Don’t let us ask for the Moon, we have automation!

Technologies to automate clinical workflow in radiation therapy

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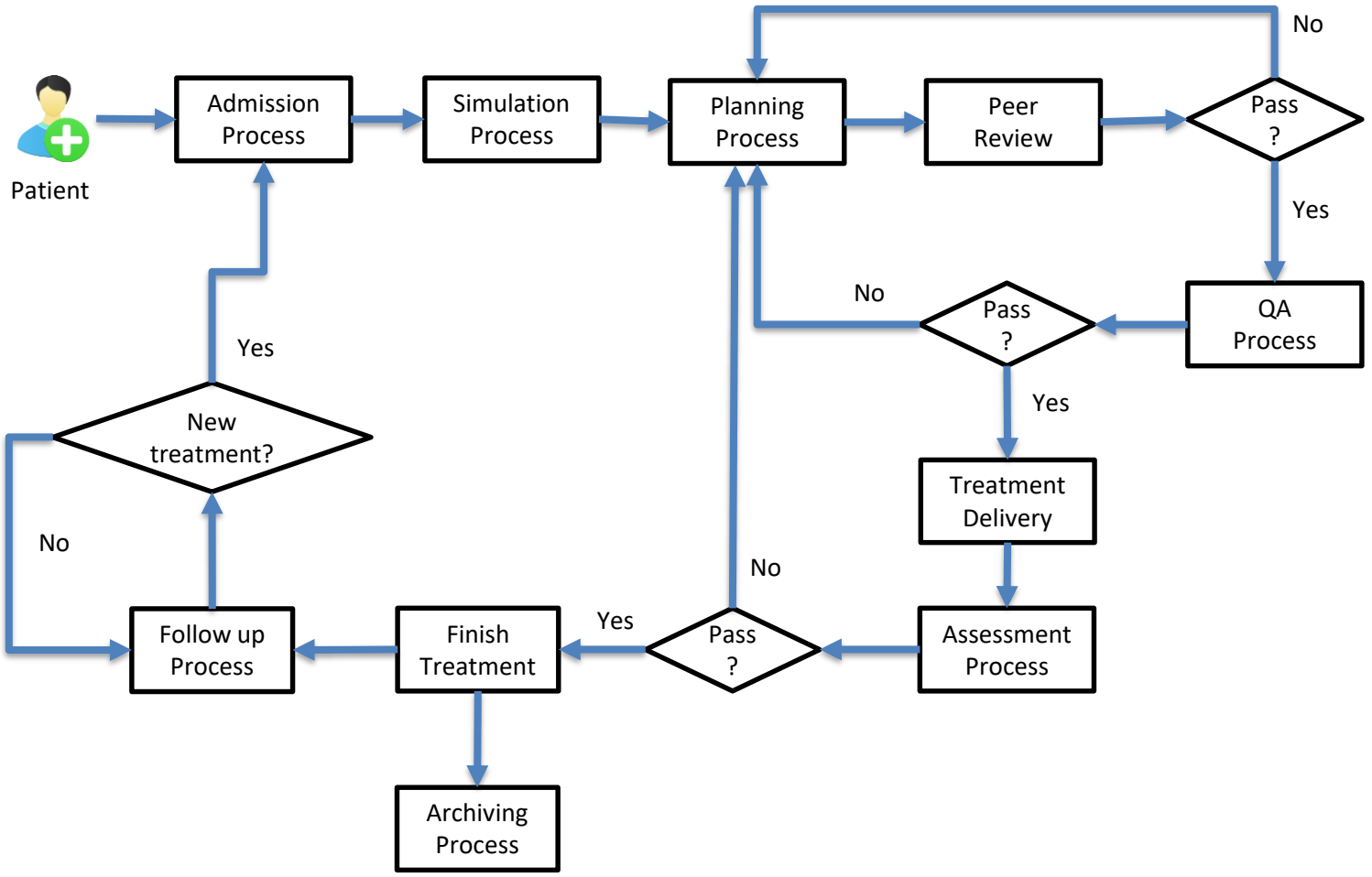
Learning objectives

1. Know what RTLS is, and how can RTLS technologies improve clinical workflow for higher operation efficiency, better patient safety and experience.
2. Know technologies to improve communications in clinic.
3. Know what DICOM and RT PACS are, and technologies to automate plan archiving.

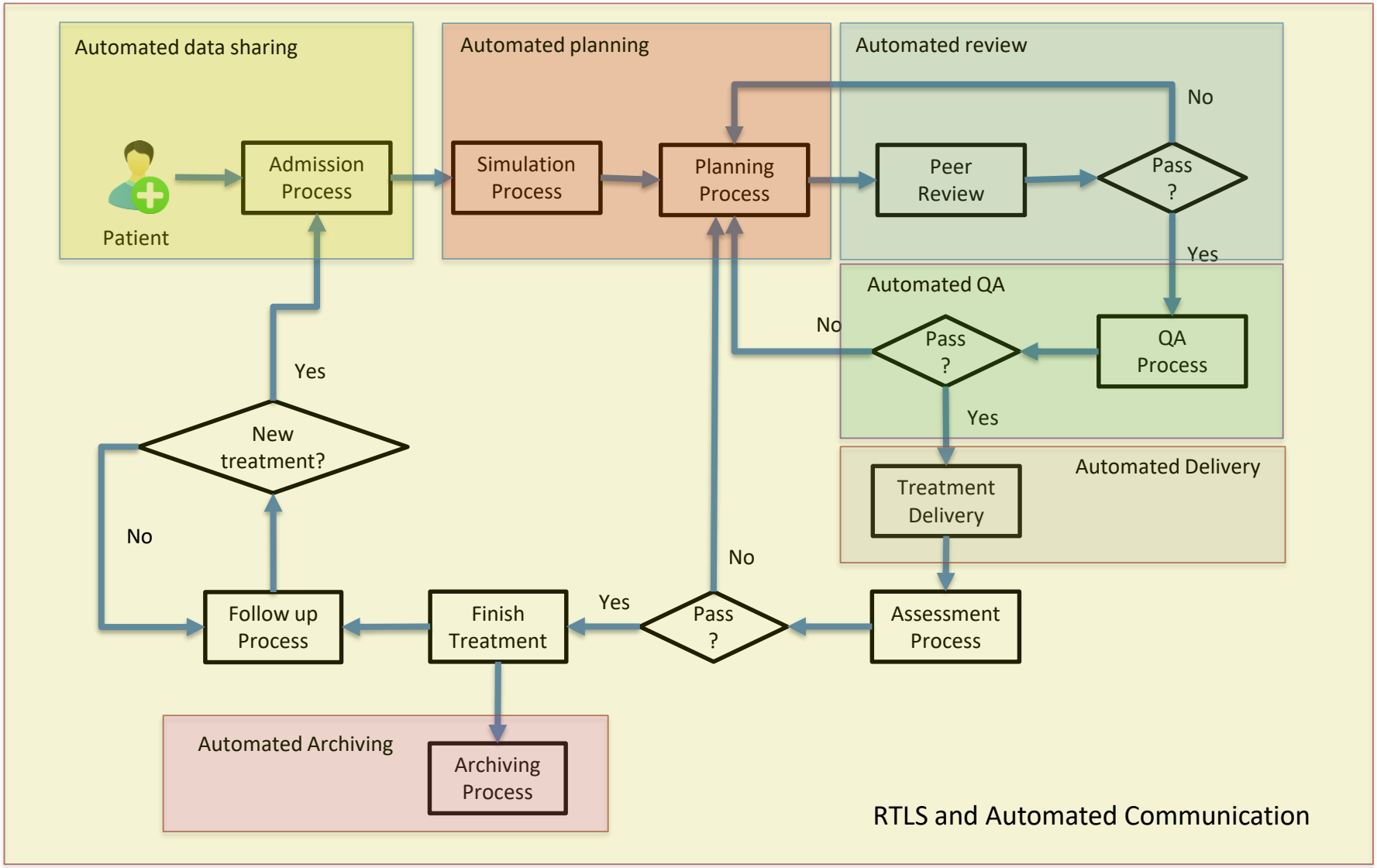
Outline

1. Clinical workflow and automation options.
2. Real-Time Location system and its applications in radiation therapy clinics.
3. Automated communications.
4. Automated chart rounds.
5. Automated plan archiving.

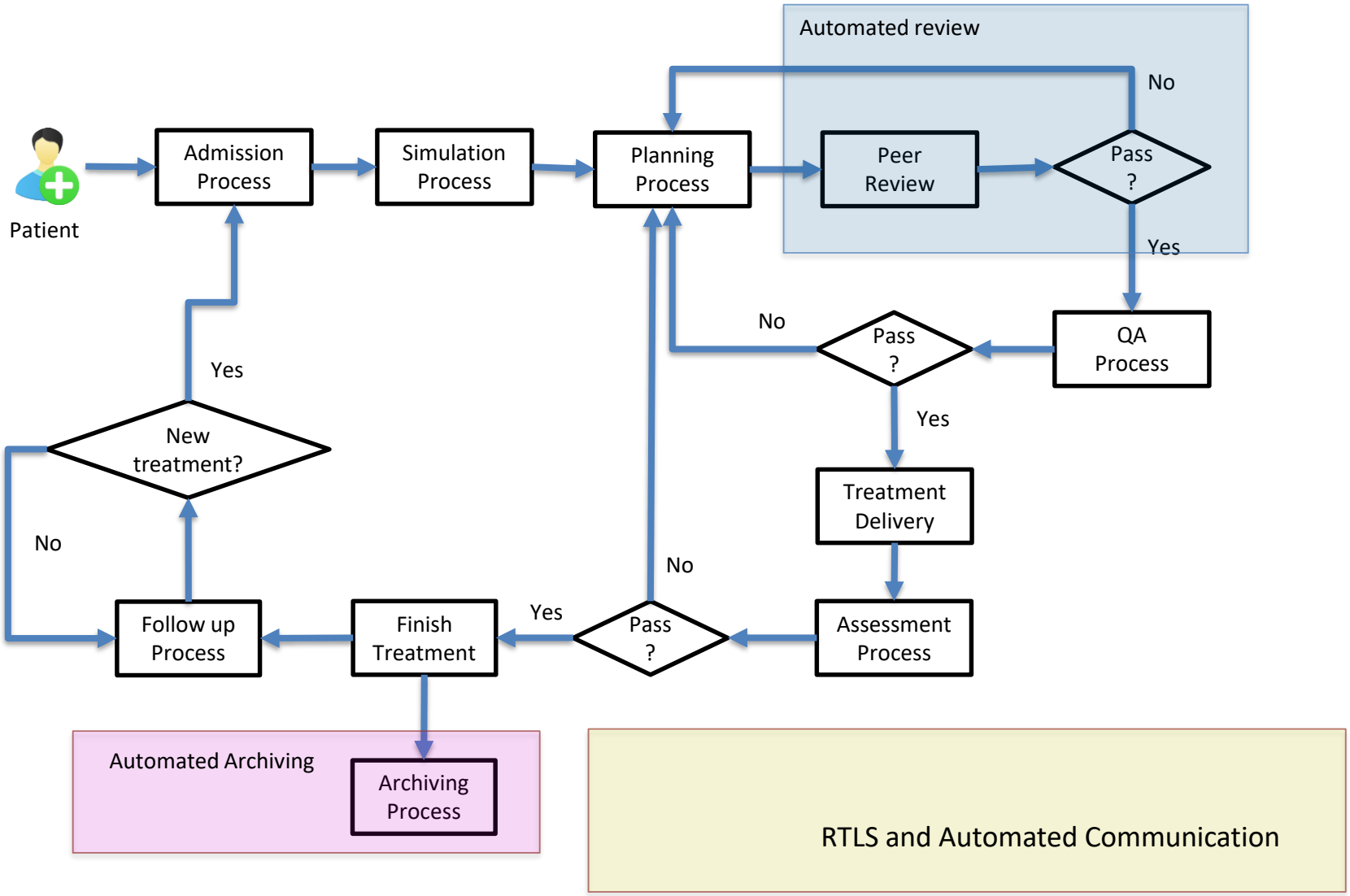
A typical clinical workflow



A typical clinical workflow



Automated portion to discuss



Real-Time Location System

Real-Time Location System (RTLS) is such a system that can tell the care team at any moment locations of patients, accessories, equipment and staff.

Why is RTLS useful ?

1. Track/verify patients
2. Track/verify patient-specific accessories
3. Track shared equipment
4. Track staff

RTLS technologies

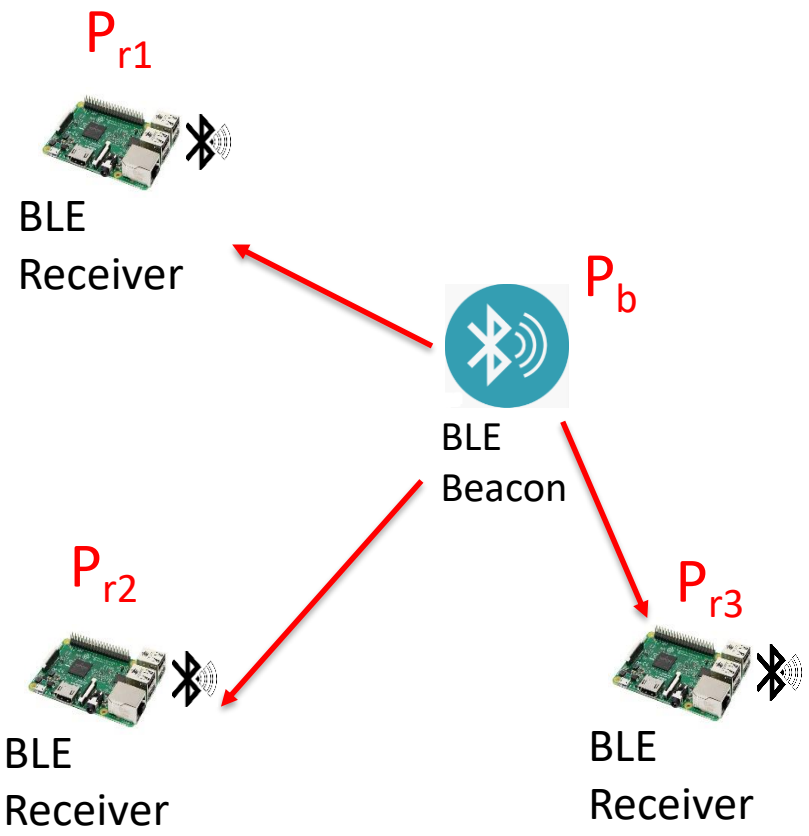
1. Active radio frequency identification (active RFID)
2. Passive radio frequency identification (passive RFID)
3. Active radio frequency-infrared hybrid (active RFID-IR)
4. Infrared (IR)
5. Optical locating
6. Passive RFID RTLS via Steerable Phased Array Antennae
7. Ultrasonic ranging (US-RTLS)
8. Bluetooth Low Energy (BLE)
9. …

BLE beacon and receiver

Form factors of BLE beacons

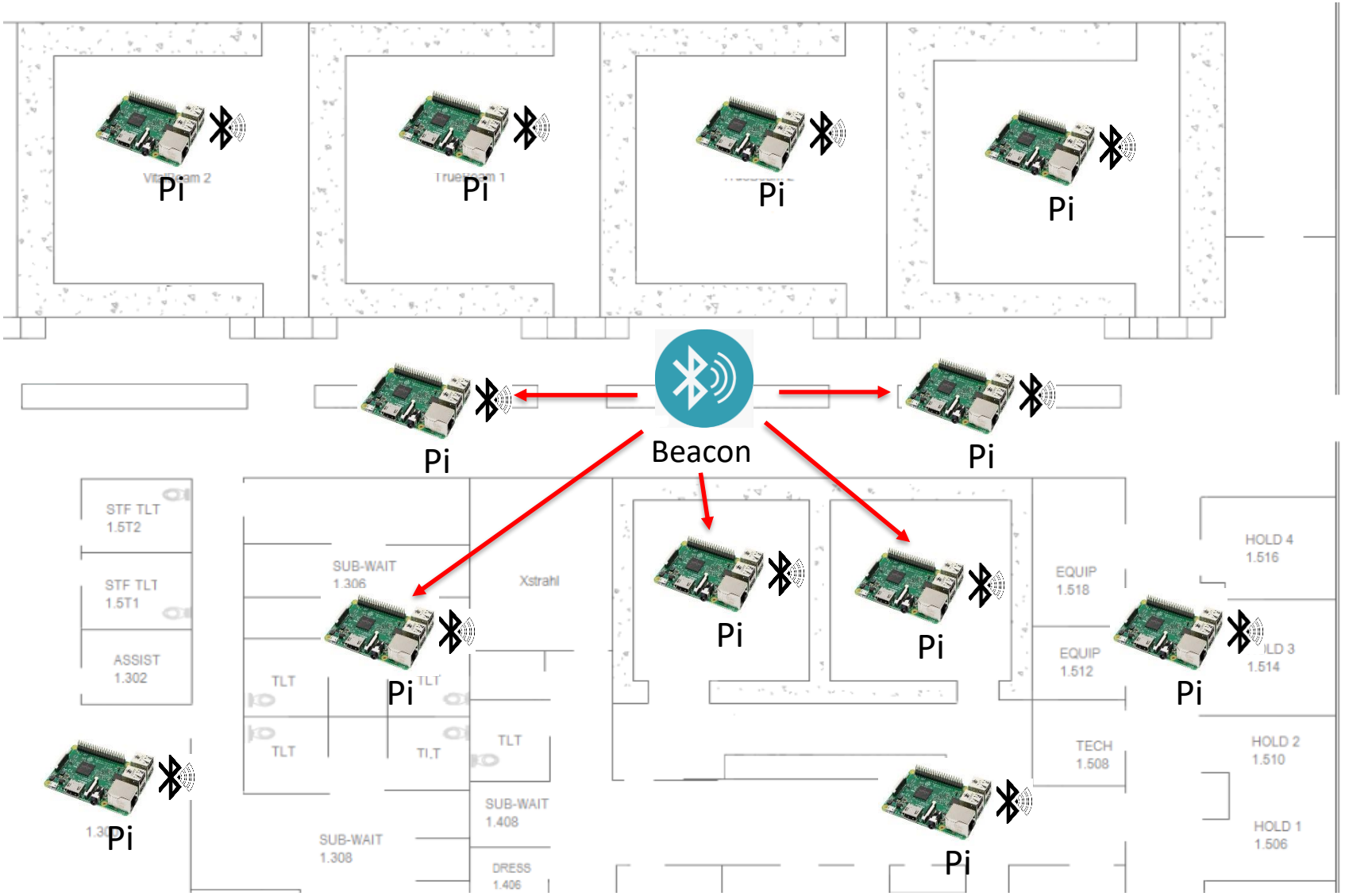
Raspberry Pi as BLE receiver

How does BLE RTLS work ?



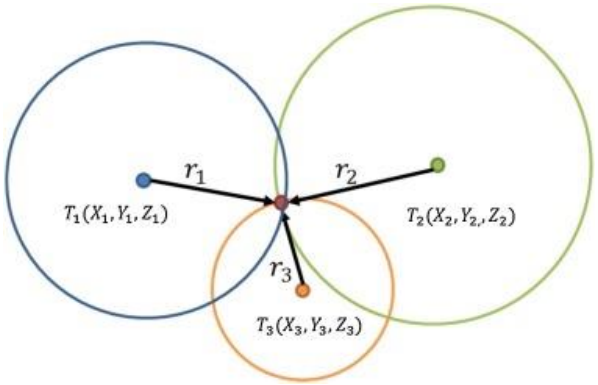
- A BLE beacon at a unknown point P_b sends RF pulse at an interval to all directions.
- BLE receivers at known locations (P_{r1}, P_{r2}, P_{r3}) receive RF signal at different strengths.
- Use an algorithm to estimate BLE beacon location P_b.

How does BLE RTLS work ?

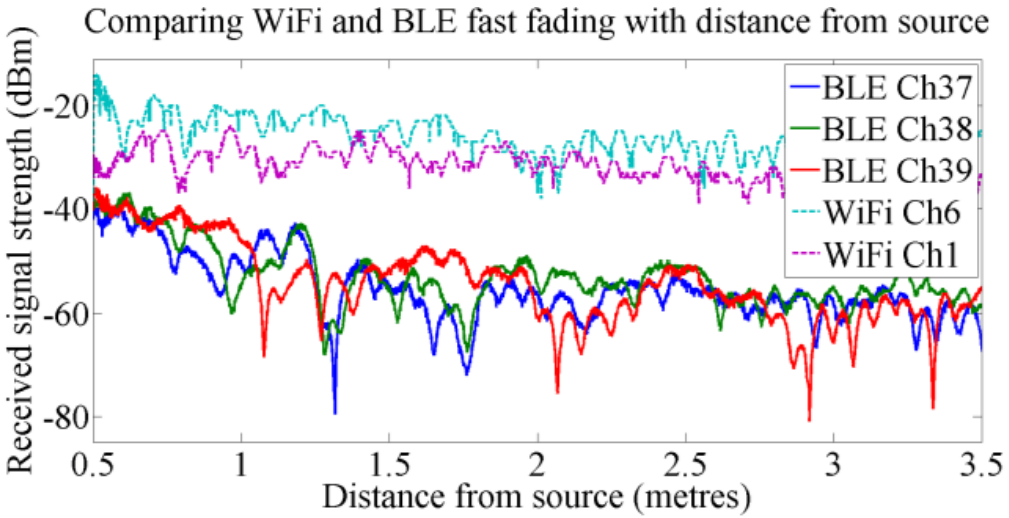


Methods for location calculation

- **Traditional methods – Trilateration, threshold**
  - Suffer from low accuracy and stability
  - Signal strength is affected by building infrastructure
  - Signal is affected by strong interference (wavelength ~ 12cm)
- **Machine learning methods – ANN, CNN, RNN**



Trilateration



Faragher et al. 2014, Computer Science.

Bluetooth signal is highly fluctuated!

AI solved the problem

PLOS ONE

RESEARCH ARTICLE

Accurate real time localization tracking in a clinical environment using Bluetooth Low Energy and deep learning

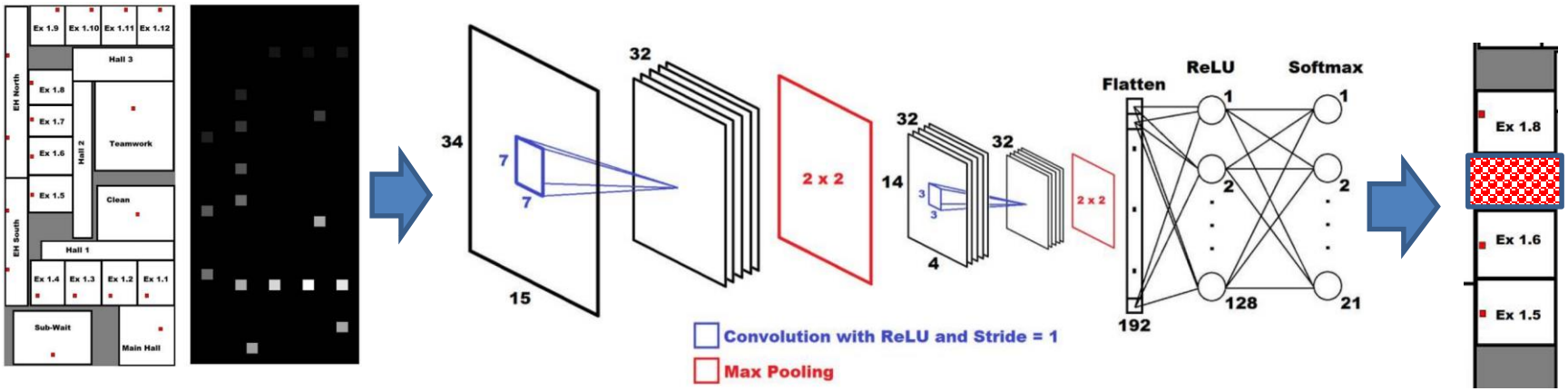
Zohaib Iqbal, Da Luo, Peter Henry, Samaneh Kazemifar, Timothy Rozario, Yulong Yan, Kenneth Westover, Weiguo Lu, Dan Nguyen, Troy Long, Jing Wang, Hak Choy, Steve Jiang*

Medical Artificial Intelligence and Automation Laboratory, Department of Radiation Oncology, University of Texas Southwestern Medical Center, Dallas, TX, United States of America

* Steve.Jiang@utsouthwestern.edu

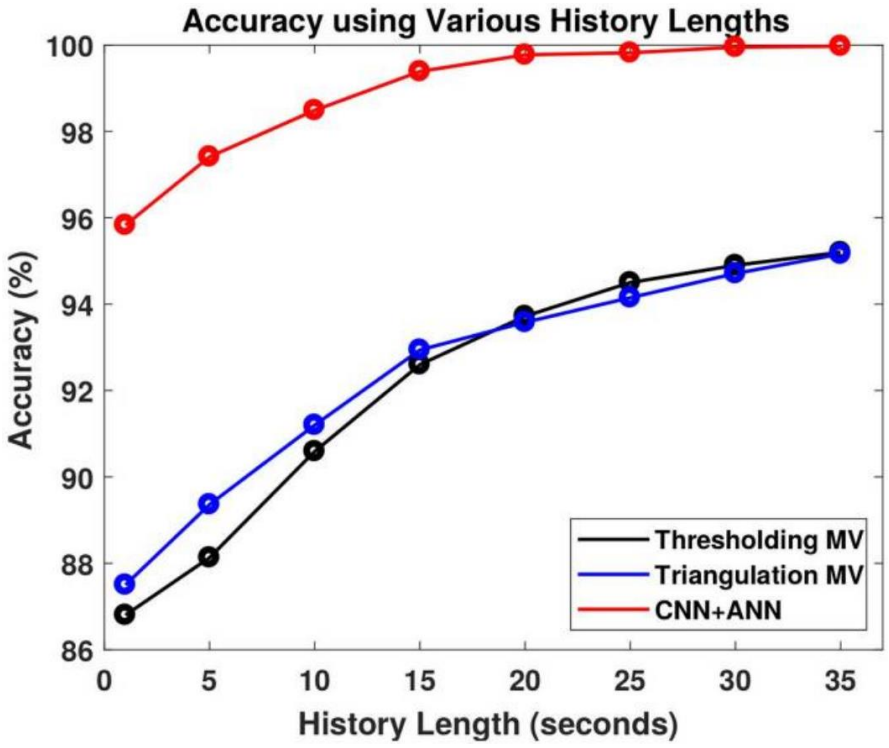
Find location in deep learning

- sensors (> 3) to calculate location
- Simulate effects of building structure and signal interference
- Train the DL database in calibration process (build location patterns)
- Find the closest pattern in the machine learning database



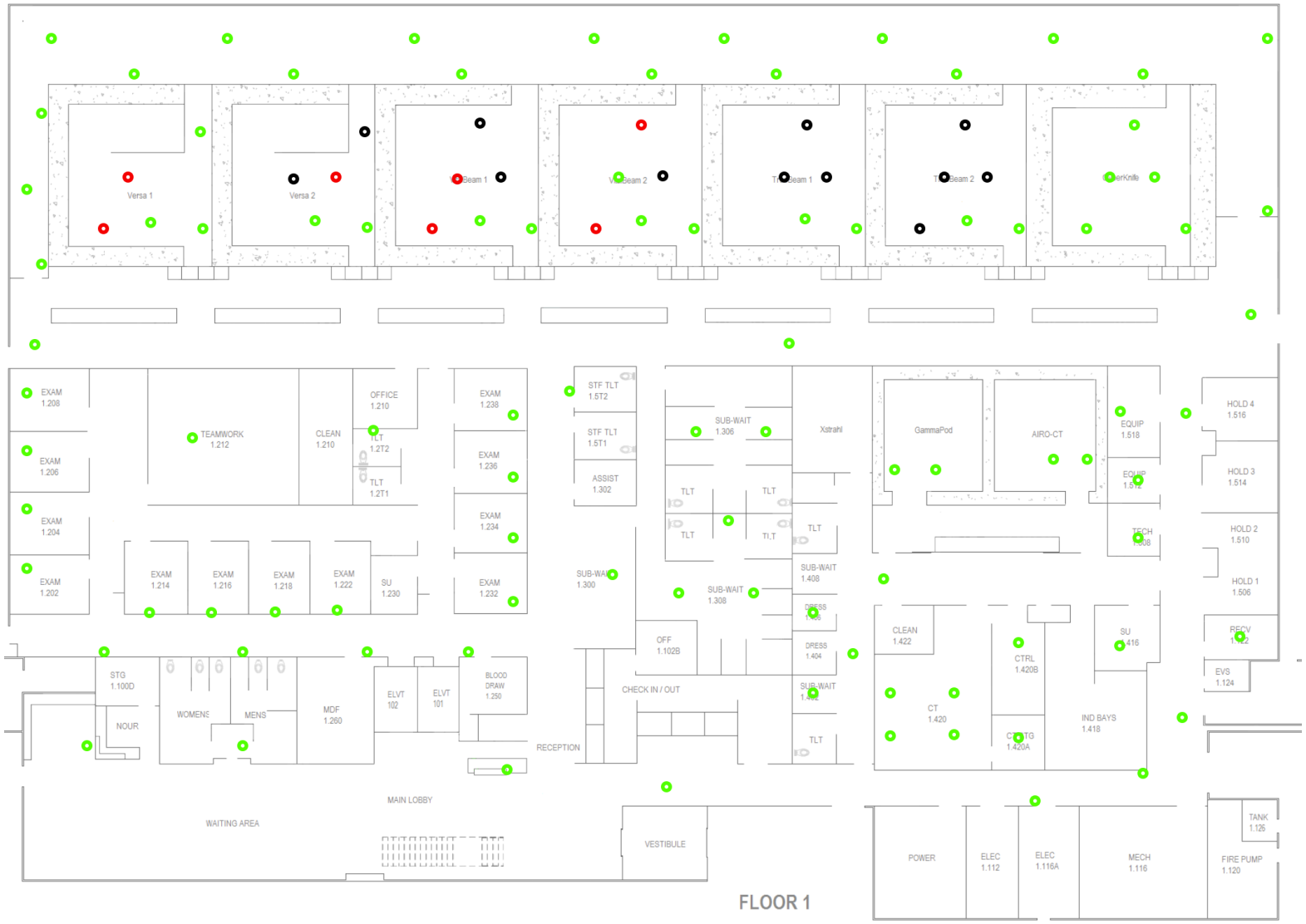
Iqbal et al. 2018, PLoS ONE

Deep Learning is more accurate than traditional methods

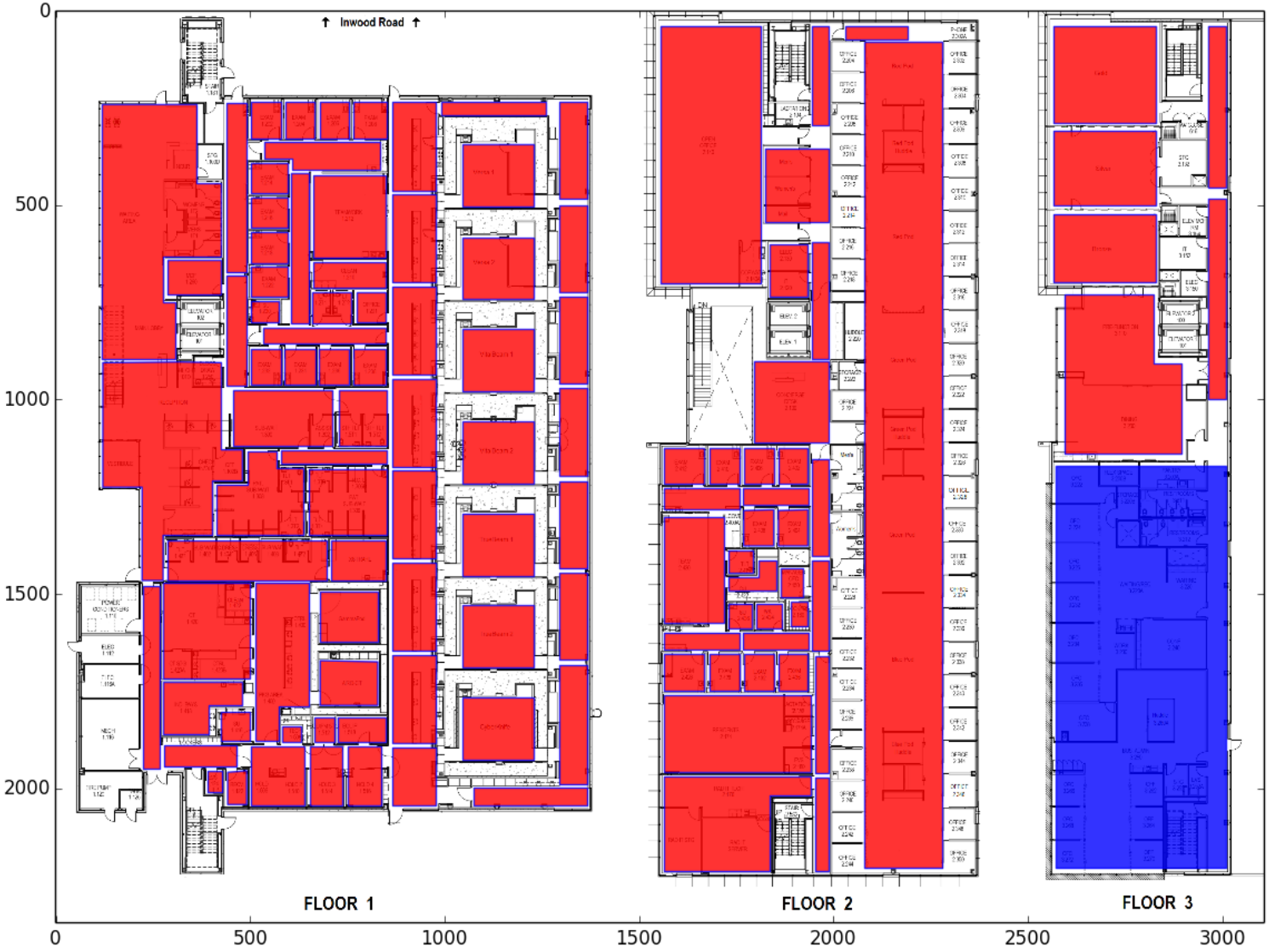


Iqbal et al. 2018, PLoS ONE

Locations of 133 Raspberry Pis



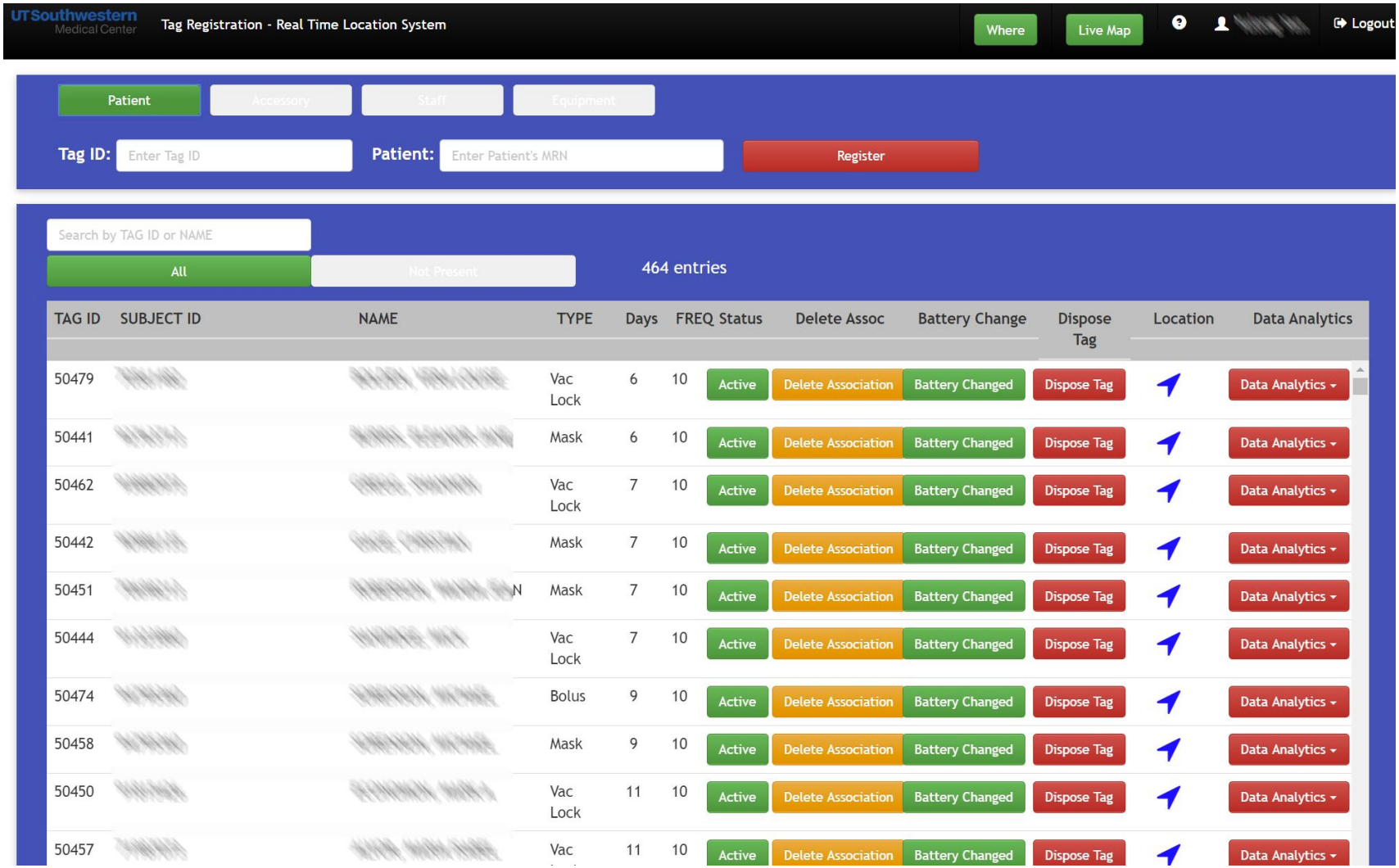
Building is divided into 144 zones



RTLS Applications

- **Tag registration and management**
- **Live Map**
  - Patient location
  - Device location
  - Accessory location
  - Staff location
- **Location “google”**
- **Electronic checklist**
  - Double check patient’s ID
  - Double check accessories
- **Timeboard**
- **Attendance auto check-in**
- **Patient auto check-in**

RTLS tag registration app



Live Map app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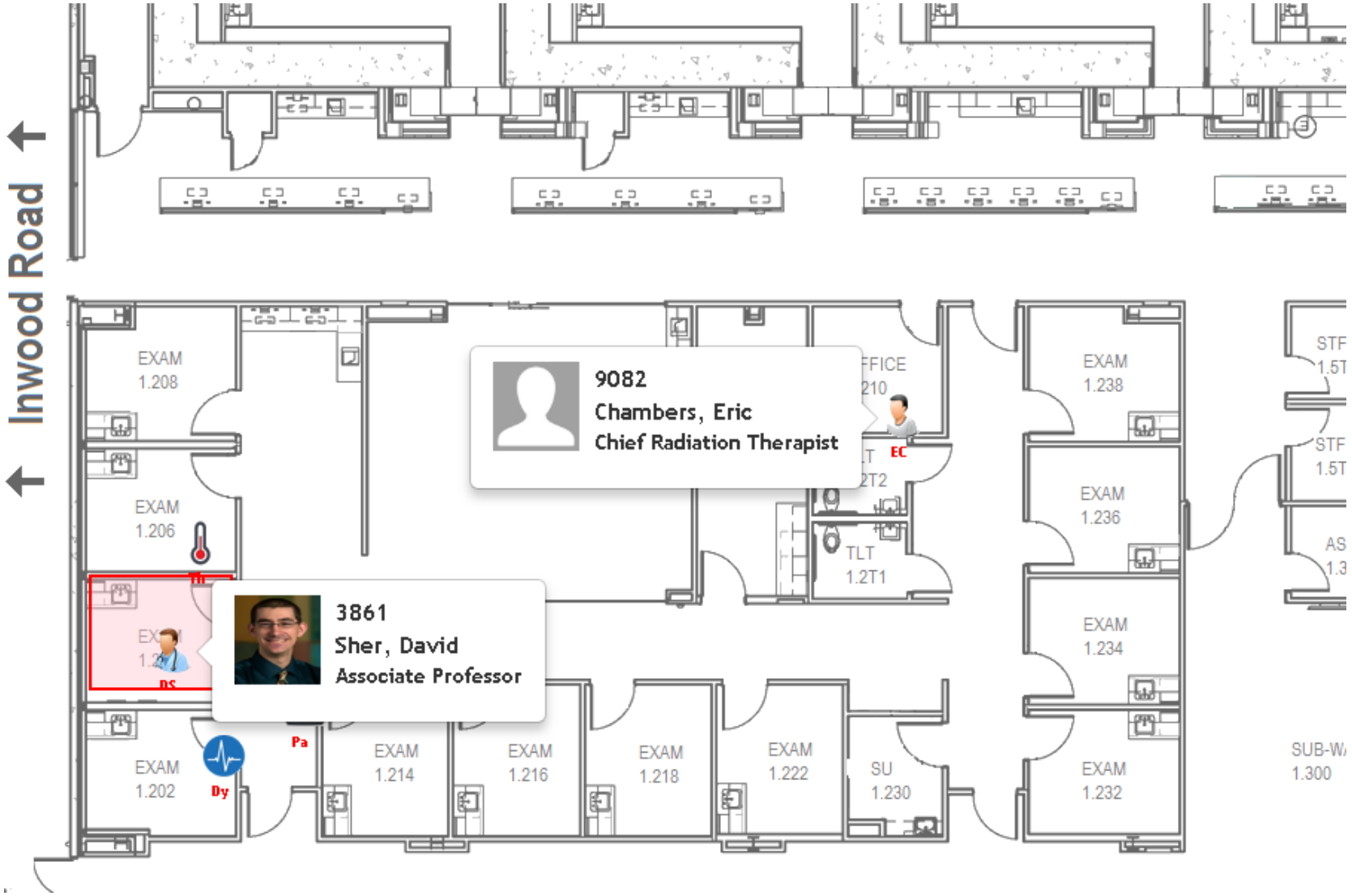
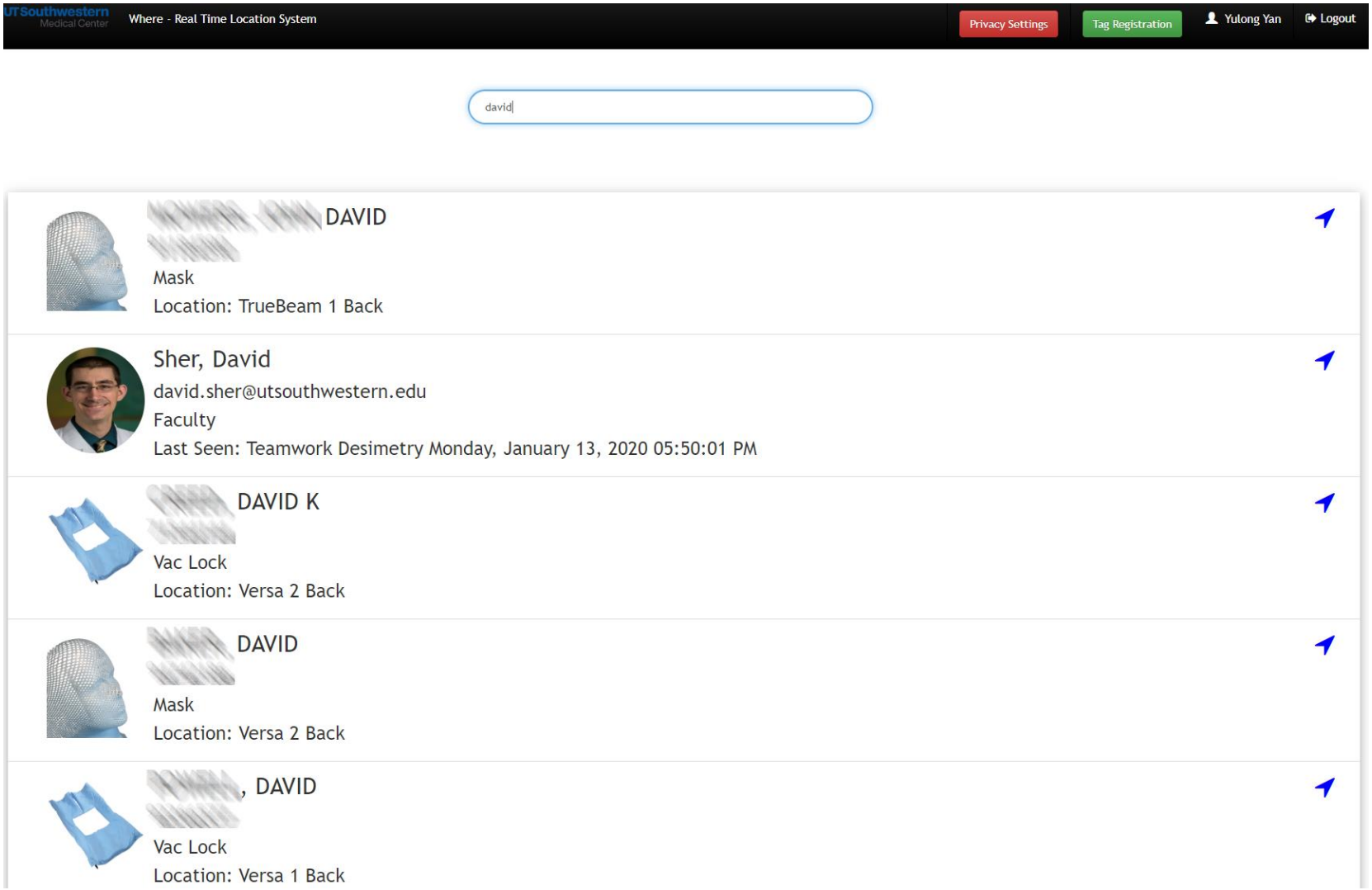
Live Map - Real Time Location System v1.1
Privacy Settings
Tag Registration
Yulong Yan
Logout
Patient
Staff
Equipment
Accessory
Unregistered
Search
Floor 1
Floor 2
Floor 3
Versa 1
Versa 2
VitalBeam 1
VitalBeam 2
TrueBeam 1
TrueBeam 2
CyberKnife
EXAM 1.208
EXAM 1.206
EXAM 1.204
EXAM 1.202
TEAMWORK 1.212
CLEAN 1.210
OFFICE 1.210
TLT 1.2T2
TLT 1.2T1
EXAM 1.238
EXAM 1.236
EXAM 1.214
EXAM 1.216
EXAM 1.218
EXAM 1.222
SU 1.230
EXAM 1.232
STF TLT 1.5T2
STF TLT 1.5T1
ASSIST 1.302
SUB-WAIT 1.306
SUB-WAIT 1.300
SUB-WAIT 1.308
SUB-WAIT 1.408
SUB-WAIT 1.402
Xstrahl
GammaPod
AIRO-CT
EQUIP 1.518
EQUIP 1.512
TECH 1.508
HOLD 4 1.516
HOLD 3 1.514
HOLD 2 1.510
HOLD 1 1.506
RECV 1.122
EVS 1.124
DRESS 1.406
DRESS 1.404
OFF 1.102B
CHECK IN / OUT
RECEPTION
CLEAN 1.422
SU 1.416
CT 1.420
OR STG 1.420A
IND BAYS 1.418
STG 1.100D
NOUR
WOMENS
MENS
MDF 1.260
ELVT 102
ELVT 101
BLOOD DRAW 1.250
MAIN LOBBY
WAITING AREA
VESTIBULE
POWER
ELEC 1.112
ELEC 1.116A
MECH 1.116
TANK 1.126
FIRE PUMP 1.120
FLOOR 1

Live Map app

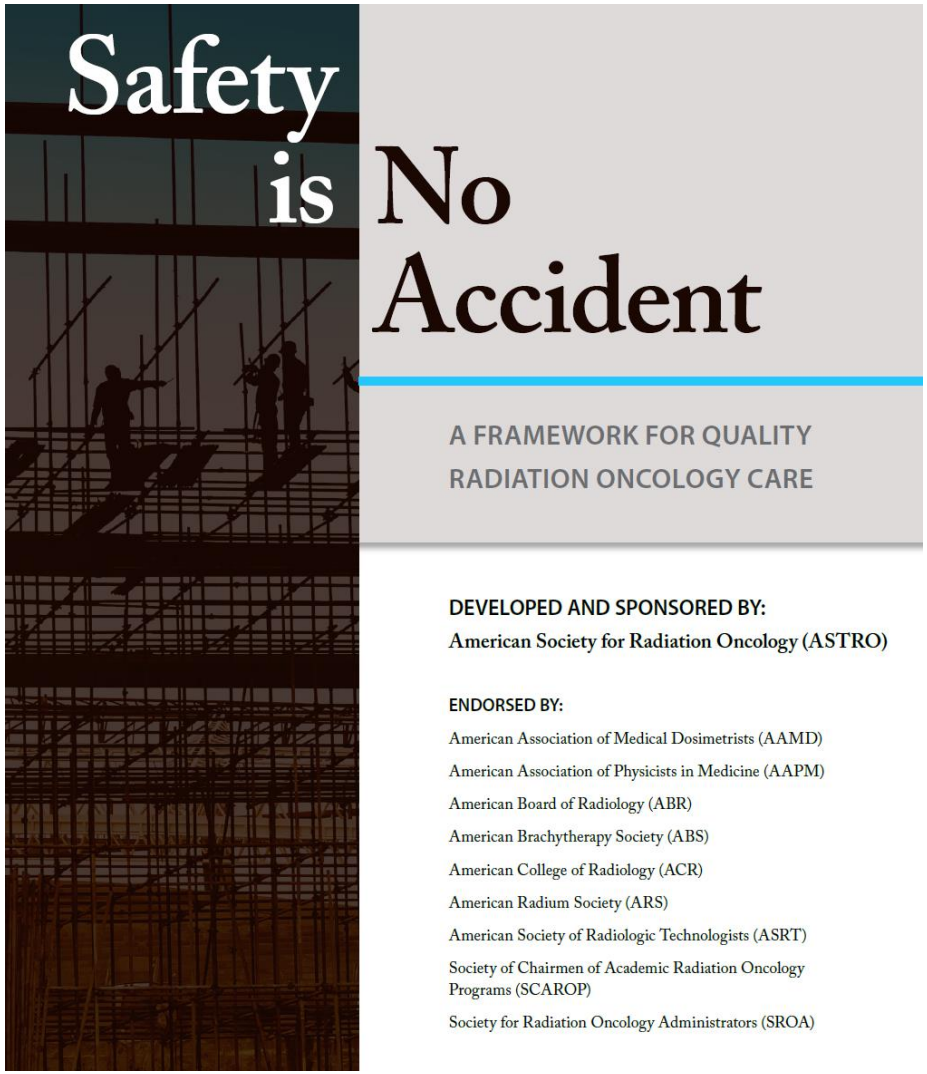

Inwood Road
EXAM 1.208
EXAM 1.206
EXAM 1.202
EXAM 1.214
EXAM 1.216
EXAM 1.218
EXAM 1.222
SU 1.230
EXAM 1.232
EXAM 1.234
EXAM 1.236
EXAM 1.238
TLT 1.2T1
9082
Chambers, Eric
Chief Radiation Therapist
3861
Sher, David
Associate Professor
EC
Dy
Pa

Location “google”



RTLS assisted electronic checklist

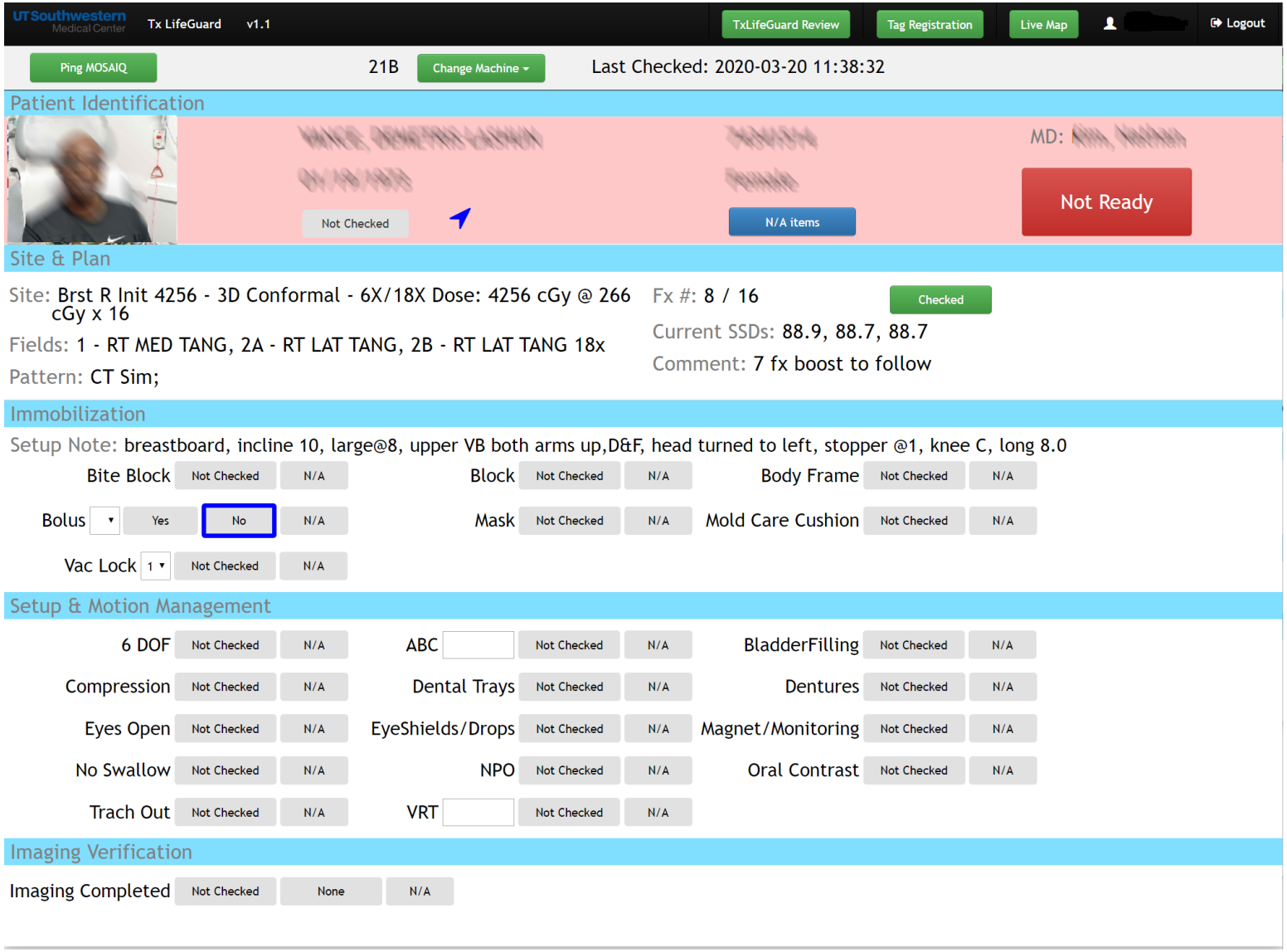
One of the most effective strategies to improve safety of radiation therapy procedures is to use a checklist to verify all relevant items prior to each treatment delivery as suggested by the ASTRO committees.



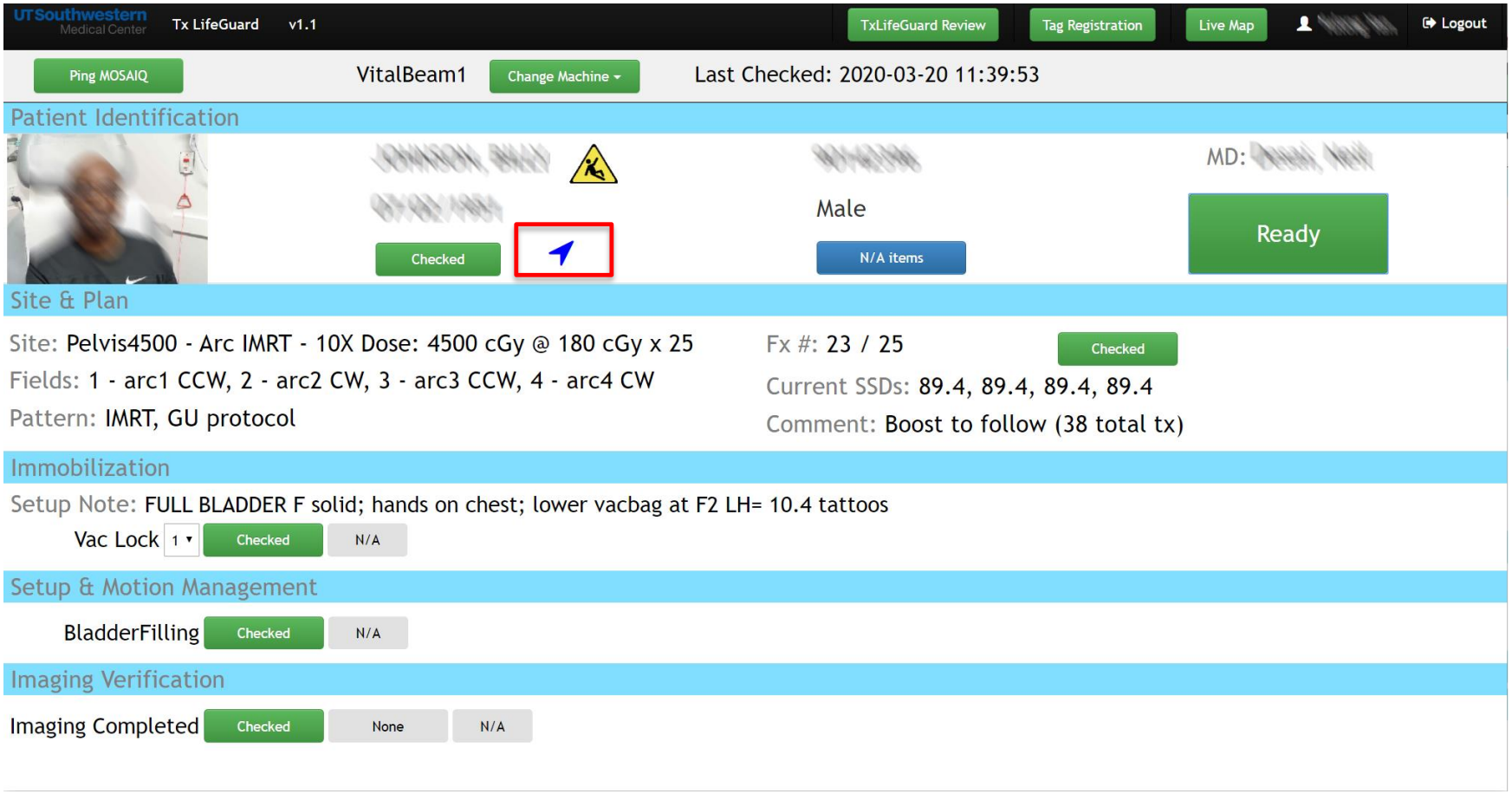
Why use electronic checklist ?

1. Directly linked to treatment console.
2. Patient specific.
3. Can be automated by RTLS.
4. Web-based app that is easy to use and maintain.
5. Backed by a database to facilitate data analysis & investigation.
6. Paperless.

Electronic checklist – superset



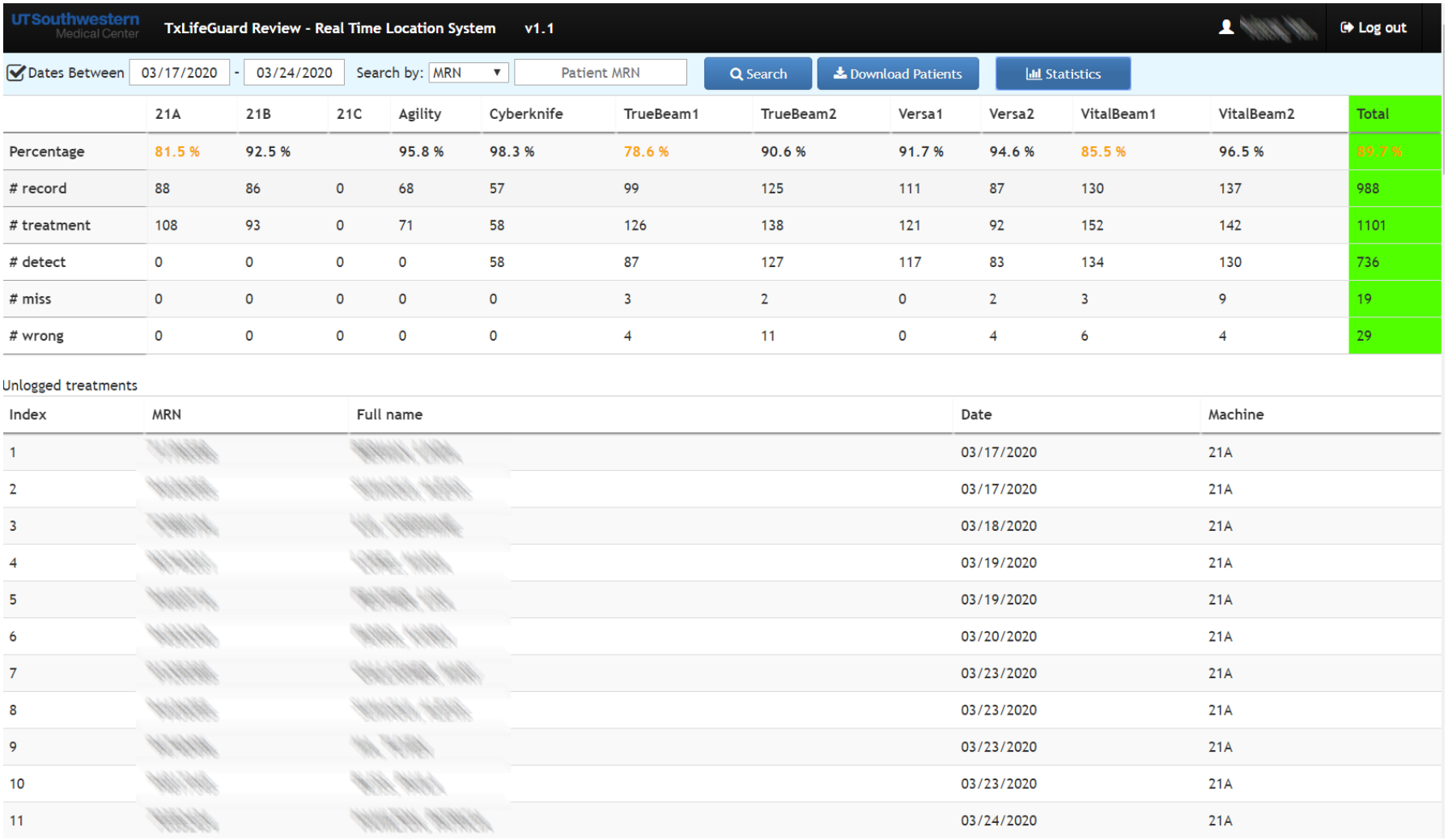
Electronic checklist – patient-specific set



When the arrow button is clicked, the app will tell users where accessories are. So it is also an electronic finder.

Electronic checklist in action

Electronic checklist - analytics



	21A	21B	21C	Agility	Cyberknife	TrueBeam1	TrueBeam2	Versa1	Versa2	VitalBeam1	VitalBeam2	Total
Percentage	81.5 %	92.5 %		95.8 %	98.3 %	78.6 %	90.6 %	91.7 %	94.6 %	85.5 %	96.5 %	89.7 %
# record	88	86	0	68	57	99	125	111	87	130	137	988
# treatment	108	93	0	71	58	126	138	121	92	152	142	1101
# detect	0	0	0	0	58	87	127	117	83	134	130	736
# miss	0	0	0	0	0	3	2	0	2	3	9	19
# wrong	0	0	0	0	0	4	11	0	4	6	4	29

Unlogged treatments

Index	MRN	Full name	Date	Machine
1	[redacted]	[redacted]	03/17/2020	21A
2	[redacted]	[redacted]	03/17/2020	21A
3	[redacted]	[redacted]	03/18/2020	21A
4	[redacted]	[redacted]	03/19/2020	21A
5	[redacted]	[redacted]	03/19/2020	21A
6	[redacted]	[redacted]	03/20/2020	21A
7	[redacted]	[redacted]	03/23/2020	21A
8	[redacted]	[redacted]	03/23/2020	21A
9	[redacted]	[redacted]	03/23/2020	21A
10	[redacted]	[redacted]	03/23/2020	21A
11	[redacted]	[redacted]	03/24/2020	21A

Result of using electronic checklist

The RTLS assisted electronic checklist works well in clinic. Due to automation and minimalistic design, the minor extra work for the care team is rewarded with noticeable improvements on clinical practice. When the care team is getting used to the electronic checklist, it will become even more effective.

	1 year no Lifeguard	4 months with Lifeguard	Projected one year with Lifeguard
Event total	16	4	12
Near miss total	12	3	9
Combined	28	7	21

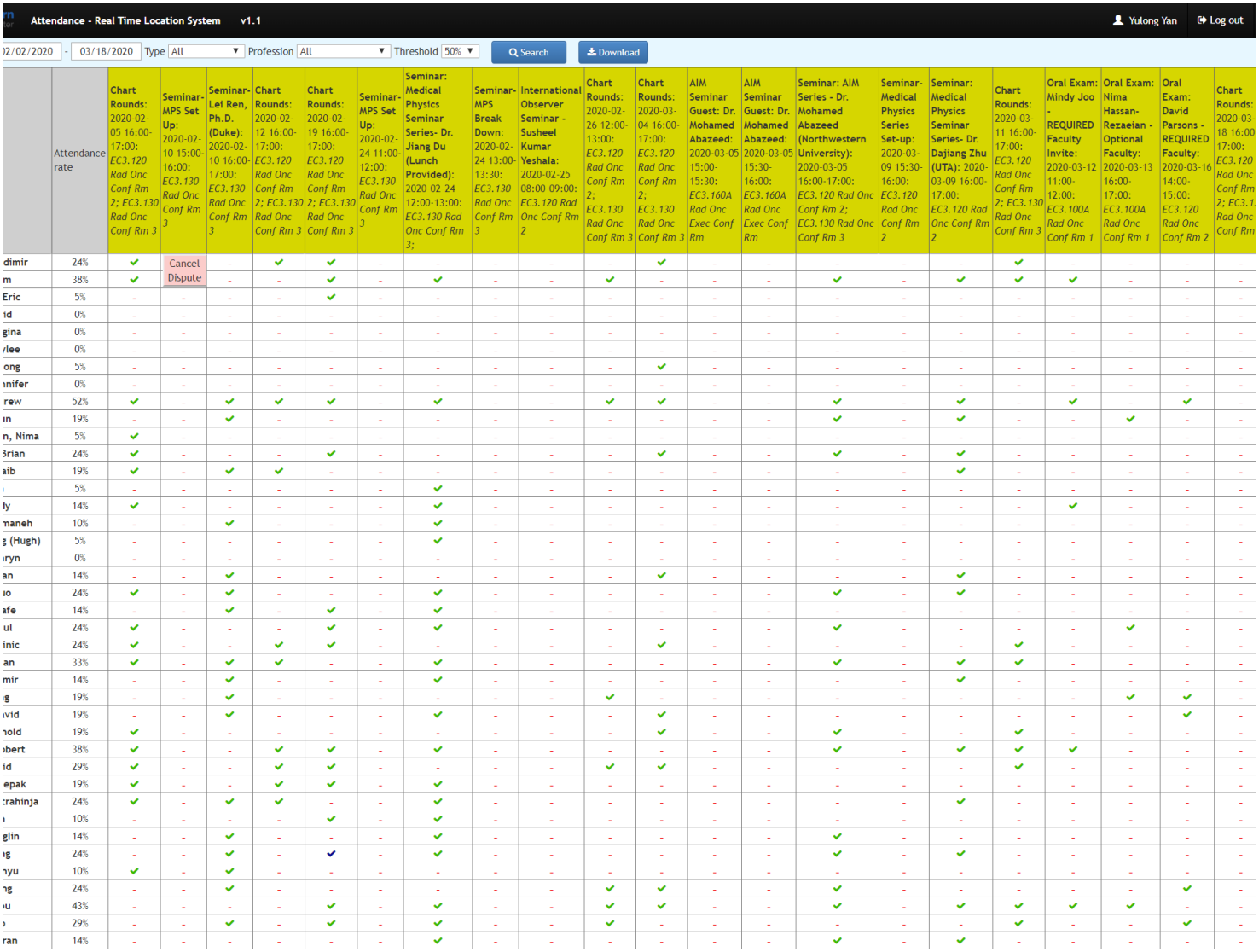
Timeboard – another RTLS app

UTSouthwestern Medical Center | Monday, 1/13/2020, 9:52a | TrueBeam1

Initial	Appointment	Arrival (wait min)	Activity
JB	9:20a	9:15a (36)	IMRT Complex
TP	10:00a	9:38a (14)	IMRT Complex
NM	10:20a	9:47a (4)	IMRT Complex

1. Have patients well informed
2. Talk to patients when they had waited for too long
3. Do adaptive scheduling when able
4. A reminder for care team

Attendance auto check-in



- Chart rounds
- Seminars
- Lectures
- Oral exams

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Potential applications

- **Upon patient's arrival**
  - Patient auto check-in
  - Kiosk / greeting board
  - Appointment reminder/updates to smart phone
- More analytics tools to improve clinical workflow and experience
- …

Automated communications

1. Patient notification
   a. Text to patient's phone (reminder or updates)
   b. Smart bulletin board (machine status)
2. Notification within a care team
   a. Interactive phone book
      1) Email
      2) Pager
      3) Call
   b. Automated reminder in email/pager
      1) Clinical duty next day
      2) Tasks to fulfil
      3) Unfinished work before overdue
3. Interactive PADs

Patient notification

- An automated SMS text messaging program is used to deliver daily appointment time reminders to patients on an elective basis. Automated text messages are sent 2 hours before treatment appointments with appointment-specific information.

(Jun Tan, et. al., "Automated Text Message Reminders Improve Radiation Therapy Compliance," IJOBP, Vol. 103, No. 5, pp. 1045e1052, 2019. DOI: https://doi.org/10.1016/j.ijrobp.2018.11.050)

Results of patient notification

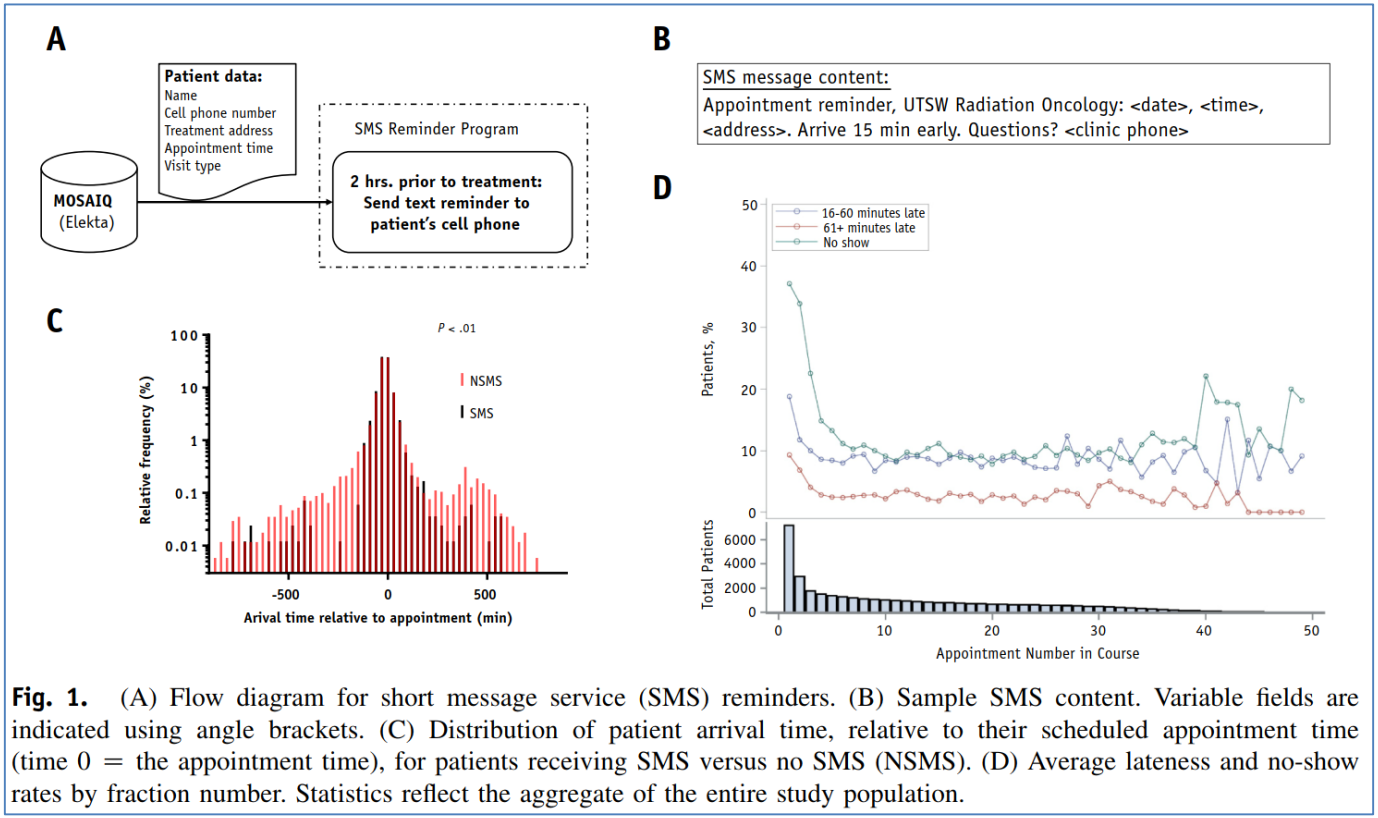


Fig. 1. (A) Flow diagram for short message service (SMS) reminders. (B) Sample SMS content. Variable fields are indicated using angle brackets. (C) Distribution of patient arrival time, relative to their scheduled appointment time (time 0 = the appointment time), for patients receiving SMS versus no SMS (NSMS). (D) Average lateness and no-show rates by fraction number. Statistics reflect the aggregate of the entire study population.

Machine status bulletin board

- Whether the treatments on each machine have been on schedule.
- The physicians seeing the patients.
- The machine doctor.

Machine status bulletin board

5:27:03 PM

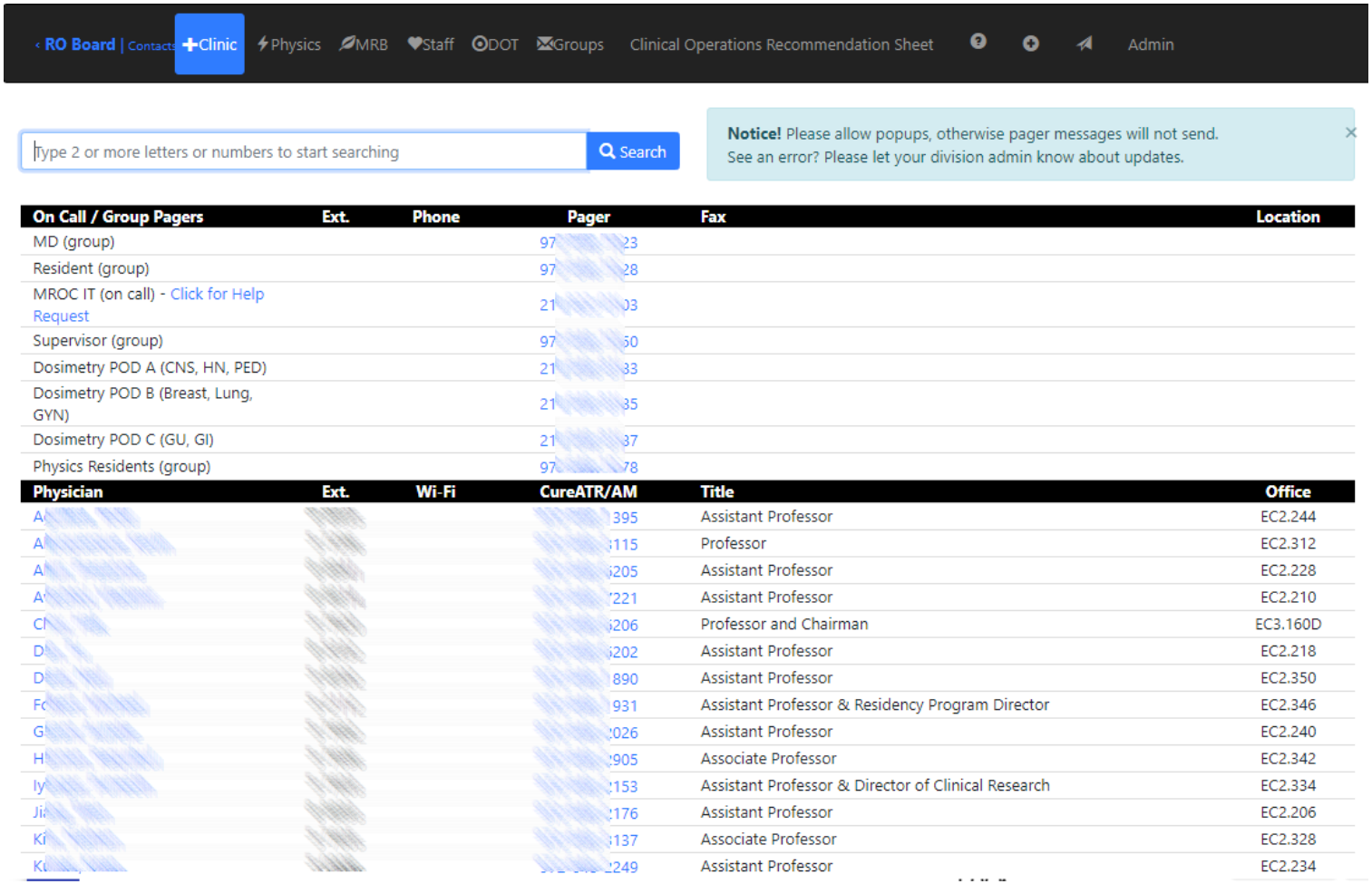
Machine Status

1	On time
2	35 min behind
3	On time
4	On time
5	more than 60 min behind
6	25 min behind
7	On time

Weekly MD Visits*

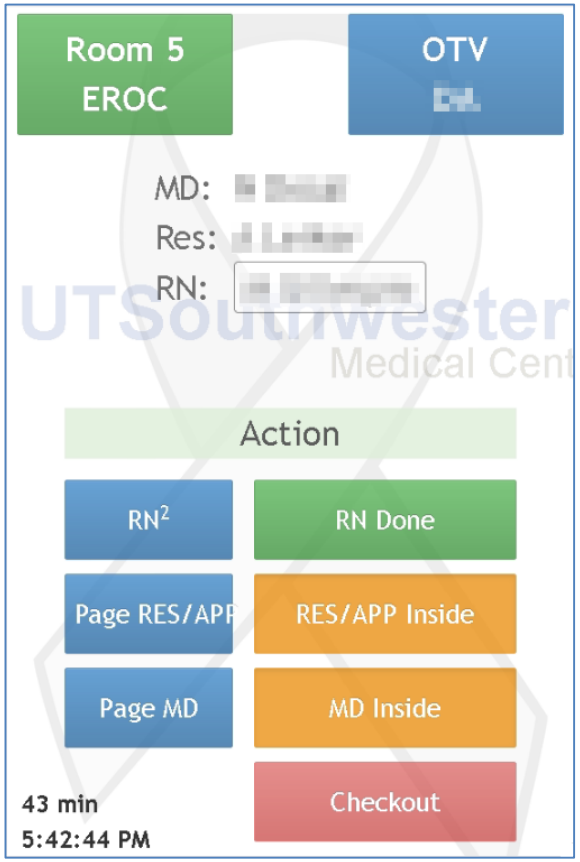
*Physicians shown above are seeing their patients who are on treatment today

Interactive searchable phonebook



Interactive Pads for exam rooms

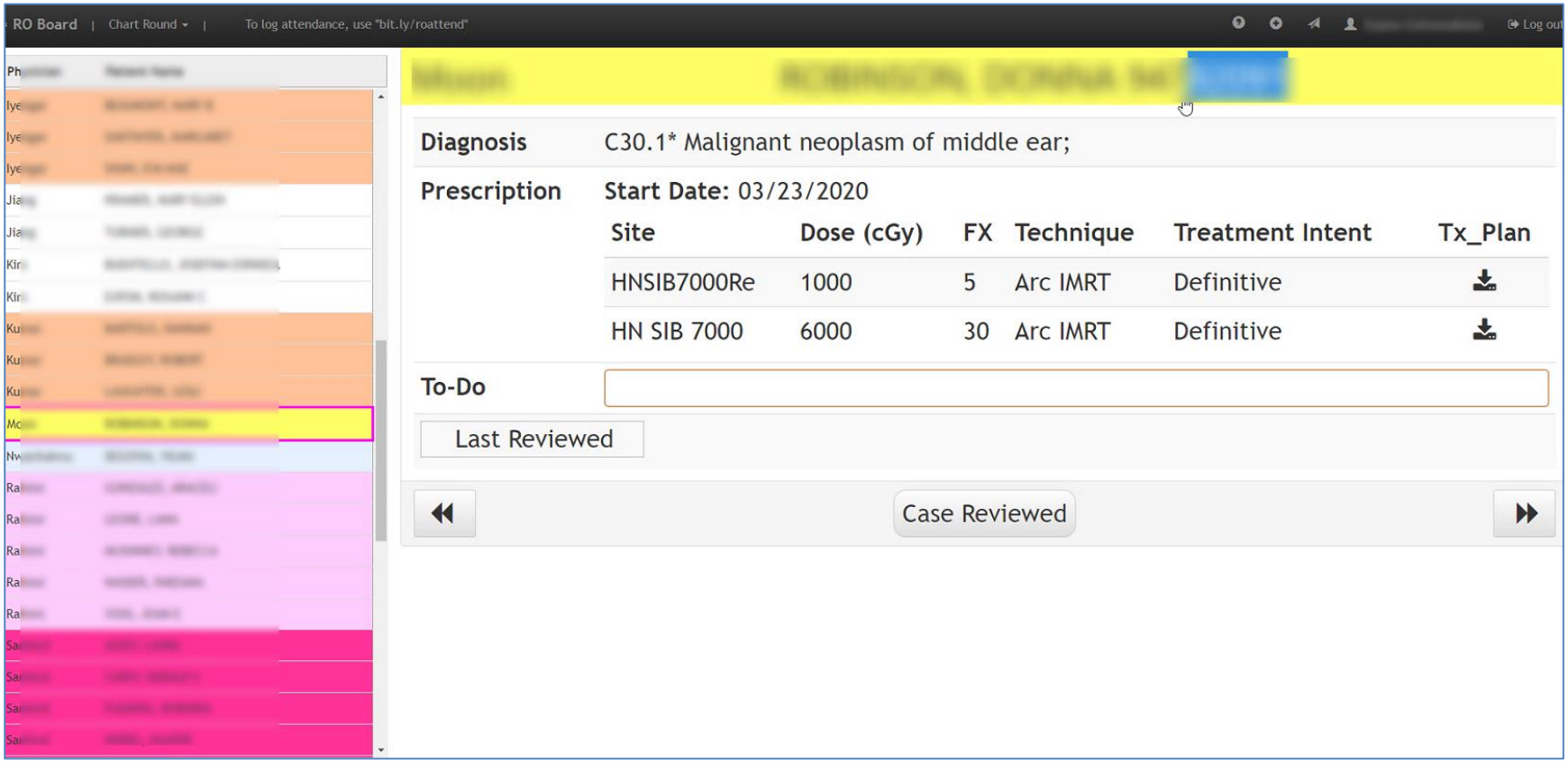
- Every exam room has a tablet outside the room by the door.
- Patient in exam room, check-in and – out time.
- Staff members in room, check-in and – out time.
- Paging a staff by clicking a function button.
- Holding room for



Automated chart rounds

- A list of patients sorted by disease group and physicians.
- Plan documents can be downloaded and reviewed
- Enter review comments.
- Log treatment break cause.
- Generate attendance report.

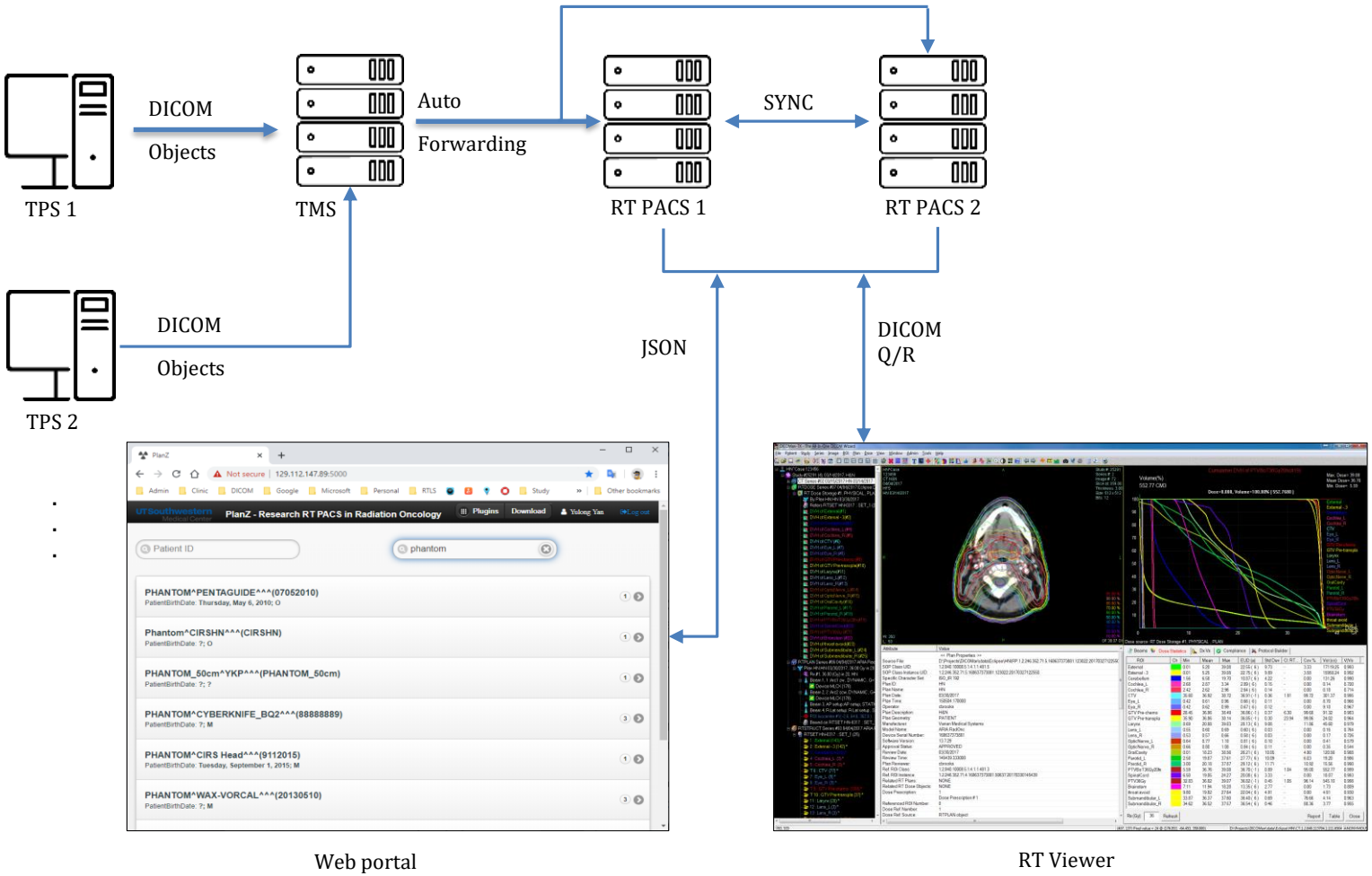
Chart rounds, patient list and review



Automated plan archiving - DICOM

- DICOM stands for Digital Imaging and Communication in Medicine.
- It is the standard devised by the National Electrical Manufacturers Association (NEMA) in association with American College of Radiology (ACR), aiming to facilitate interoperability between systems claiming DICOM conformance in a multi-vendor environment.
- DICOM modalities for radiation therapy are also called DICOM RT. A RT plan can be exported and archived in a Picture Archiving and Communication System (PACS).
- A PACS equipped with a RT viewer is called RT PACS.

Automated plan archiving



Web portal

RT Viewer

Why do we need a RT PACS ?

- A secondary plan backup system in addition to vendor provided backup solutions.
- Standardized data format, is vendor independent.
- Interchangeable between different systems.
- Fast data retrieval for clinical practice and research.
- Much longer “shelf life”.

In short, things are easier in DICOM.

SAM Questions

Question 1

What is RTLS ?

A. A Real-Time Location System that tracks assets and people for a better workflow.

B. A Radiation Therapy Localization System that localizes and tracks tumor in real time.

C. A Real-Time Localization System that localizes and tracks moving targets.

D. A Radiation Therapy Lifeguard System to improve patient's safety in a radiation therapy clinic.

Question 2

Ways to improve safety of radiation therapy procedures.

A. Check patient's identity in at least two methods.

B. Match treatment plan and its treating site.

C. Use a patient-specific checklist to verify the completion of all checks.

D. All of above.

Question 3

Better communications within a care team, and between patients and care team will

A. increase clinical operation cost and interrupt clinical procedures too often.

B. improve clinical operation efficiency and patient experience.

C. improve patient safety.

D. only decrease patients' wait time.

Question 4

Can radiation therapy plans be archived in DICOM objects ?

A. No, radiation therapy plans cannot be archived in DICOM format.

B. Yes.