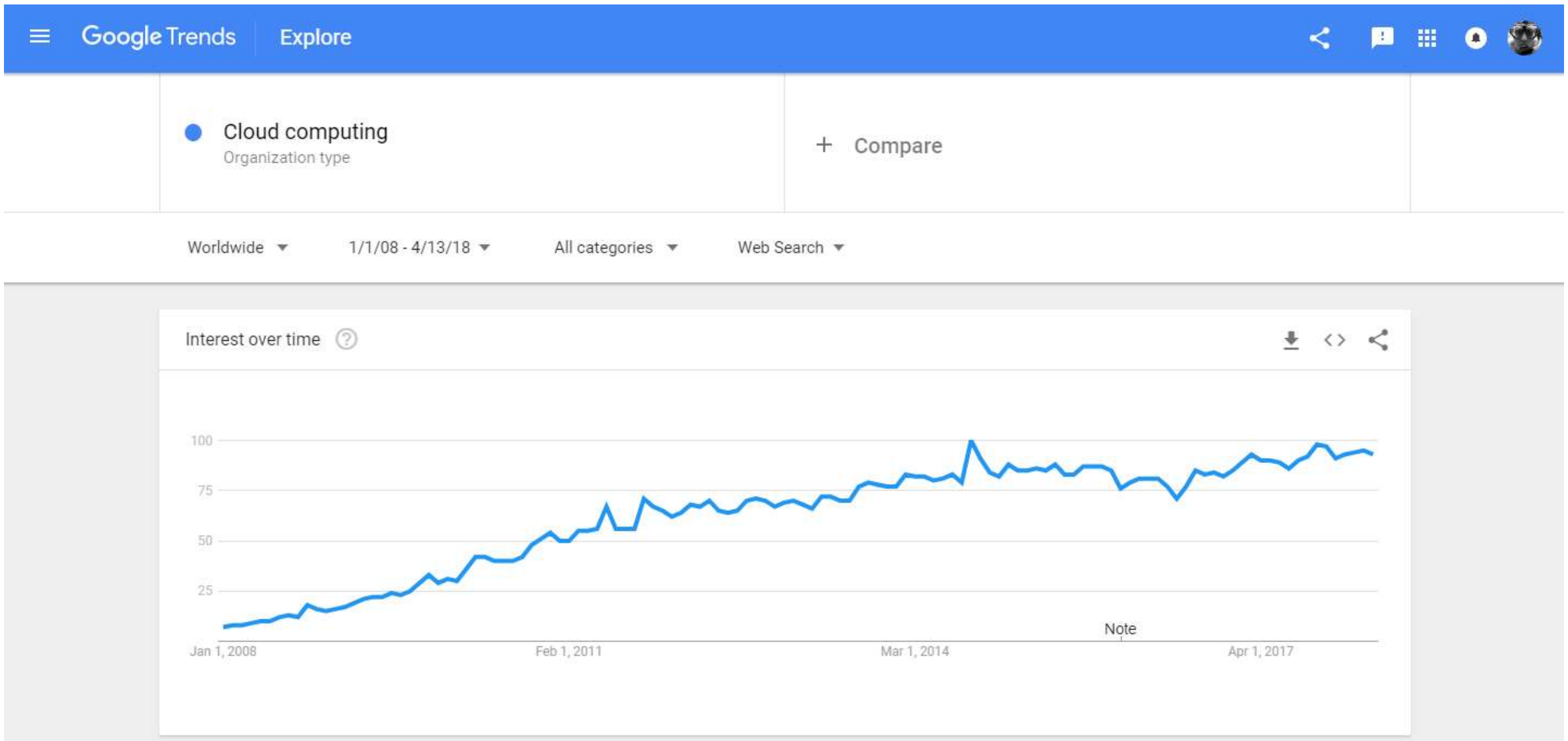
Part 2

Future of automation?

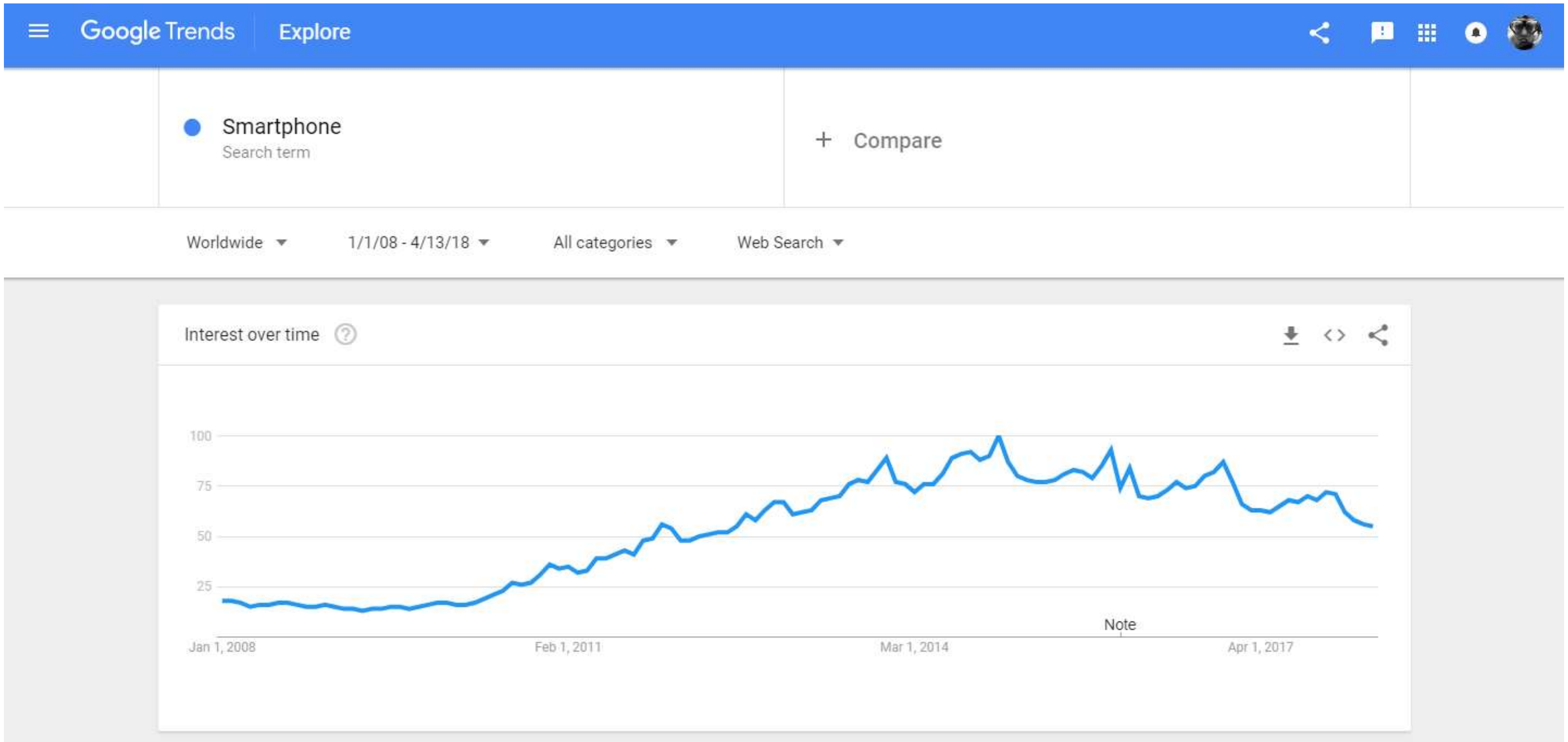
Wearable technology



Cloud computing – organizations

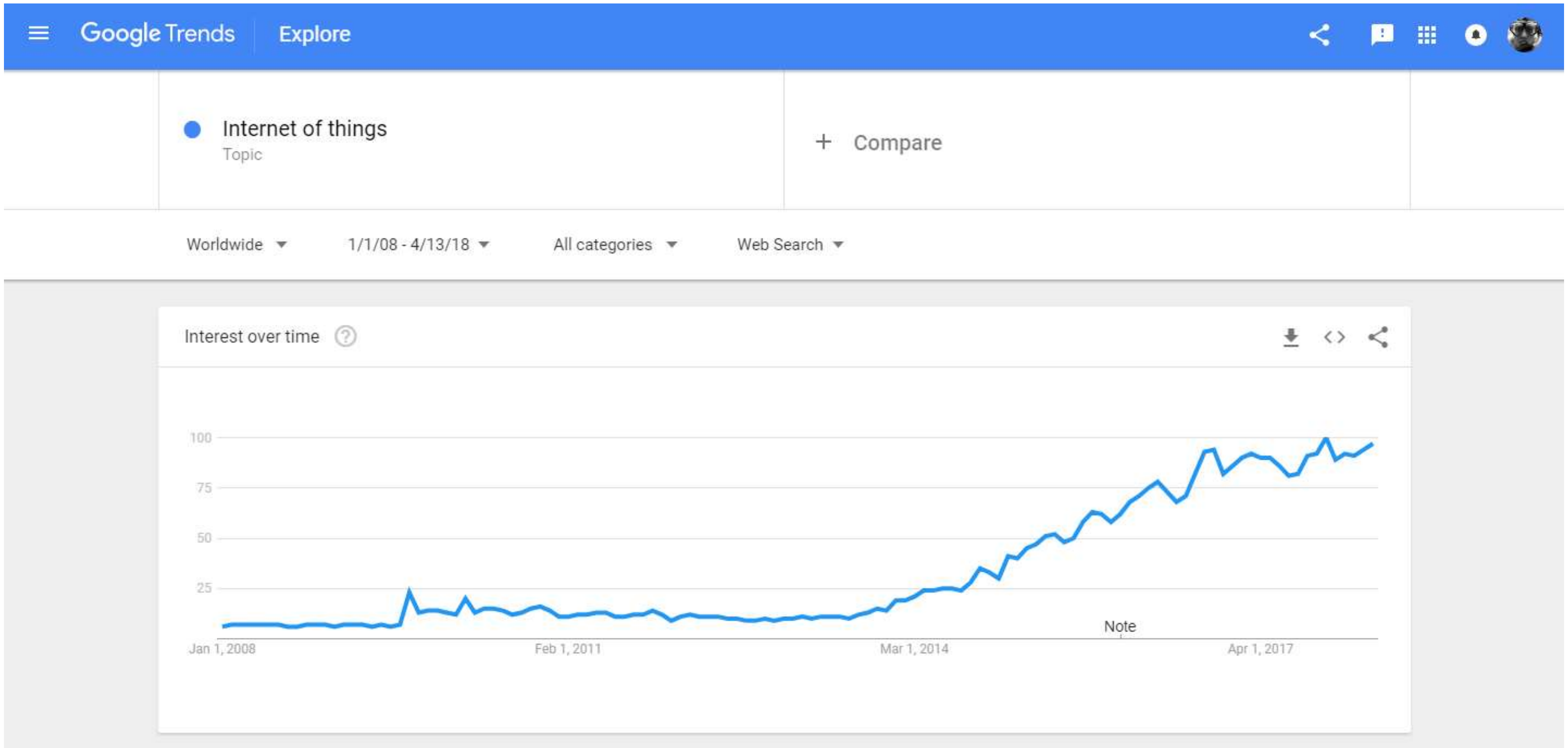


Smartphone

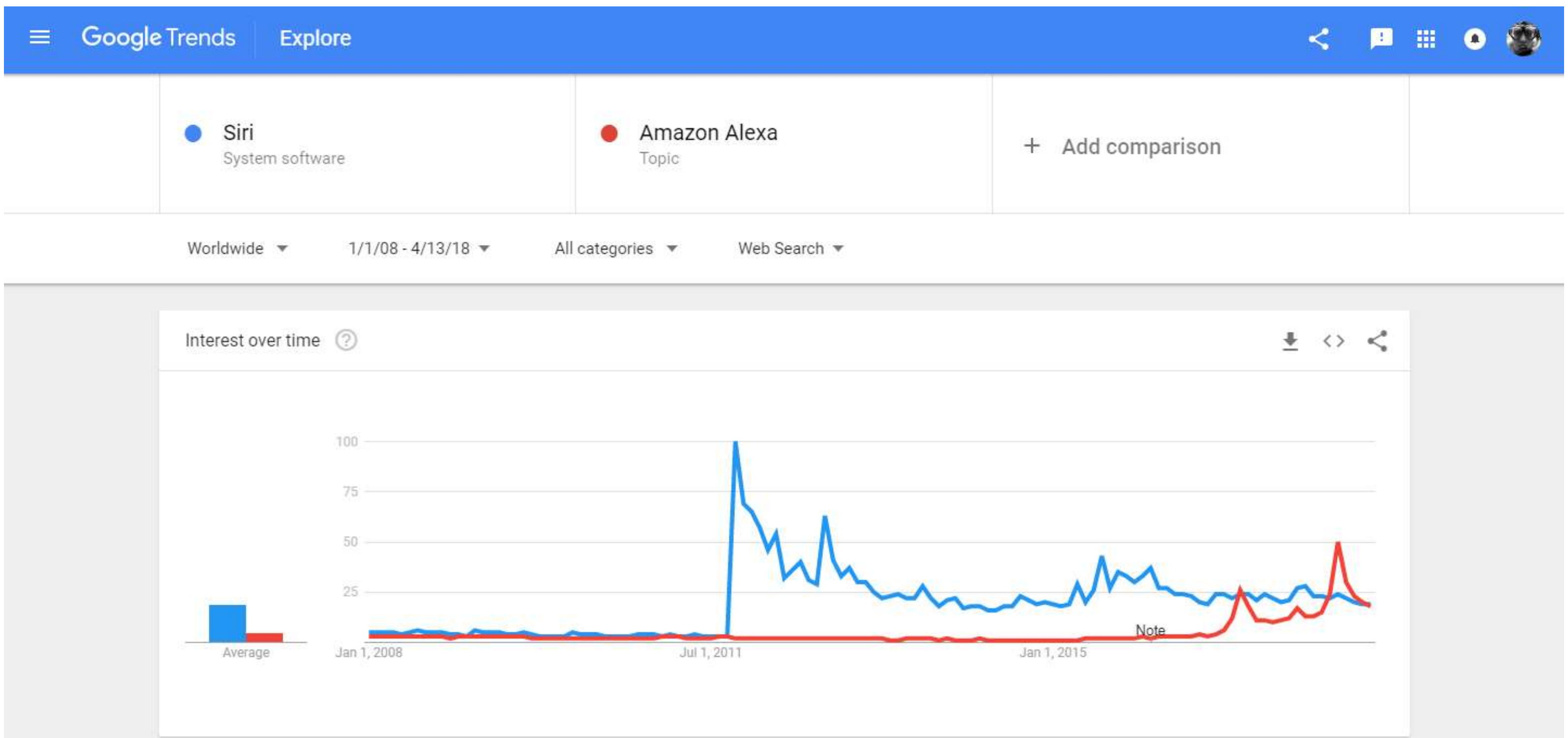


Google Trends
Explore
Smartphone
Search term
+ Compare
Worldwide
1/1/08 - 4/13/18
All categories
Web Search
Interest over time
100
75
50
25
Note
Jan 1, 2008
Feb 1, 2011
Mar 1, 2014
Apr 1, 2017

Internet of things



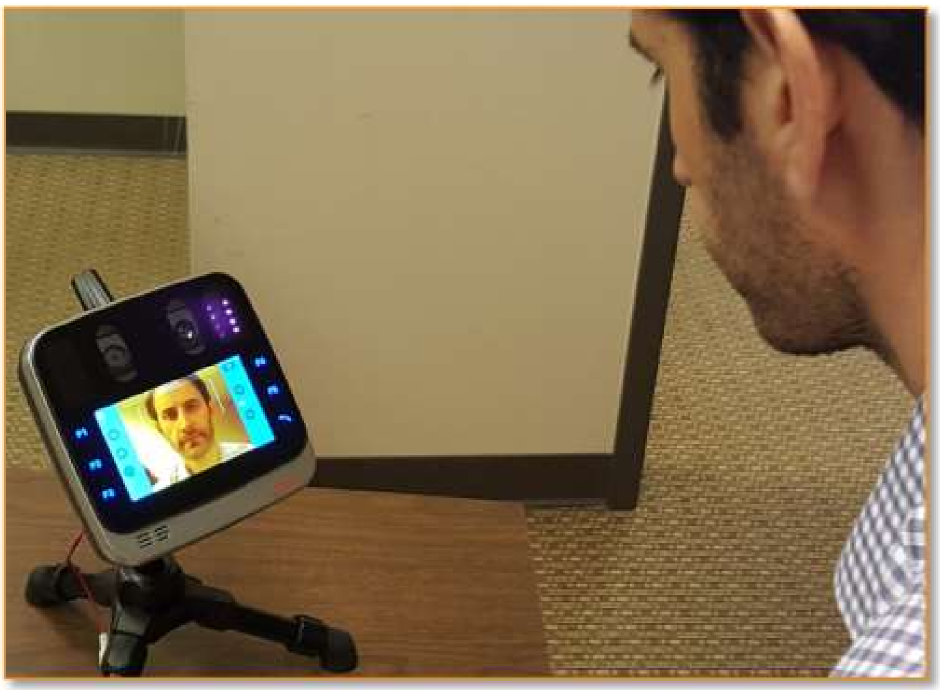
Siri & Alexa



Google Trends
Explore
Siri
System software
Amazon Alexa
Topic
+ Add comparison
Worldwide
1/1/08 - 4/13/18
All categories
Web Search
Interest over time
100
75
50
25
Average
Jan 1, 2008
Jul 1, 2011
Jan 1, 2015
Note


Kent Phillips/Disney

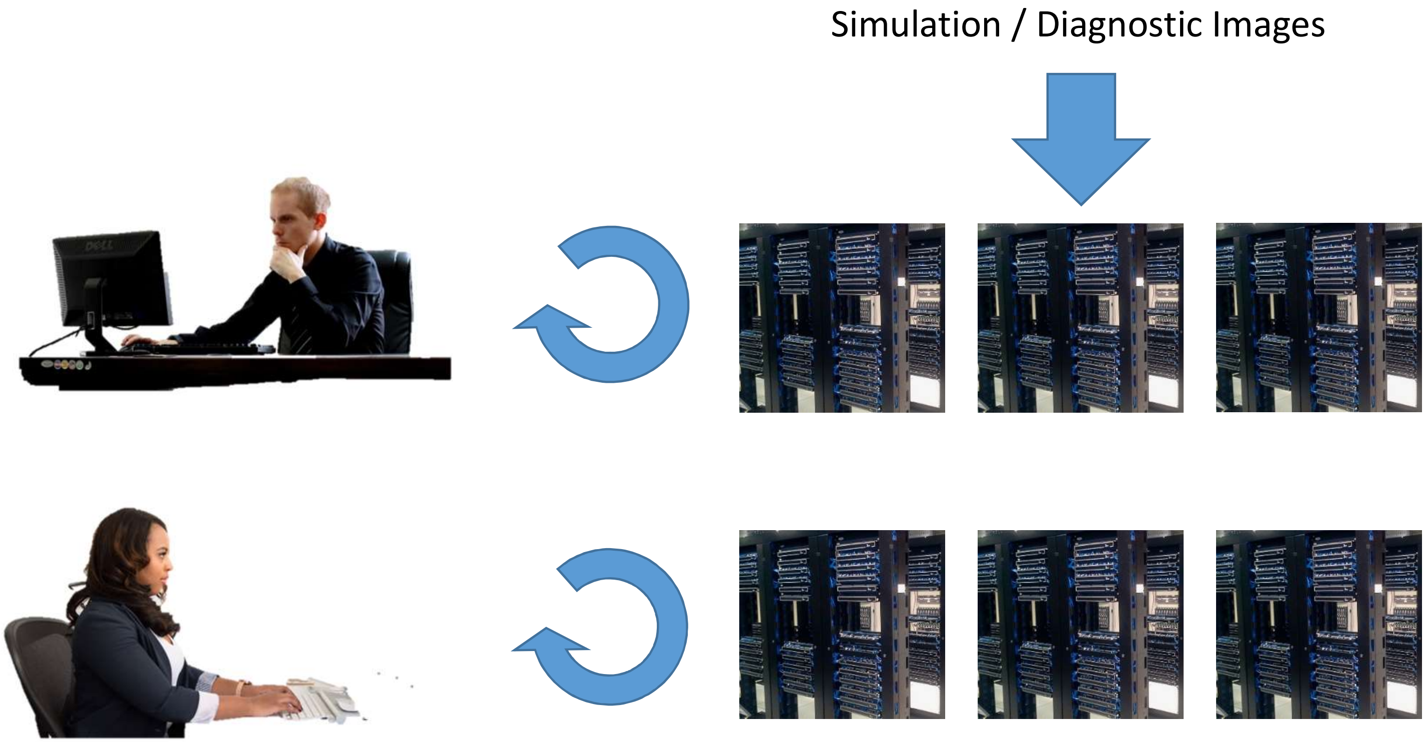
Biometrics / eVisits



Images: IdentiSys Inc.

How could automation change roles?

Dosimetrist – Trainers

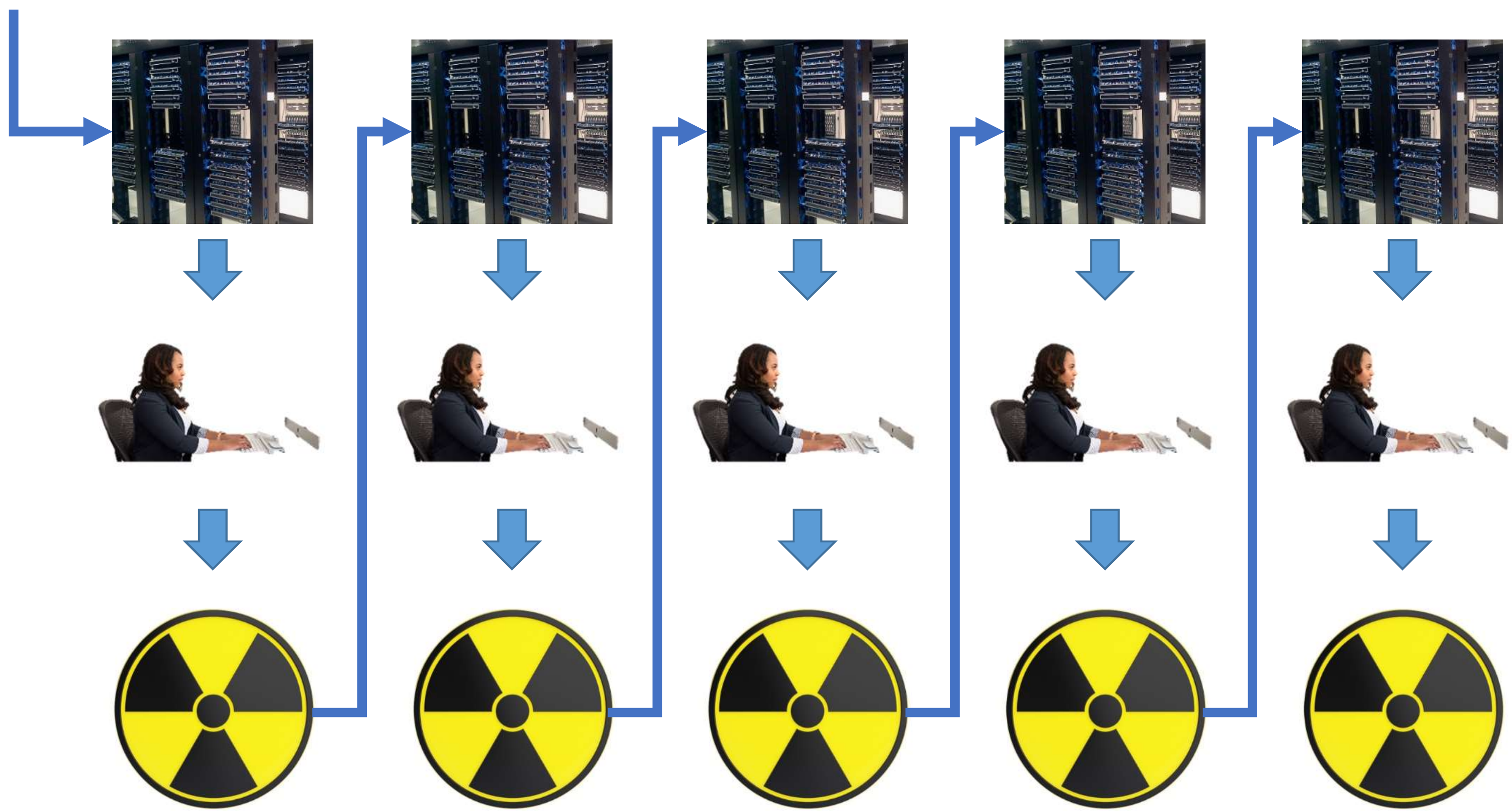


Dosimetrist – Pre-post automation

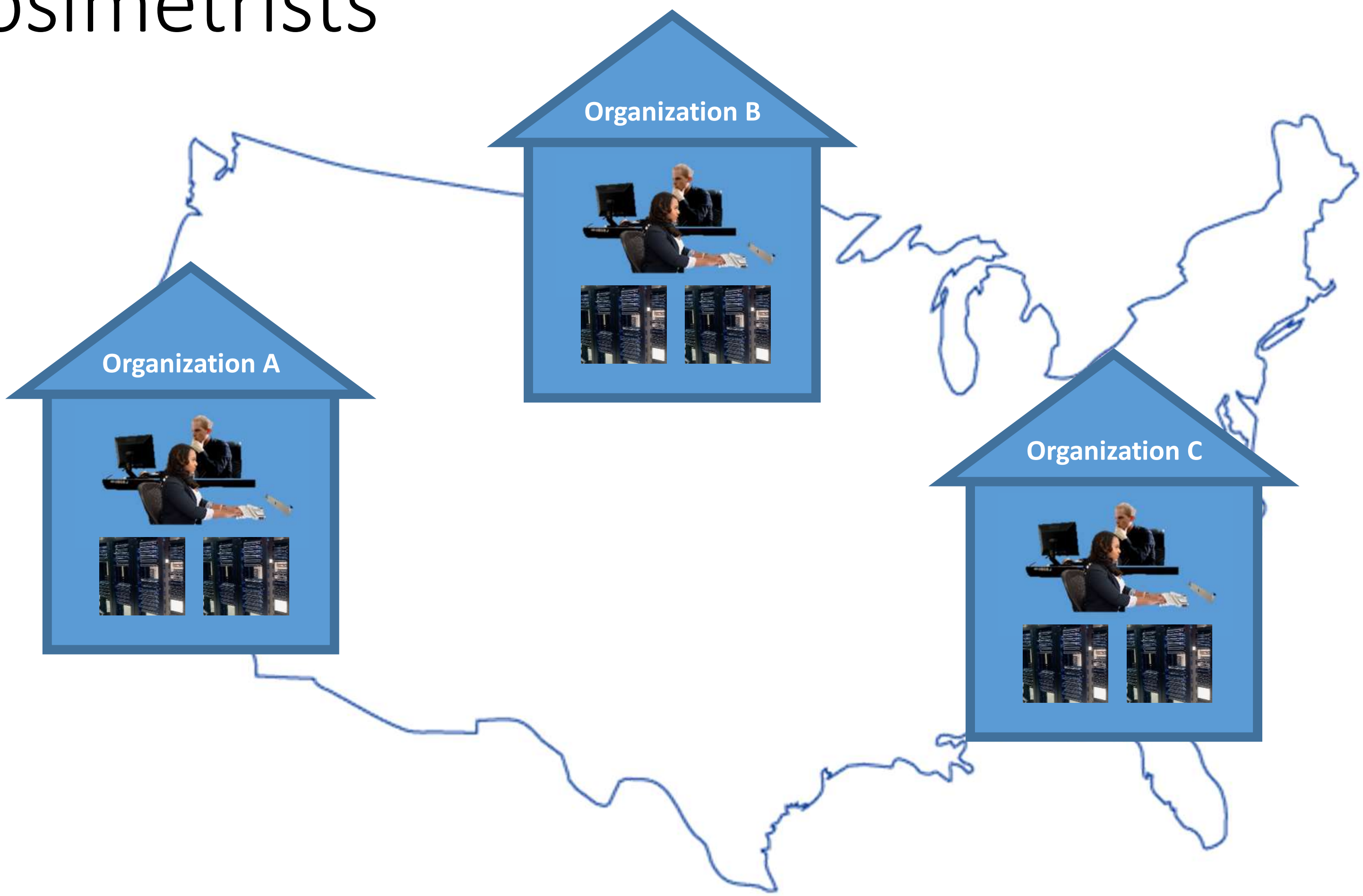
Pre-planners
Automation Prep

Post-planners
Evaluators

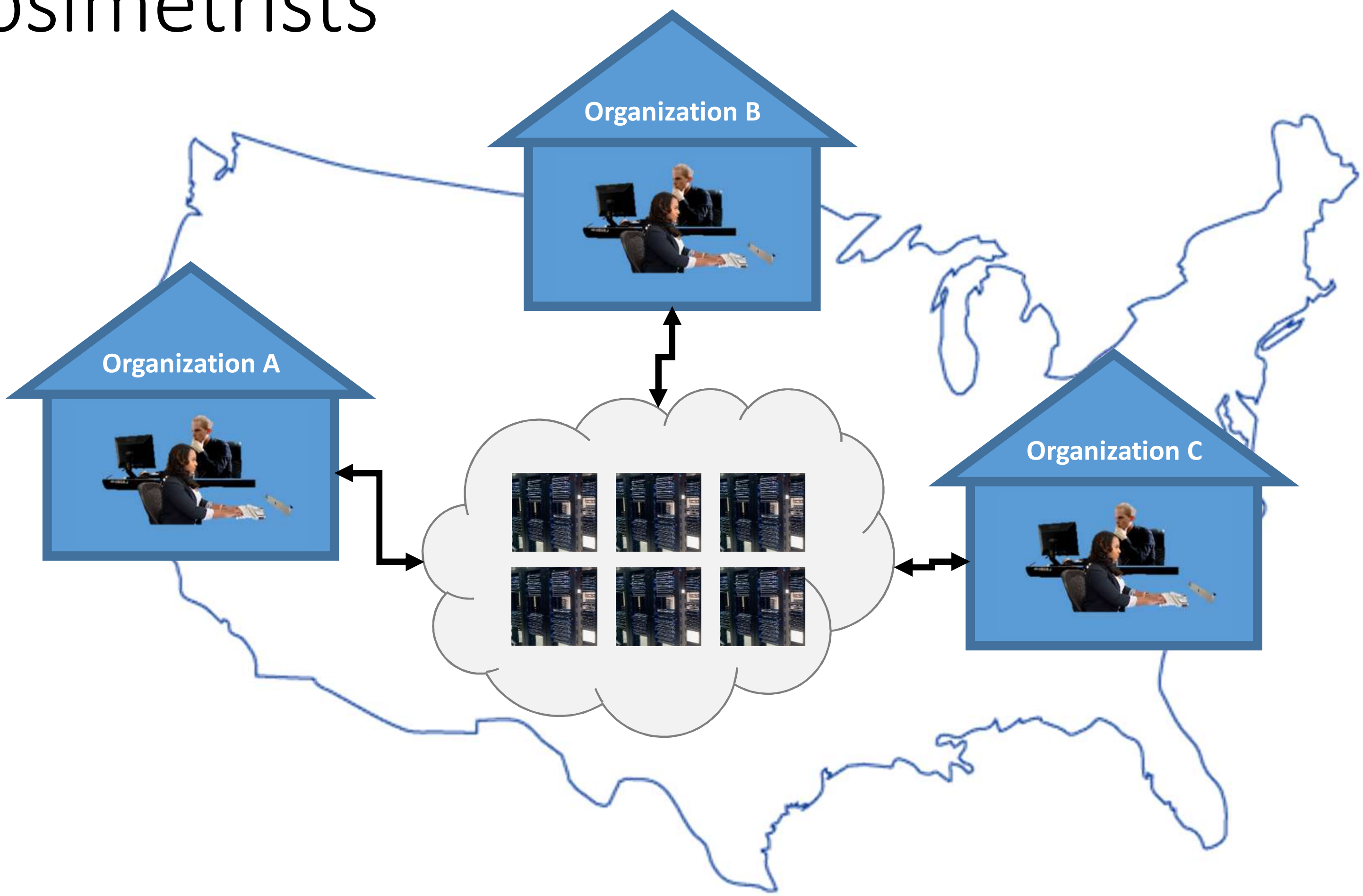
Dosimetrist – Daily / adaptive



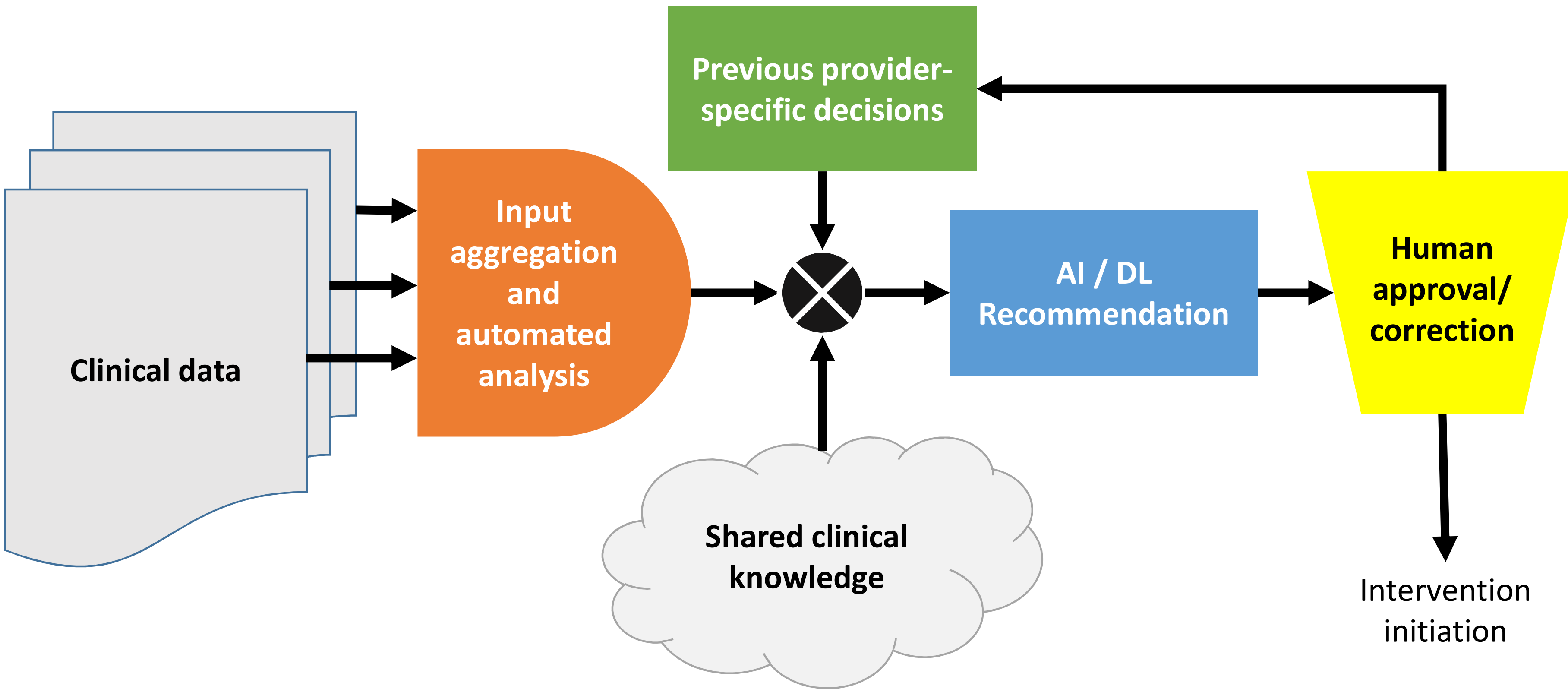
Dosimetrists



Dosimetrists



Physicians


Previous provider-specific decisions
Input aggregation and automated analysis
Clinical data
AI / DL Recommendation
Human approval/ correction
Shared clinical knowledge
Intervention initiation

Anonymous, Adam
Male
DOB: 1/1/1960

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

- [ ] Previous treatment
- [ ] Devices; for immobilization and beam shaping
- [ ] CT Guidance for placement of XRT fields
- [ ] Motion management / 4DCT simulation

Contrast for CT

Select from list or type here...

Fusion of image data sets

Select from list or type here...

Port films (MV imaging)

Select from list or type here...

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.

Labs 3

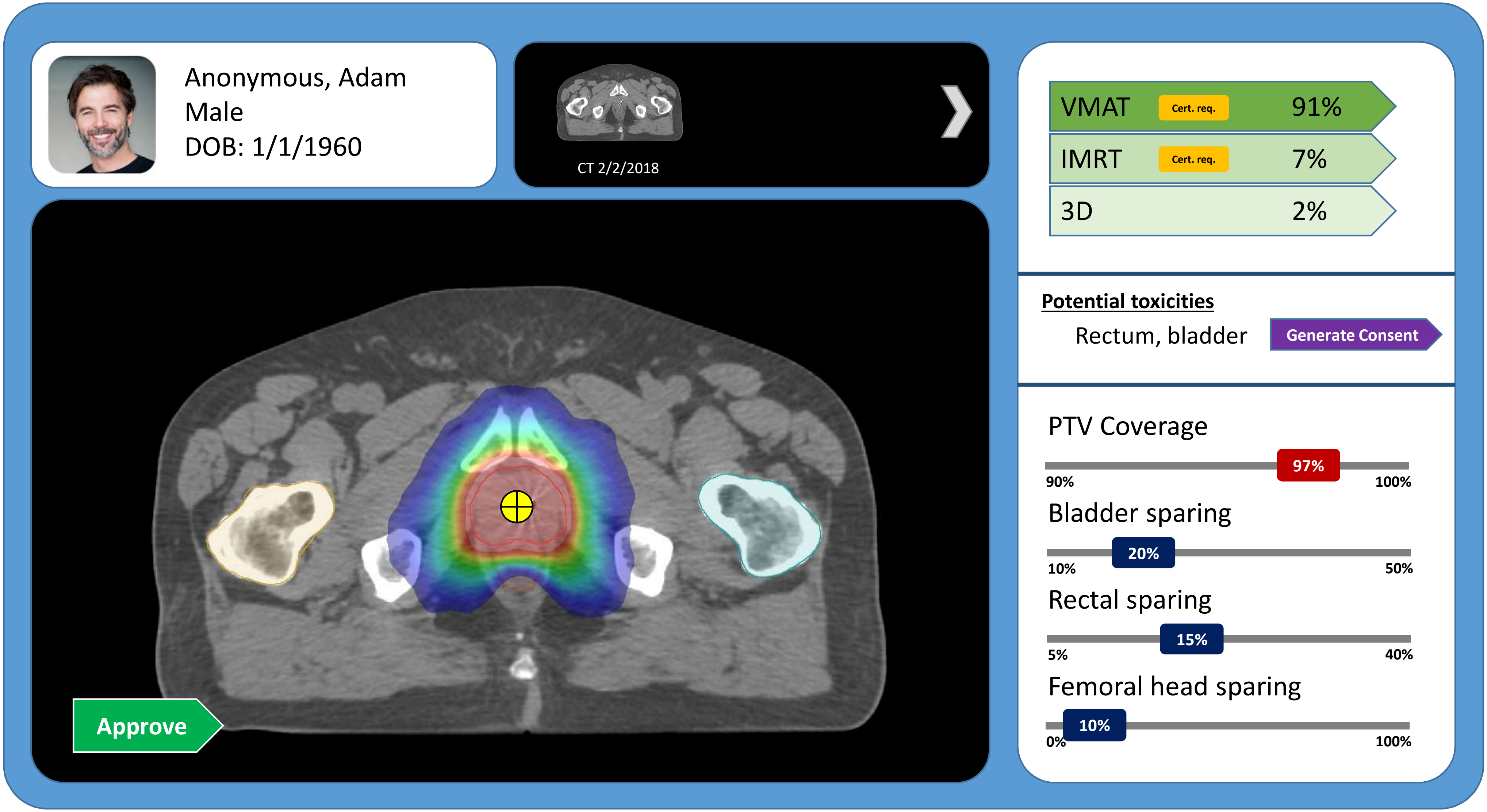
Biopsy 1

Radiology

VMAT	Cert. req.	91%
IMRT	Cert. req.	7%
3D		2%

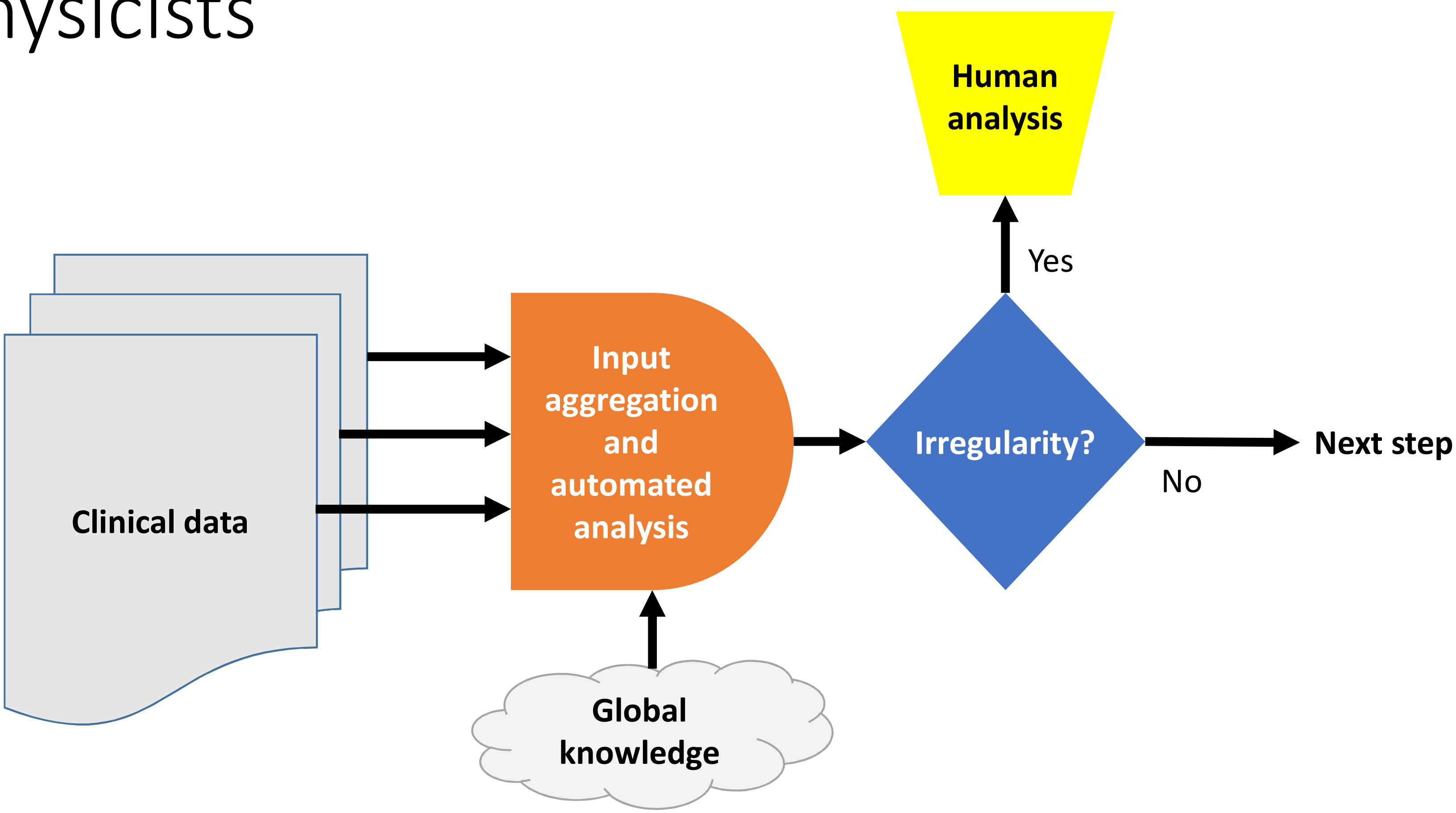
78Gy / 39fx	→NCCN	91%
60Gy / 20fx		7%
35Gy / 5fx		2%

CBCT Daily	80%
kV/kV Daily	20%



Anonymous, Adam
Male
DOB: 1/1/1960
CT 2/2/2018
VMAT
Cert. req.
91%
IMRT
Cert. req.
7%
3D
2%
Potential toxicities
Rectum, bladder
Generate Consent
PTV Coverage
97%
90%
100%
Bladder sparing
20%
10%
50%
Rectal sparing
15%
5%
40%
Femoral head sparing
10%
0%
100%
Approve

Physicists



Human analysis
Yes
Clinical data
Input aggregation and automated analysis
Irregularity?
Next step
No
Global knowledge

Physics – Acceptance testing

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

Sridhar Yaddanapudi[a),*] and Bin Cai*
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Taylor Harry
Department of Radiation Medicine and Applied Sciences, University of California San Diego, Moores Cancer Center, 3855 Health Sciences Dr., La Jolla, CA 92093, USA

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

Keith Stinson and Camille Noel
Varian Medical Systems, 3100 Hansen Way, Palo Alto, CA 94304, USA

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

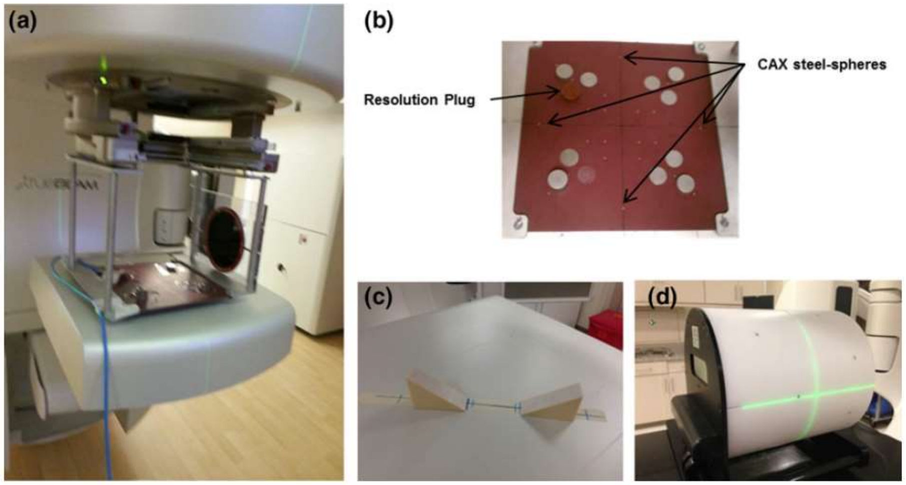
Todd Pawlicki
Department of Radiation Medicine and Applied Sciences, University of California San Diego, Moores Cancer Center, 3855 Health Sciences Dr., La Jolla, CA 92093, USA

Sasa Mutic and S. Murty Goddu
Department of Radiation Oncology, Washington University School of Medicine, 4921 Parkview Place, St. Louis, MO 63110, USA

(Received 10 November 2016; revised 11 April 2017; accepted for publication 11 April 2017; published 26 May 2017)

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 (aS1000) 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

Medical Physics, 44 (7), July 2017



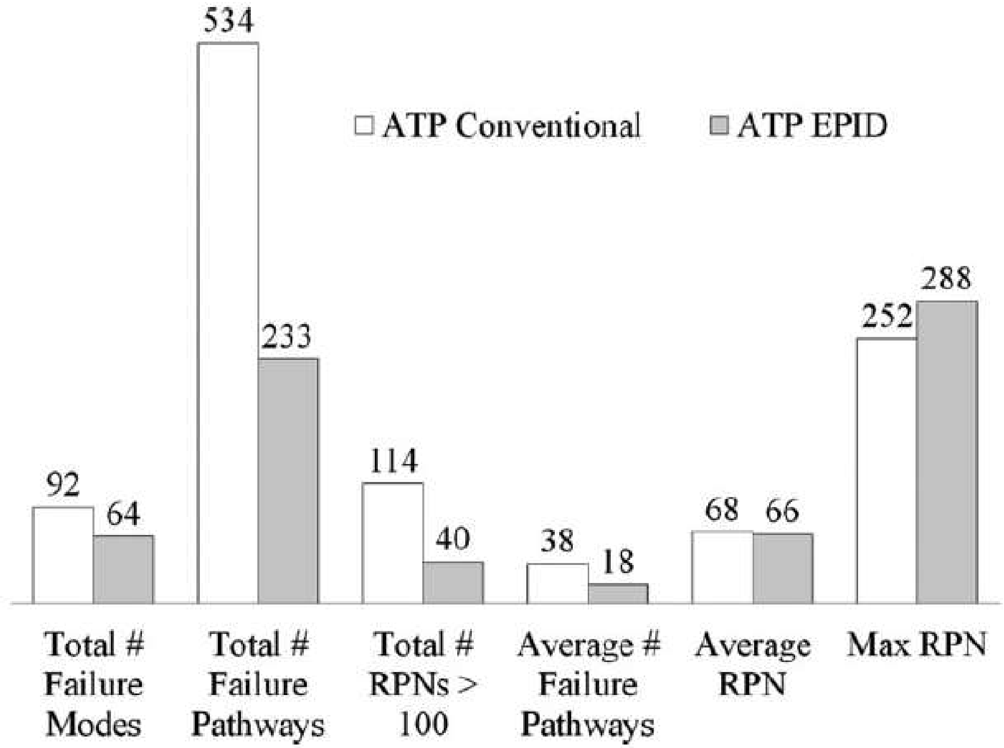
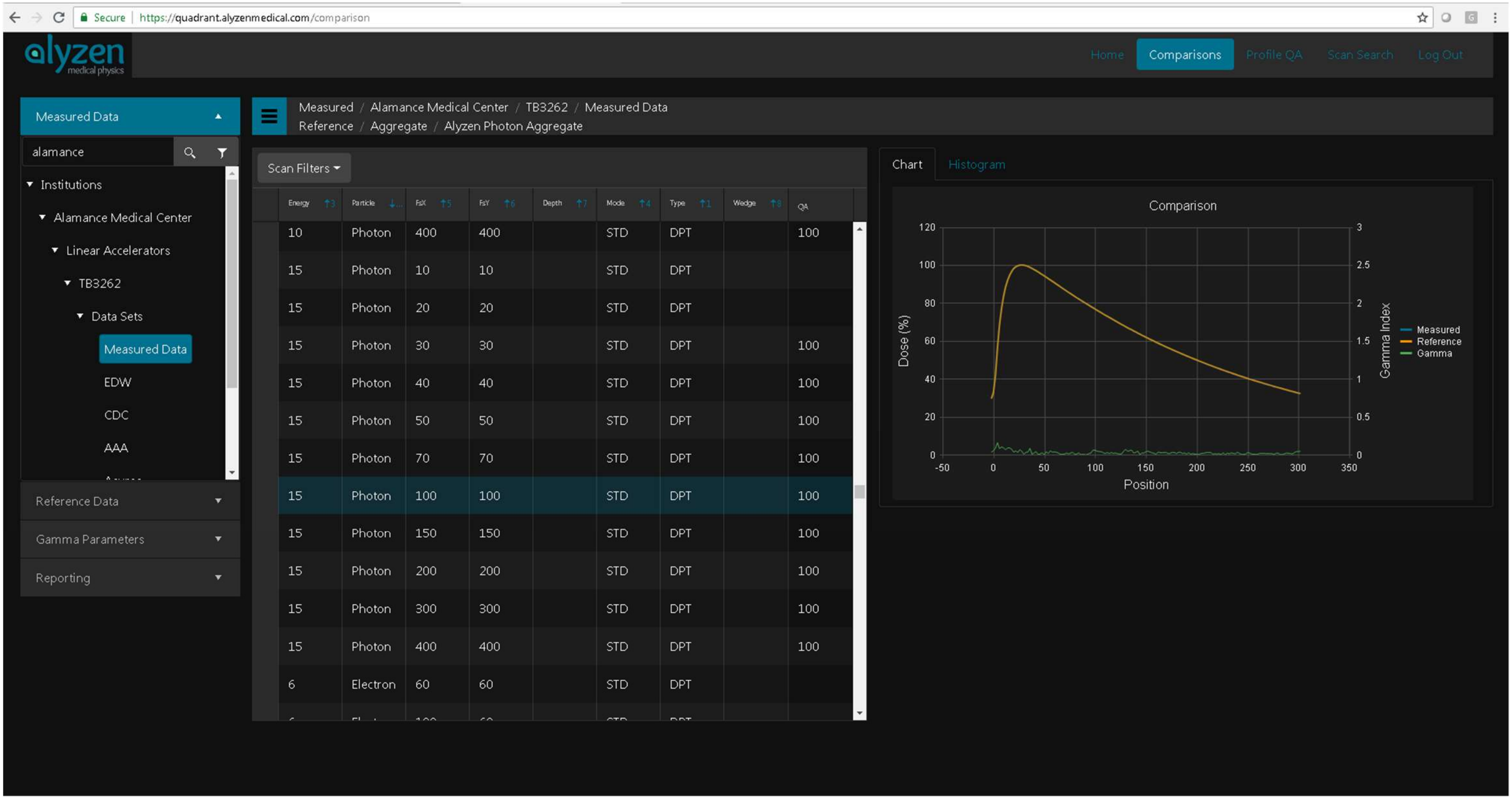


FIG. 2. Overall results for the FMEA analysis shown side by side for the ATP_{conv} and ATP_{EPID}. The average failure pathways and average RPN were calculated for each individual ATP_{EPID}. The average failure pathways and average RPN were calculated for each individual ATP test then averaged over all tests.ATP test then averaged over all tests.

T Harry et al. Risk assessment of a new acceptance testing procedure for conventional linear accelerators. Med. Phys. 44 (11), November 2017


Secure https://quadrant.alyzenmedical.com/comparison
alyzen medical physics
Home
Comparisons
Profile QA
Scan Search
Log Out
Measured Data
alamance
Institutions
Alamance Medical Center
Linear Accelerators
TB3262
Data Sets
Measured Data
EDW
CDC
AAA
Reference Data
Gamma Parameters
Reporting
Measured / Alamance Medical Center / TB3262 / Measured Data
Reference / Aggregate / Alyzen Photon Aggregate
Scan Filters
Energy Particle FsX FsY Depth Mode Type Wedge QA
10 Photon 400 400 STD DPT 100
15 Photon 10 10 STD DPT
15 Photon 20 20 STD DPT
15 Photon 30 30 STD DPT 100
15 Photon 40 40 STD DPT 100
15 Photon 50 50 STD DPT 100
15 Photon 70 70 STD DPT 100
15 Photon 100 100 STD DPT 100
15 Photon 150 150 STD DPT 100
15 Photon 200 200 STD DPT 100
15 Photon 300 300 STD DPT 100
15 Photon 400 400 STD DPT 100
6 Electron 60 60 STD DPT
Chart
Histogram
Comparison
Dose (%)
Gamma Index
Position
Measured
Reference
Gamma
120
100
80
60
40
20
0
3
2.5
2
1.5
1
0.5
0
-50 0 50 100 150 200 250 300 350

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

The effectiveness of pretreatment physics plan review for detecting errors in radiation therapy

Olga Gopan, Jing Zeng, Avrey Novak, Matthew Nyflot, and Eric Ford[a)]
Department of Radiation Oncology, University of Washington Medical Center, 1959 NE Pacific Street, Box 356043, Seattle, Washington 98195

(Received 26 April 2016; revised 30 June 2016; accepted for publication 1 August 2016; published 24 August 2016)

Purpose: The pretreatment physics plan review is a standard tool for ensuring treatment quality. Studies have shown that the majority of errors in radiation oncology originate in treatment planning, which underscores the importance of the pretreatment physics plan review. This quality assurance measure is fundamentally important and central to the safety of patients and the quality of care that they receive. However, little is known about its effectiveness. The purpose of this study was to analyze reported incidents to quantify the effectiveness of the pretreatment physics plan review with the goal of improving it.
Methods: This study analyzed 522 potentially severe or critical near-miss events within an institutional incident learning system collected over a three-year period. Of these 522 events, 356 originated at a workflow point that was prior to the pretreatment physics plan review. The remaining 166 events originated after the pretreatment physics plan review and were not considered in the study. The applicable 356 events were classified into one of the three categories: (1) events detected by the pretreatment physics plan review, (2) events not detected but "potentially detectable" by the physics review, and (3) events "not detectable" by the physics review. Potentially detectable events were further classified by which specific checks performed during the pretreatment physics plan review detected or could have detected the event. For these events, the associated specific check was also evaluated as to the possibility of automating that check given current data structures. For comparison, a similar analysis was carried out on 81 events from the international SAFRON radiation oncology incident learning system.
Results: Of the 356 applicable events from the institutional database, 180/356 (51%) were detected or could have been detected by the pretreatment physics plan review. Of these events, 125 actually passed through the physics review; however, only 38% (47/125) were actually detected at the review. Of the 81 events from the SAFRON database, 66/81 (81%) were potentially detectable by the pretreatment physics plan review. From the institutional database, three specific physics checks were particularly effective at detecting events (combined effectiveness of 38%): verifying the isocenter (39/180), verifying DRRs (17/180), and verifying that the plan matched the prescription (12/180). The most effective checks from the SAFRON database were verifying that the plan matched the prescription (13/66) and verifying the field parameters in the record and verify system against those in the plan (23/66). Software-based plan checking systems, if available, would have potential effectiveness of 29% and 64% at detecting events from the institutional and SAFRON databases, respectively.
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.
 [http://dx.doi.org/10.1118/1.4961010]

Key words: physics plan review, quality assurance, incident learning, patient safety, error detection

1. INTRODUCTION

The pretreatment physics plan review is a standard tool for ensuring treatment quality and is recommended by numerous

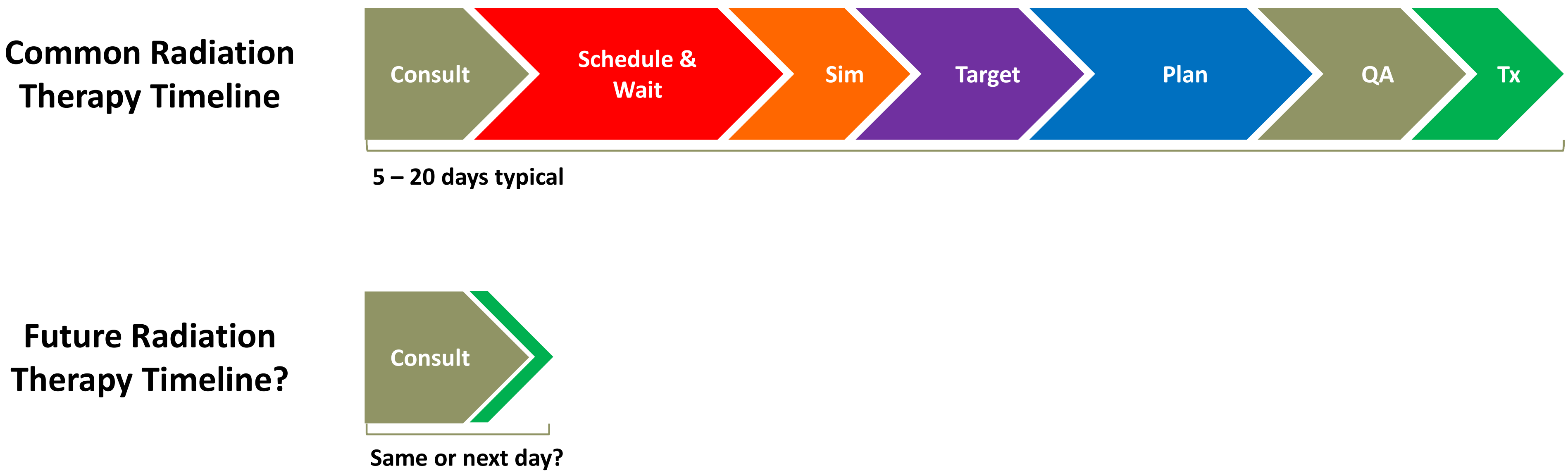
potential effectiveness of the pretreatment physics plan review, and more data are needed on this effectiveness.

The pretreatment physics plan review involves the human inspection and evaluation of various aspects of a treatment

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.

Med. Phys. 43 (9), September 2016

Radiation therapy timeline



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/

ASTRO 2017 Keynote Address

"Man has to partner with machine and data science to make informed decisions. It's absolutely inevitable."

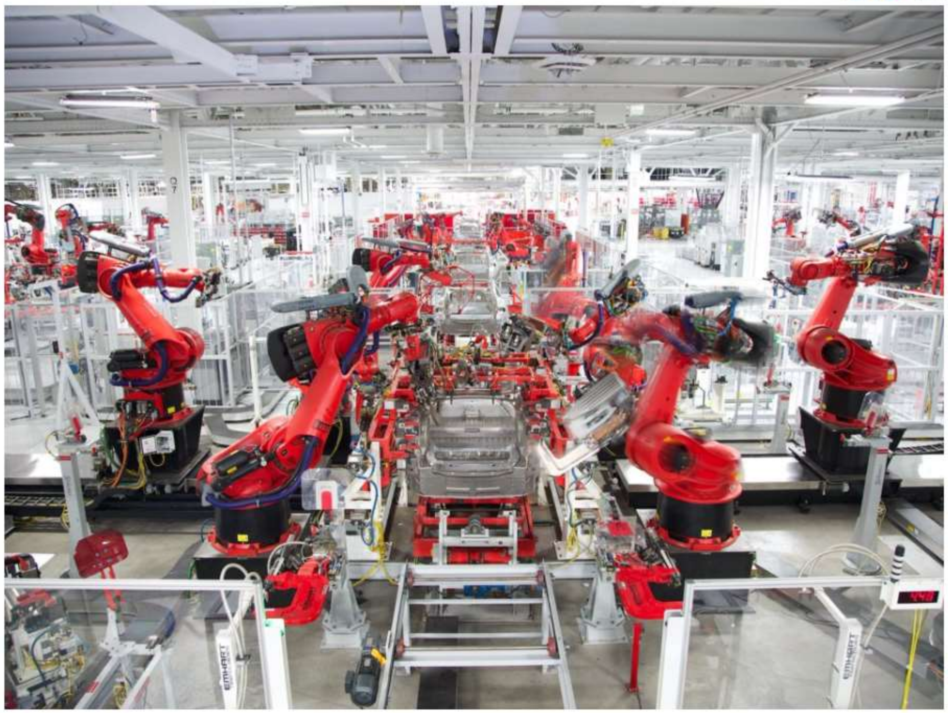
Richard Zane, MD
Chief Innovation Officer
University of Colorado Health System

Zane R. Can Innovation and the Digital Revolution Save Healthcare? ASTRO Annual Meeting Keynote, 2017.
https://www.astro.org/17vmpreview/

BUSINESS INSIDER

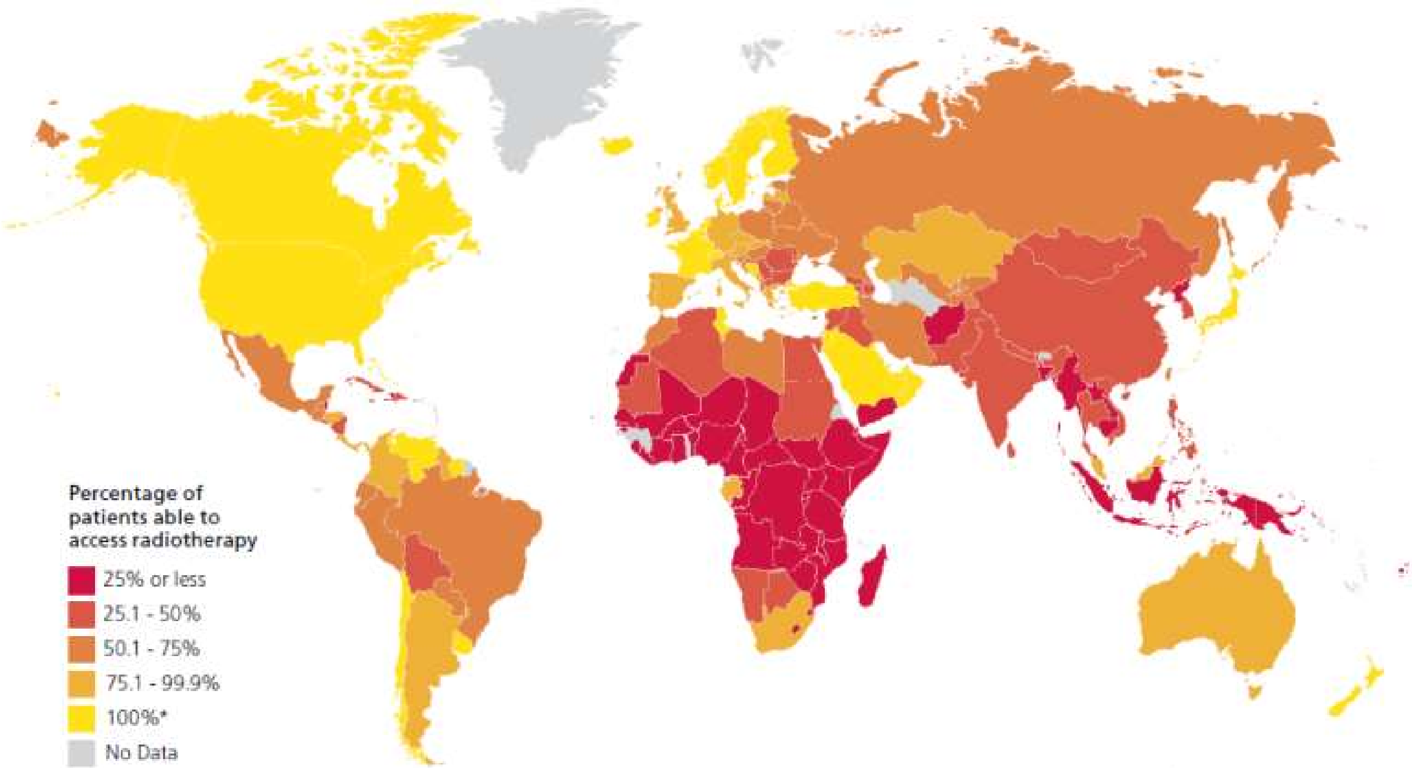
Elon Musk says he agrees that there are too many robots on the Model 3 production line

Mark Matousek Apr. 13, 2018, 11:10 AM



The factory in Fremont, California, where Tesla produces its vehicles. Tesla

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.

Source: *The Cancer Atlas*, second edition.

Global Cancer Facts & Figures 3rd edition (2015).

Thank you!