MICHIGAN MEDICINE

Automation in Treatment Planning QA

Toward Self-driving Patient Care

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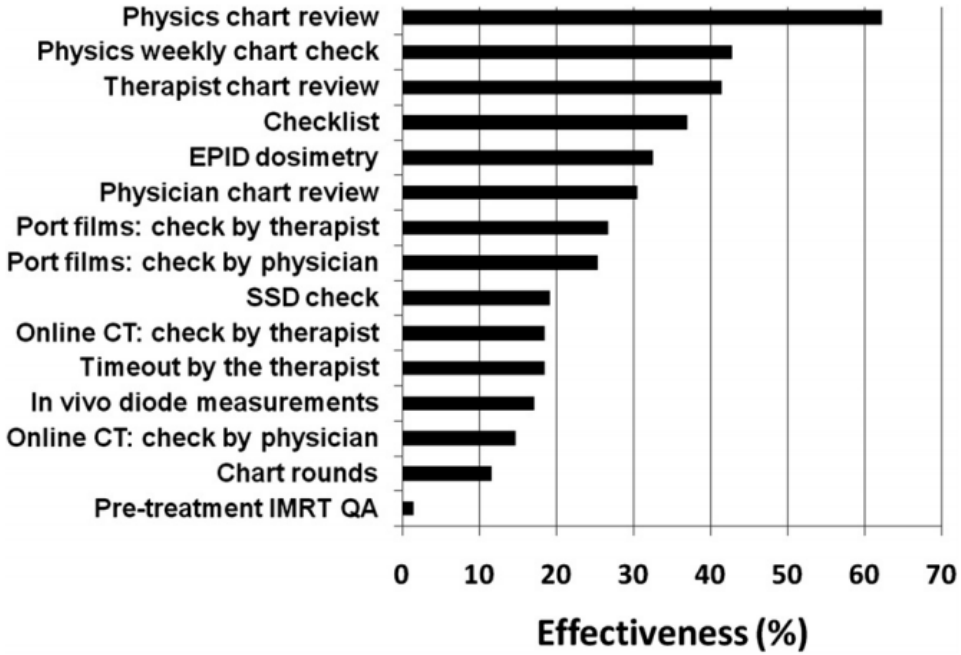
RADIATION ONCOLOGY

Physics chart review effectiveness

- The physics plan check has the *potential* to be one of the most effective checks



Ford et al., Int J Radiation Oncol Biol Phys. 84(3):e263-269 (2012).

Physics chart review effectiveness

TABLE II. Number of events from the departmental and SAFRON databases potentially detectable by the physics plan review.

	Potentially detectable					
	Detected prior to review	Detected at review	Not detected	Total	Not detectable Total	All Total
Departmental	55	47	78	180 (51%)	176 (49%)	356
SAFRON	0	0	66	66 (81%)	15 (19%)	81

- Processes that rely on human intervention are inherently less effective

Gopan et al., Med Phys. 43(9):5181 (2016).

Automated Plan Checking in Radiotherapy

- Automation and safety barriers are the most effective safety methods for reducing errors (SINA, 2012)
- Specific aspects of the physics plan evaluation are ideally suited for such automation
- Already investigated / implemented by many institutions

- Furhang EE, Dolan J, Sillanpaa JK, Harrison LB. **Automating the initial physics chart checking process.** J Appl Clin Med Phys. 2009;10(1):2855
- Breen SL, Zhang B. **Audit of an automated checklist for quality control of radiotherapy treatment plans.** Radiother Oncol. 2010;97(3):579–84
- Yang D, Moore KL. **Automated radiotherapy treatment plan integrity verification.** Med Phys. 2012;39(3):1542–51
- Olsen LA, Robinson CG, He GR, et al. **Automated radiation therapy treatment plan workflow using a commercial application programming interface.** Pract Radiat Oncol. 2013;4(6):358–67
- Halabi T, Lu H. **Automating checks of plan check automation.** J Appl Clin Med Phys.2014;15(4):1–8
- Li HH, Ms YW, Yang D, Mutic S. **Software tool for physics chart checks.** Pract Radiat Oncol. 2014;4(6):e217–e225
- Dewhurst JM, Lowe M, Hardy MJ, Christopher J, Whitehurst P, Rowbottom CG. **AutoLock: a semiautomated system for radiotherapy treatment plan quality control.** J Appl Clin Med Phys. 2015;16(3):339–50
- Covington EL, Chen X, Younge KC, et al. **Improving treatment plan evaluation with automation.** J Appl Clin Med Phys. 2016;17(6):16-31

Background and history of Plan Checker Tool

- 2013, In-house → Commercial planning system
  - Track errors via in-house incident learning system
  - Gathered information on treatment unit delays
    - Hand-offs, interruptions and non-standard work can lead to problems
    - Prescription mismatches, missing imaging fields, incorrect field names

Dosimetry and Physics Check Elements

- Is the site correct? Laterality?
- Are the documents approved?
- Any mistakes / omissions on the planning directive?
- OARs correct? Approved? Any missing? Stray points?
- Margins correct?
- ITV needed? Correct and documented?
- Correct dataset used? Named correctly?
- Registration required? Is there more than one? Was it used appropriately?
- Is the imaging good enough for what
- Orientation documented correctly?
- Has the patient had previous treatm
  records been uploaded into docume
- Is a physics consult needed? How ab
  consult?
- Did SBRT rounds get completed?
- Anything on the directive not make sense?
- Does the plan meet the physician-defined planning goals?
- Could the plan be improved with a different geometry / modality?
- Is the dose prescription correct?
- Is the course named correctly? How about the plan?
- Plan normalization ok?
- Calculation model correct? How about the calculation resolution?
- Fields named correctly? In the right order? Shaped correctly?
- EDW used appropriately?
- How about FiF? Does the unmerged plan match the merged plan? Are the MU correct? Enough time to complete the field? Does the Mobius document correctly reflect the segments?
- Appropriate energy used?
- Is different imaging needed?
- Is the origin in the right place?
- Is there more than one iso? Is that documented clearly?
- Do all the parameters in Prescribe Treatment match the plan?
- Is the reference point in the right spot? Does it have the right dose limits?
- Does the plan have bolus? Is the structure there? Is it attached to the fields? Is it attached to any fields it shouldn't be attached to? Is it documented on the setup sheet?
- Does the plan have a tray? Is it the correct one? Does it have the correct code?
- Does the plan have a cutout? Is it the correct size? Was the right applicator used? Does it have the correct code?
- Were the optimization objectives designed correctly? Optimized with the correct resolution?
- All the field dose rates correct?
- Tolerance tables added and correct?
- Plan scheduling completed? Are the imaging templates attached?
- Has the plan been reviewed by the physician? Planning
  etrist?
  oved? Is the plan linked to it?
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  e match anatomy?
  In the right direction? What about
  angle of the SSD?
  correct labelling VM, IM, FiF, SB
  roblems? Clearance? Did it have a structure to calc dose to or a norm point? Is it uploaded and approved?
- Do any of the setup fields have MLCs?
- Are any of the scheduled machines going to be a problem?
- Are all the instructions to the therapists clear?
- Any patient alerts needed?
- Does the patient have a CIED? Are the questionnaires done?
- Is the carepath correct?
- Should the plan be treatment approved? Did I remember to do this?
- Do I need to follow up on anything after QA?

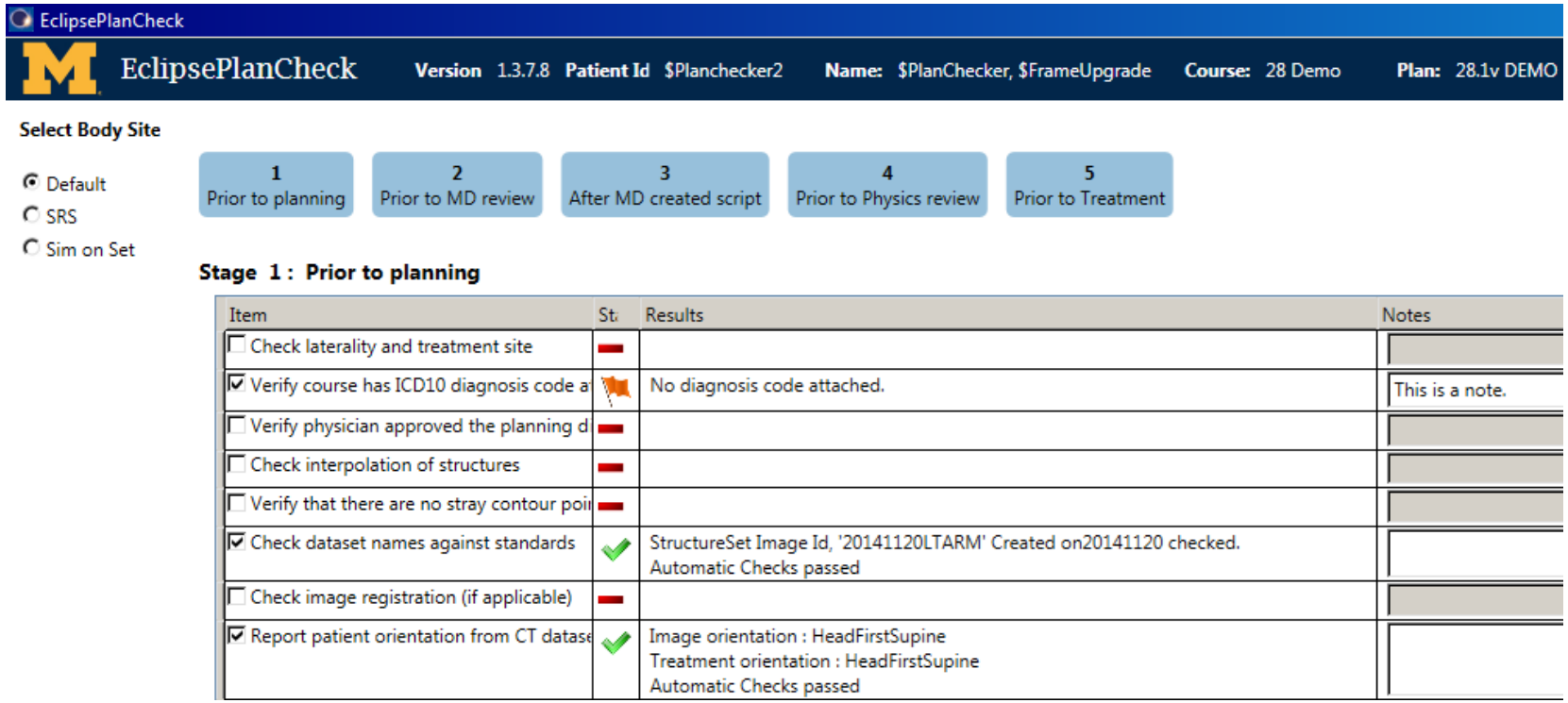
Is this the best treatment plan?
What about the physics?

Background and history of Plan Checker Tool

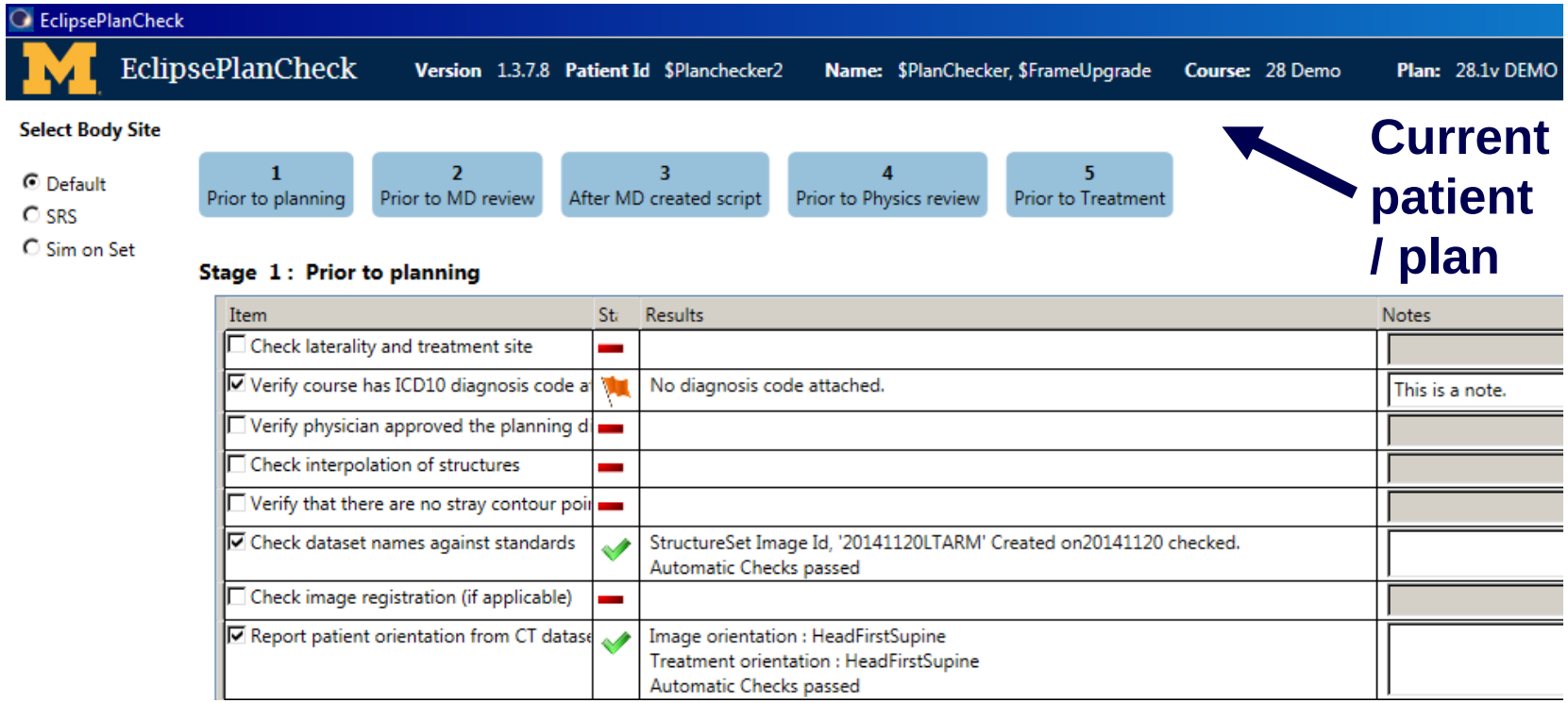
- Used data from treatment units and incident learning system to identify QA elements for automatic, semi-automatic, and manual checks
- Initiated collaboration with Memorial Sloan Kettering Cancer Center in 2014

E. L. Covington et al., Improving Plan Quality with Automation of Treatment Plan Checks. Journal of Applied Clinical Medical Physics 17(6): 16-31, 2016.

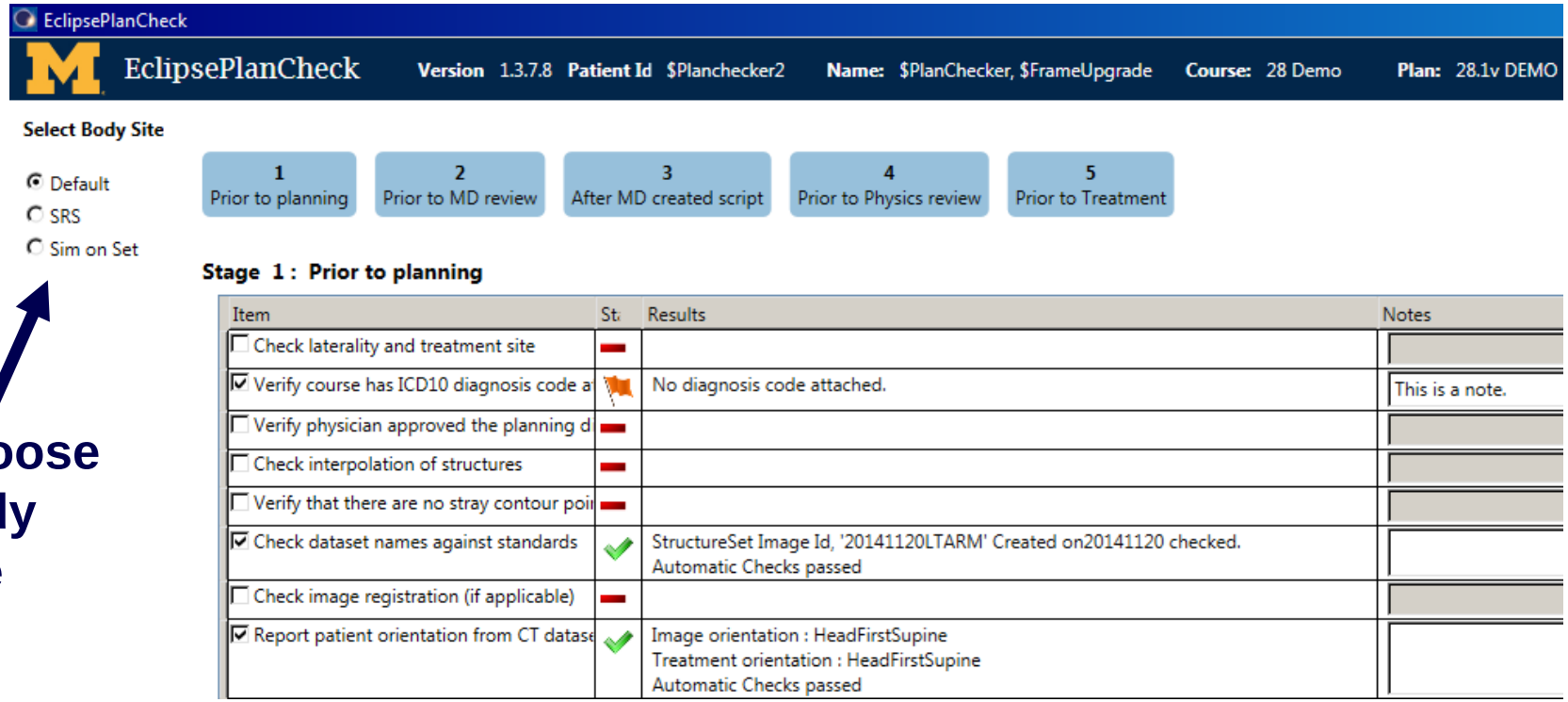
Plan Checker Tool Interface



Plan Checker Tool Interface

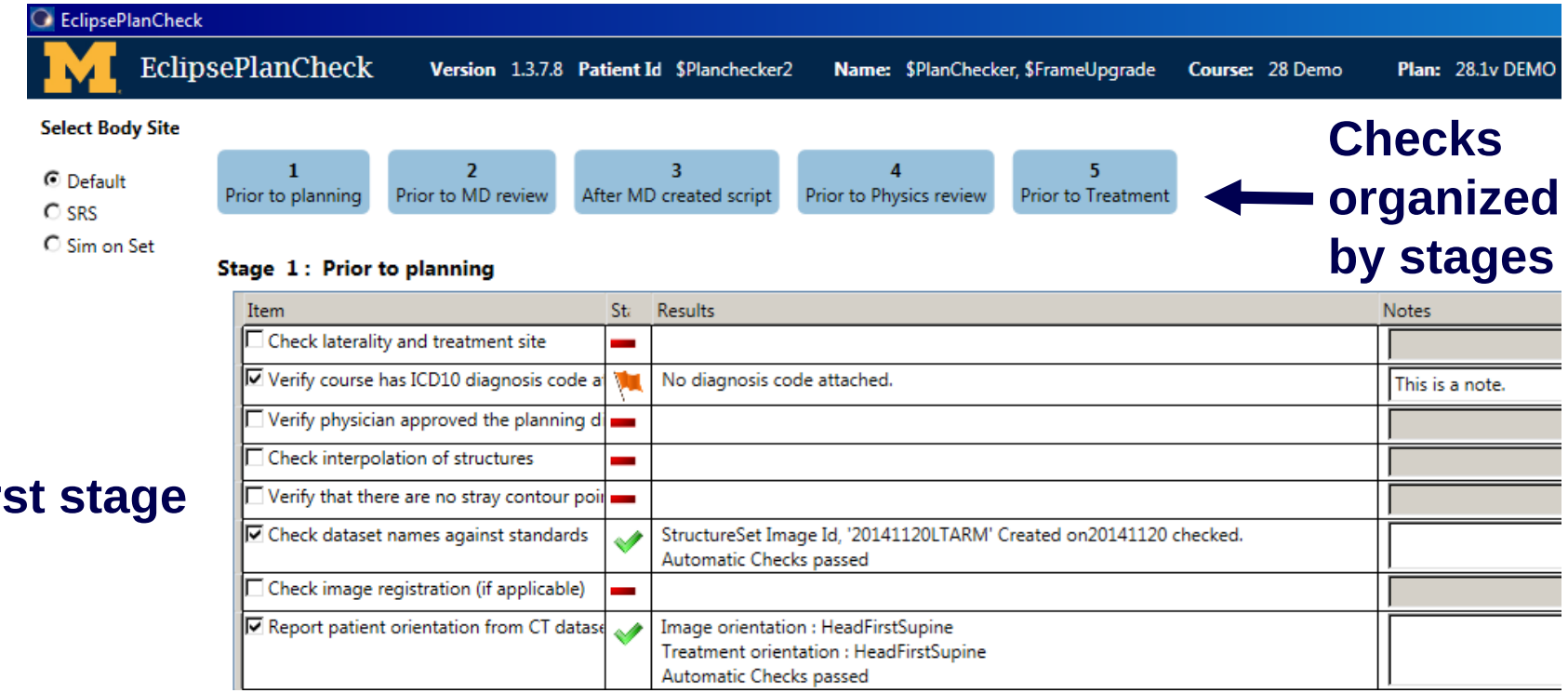


Plan Checker Tool Interface



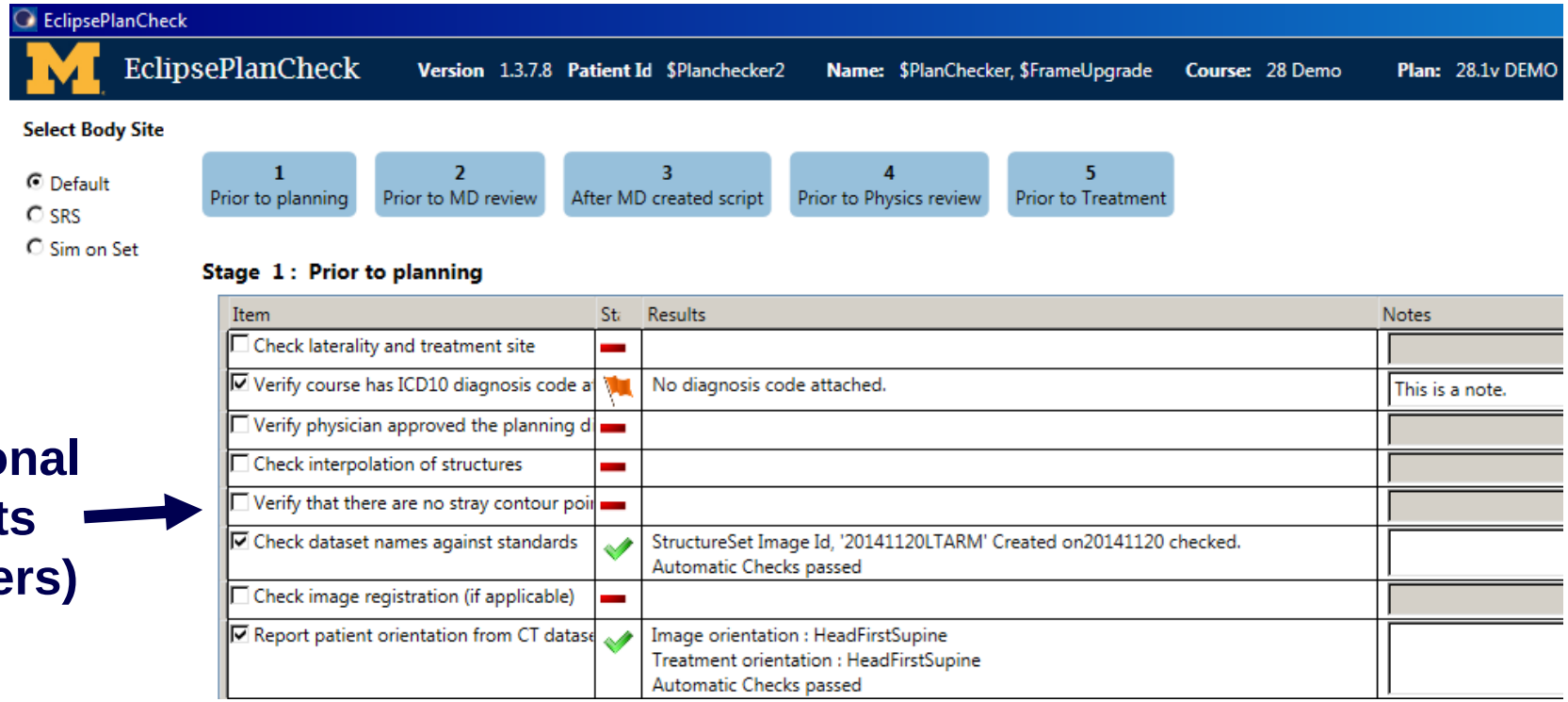
Choose body site

Plan Checker Tool Interface



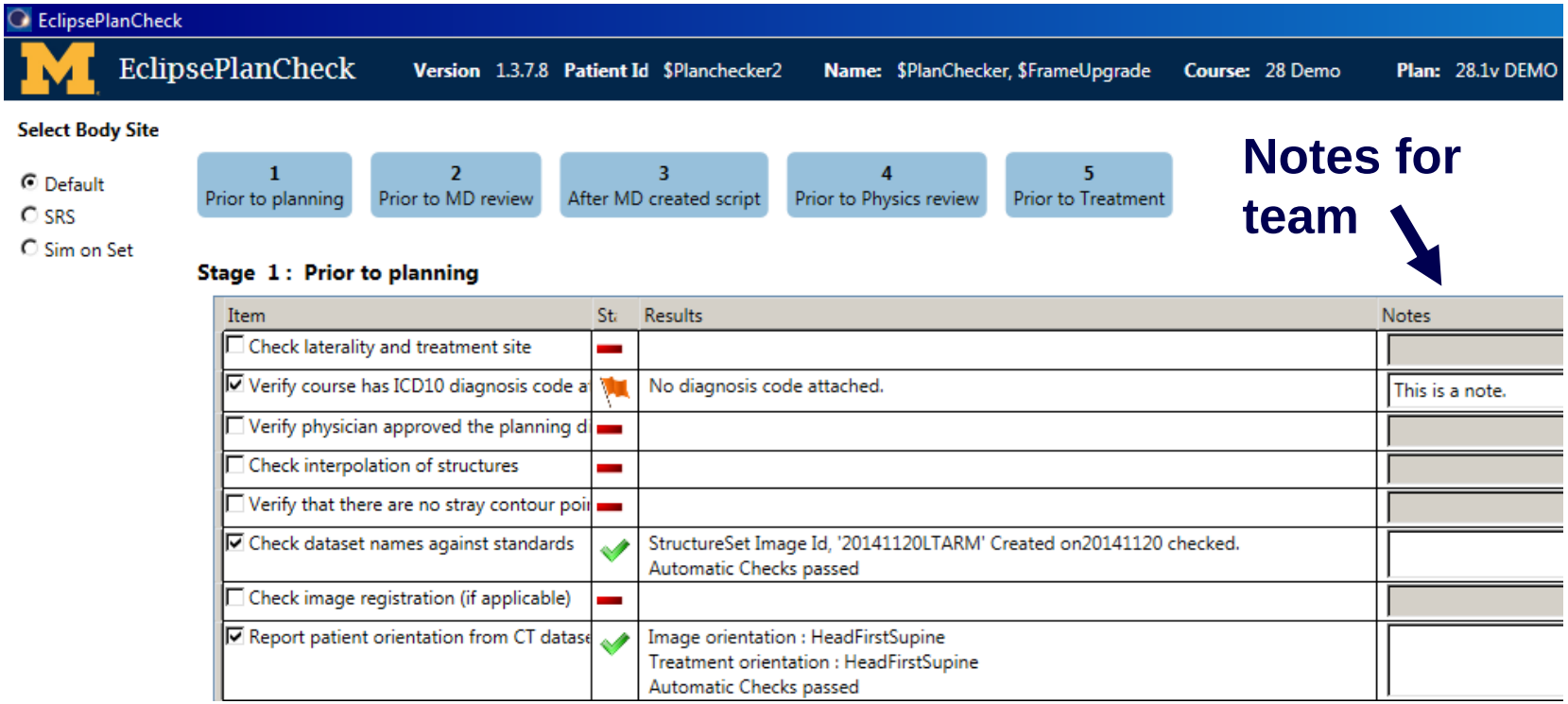
First stage

Plan Checker Tool Interface



Functional subunits (checkers) →

Plan Checker Tool Interface



Plan Checker Tool Interface

Graphical depiction of results / checker status

Report patient orientation from CT dataset		Image orientation : HeadFirstSupine Treatment orientation : HeadFirstSupine Automatic Checks passed
Report number of CT slices in planning dataset		Number of CT slices in planning dataset '20141120LTARM' is '144'.
Verify number of CT slices against move sheet		
Verify 3D vs IMRT Carepath		This is a VMAT plan but may be on a 3D carepath. Please confirm carepath is correct

Automation considerations

- ILS-driven data is a must
- Error messaging – is it clear enough for easy / fast interpretation?
- False flags and complacency – will the user read all of the output?
- Communication with team members

Error messaging

Item	Status	Results
Verify field names	**Flagged**	'CW_T90' does not follow standard naming convention. 'CW' 'CCW' follow standard naming convention. 'CW' 'CCW' 'CW_T90' are labeled with the correct direction. 'kV AP' 'kV RLAT' 'CBCT' follow standard naming convention.

Error messaging

Item	Status	Results
Verify field names	Flagged	'CW_T90' does not follow standard naming convention. ~~'CW' 'CCW' follow standard naming convention.~~ ~~'CW' 'CCW' 'CW_T90' are labeled with the correct direction.~~ ~~'kV-AP' 'kV-RLAT' 'CBCT' follow standard naming convention.~~

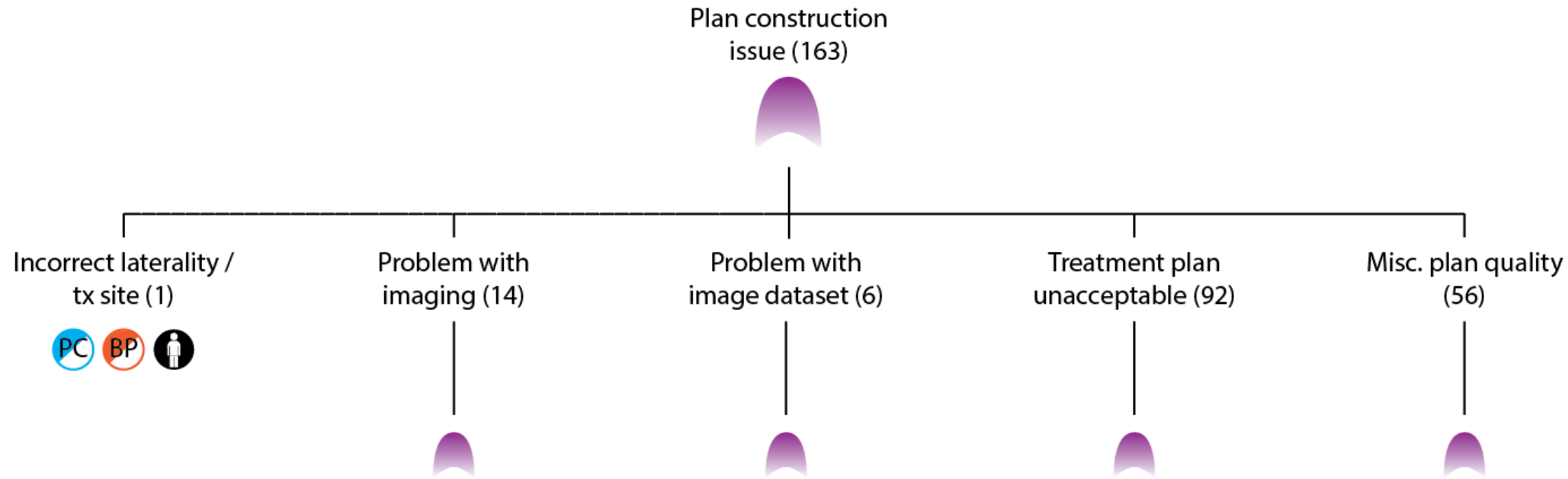
‘CW_T90’ should be ‘CW_T45’

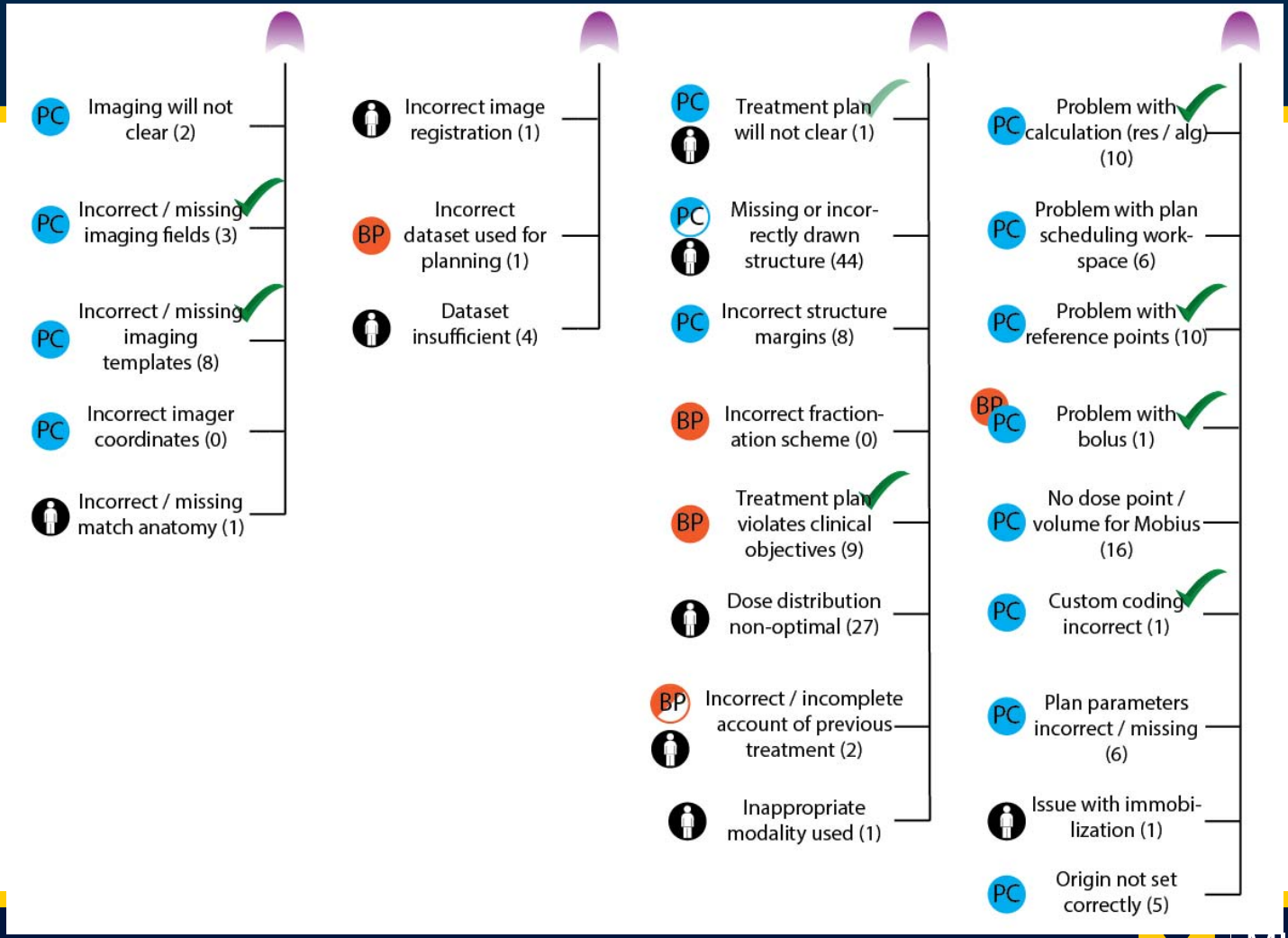
False flags

Report patient orientation from CT dataset		Image orientation : HeadFirstSupine Treatment orientation : HeadFirstSupine Automatic Checks passed
Report number of CT slices in planning dataset		Number of CT slices in planning dataset '20141120LTARM' is '144'.
Verify number of CT slices against move sheet		
Verify 3D vs IMRT Carepath		This is a VMAT plan but may be on a 3D carepath. Please confirm carepath is correct

Checker that consistently flagged for a subset of plans that have a correct Care Path

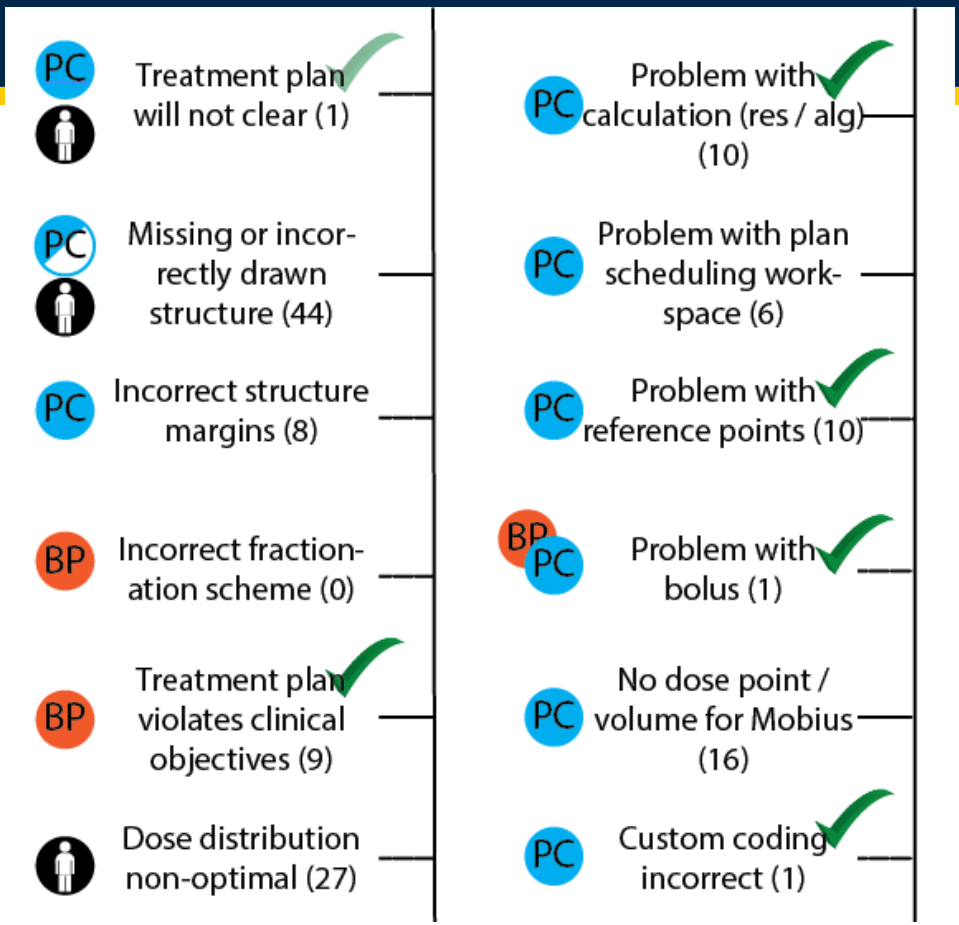
Errors caught by Physics Plan Check, 1 year period of 3/17-3/18


Plan construction issue (163)
Incorrect laterality / tx site (1)
PC
BP
Problem with imaging (14)
Problem with image dataset (6)
Treatment plan unacceptable (92)
Misc. plan quality (56)


PC Imaging will not clear (2)
PC Incorrect / missing imaging fields (3)
PC Incorrect / missing imaging templates (8)
PC Incorrect imager coordinates (0)
Incorrect / missing match anatomy (1)
Incorrect image registration (1)
BP Incorrect dataset used for planning (1)
Dataset insufficient (4)
PC Treatment plan will not clear (1)
PC Missing or incorrectly drawn structure (44)
PC Incorrect structure margins (8)
BP Incorrect fractionation scheme (0)
BP Treatment plan violates clinical objectives (9)
Dose distribution non-optimal (27)
BP Incorrect / incomplete account of previous treatment (2)
Inappropriate modality used (1)
PC Problem with calculation (res / alg) (10)
PC Problem with plan scheduling workspace (6)
PC Problem with reference points (10)
BP PC Problem with bolus (1)
PC No dose point / volume for Mobius (16)
PC Custom coding incorrect (1)
PC Plan parameters incorrect / missing (6)
Issue with immobilization (1)
PC Origin not set correctly (5)

Legend

- PC — This issue could be reliably caught in Plan Checker
- PC — A subset of these issues could be reliably caught in Plan Checker
- BP — This issue could be reliably caught in BluePrint
- BP — A subset of these issues could be reliably caught in BluePrint
- Automation to check for this may not be straightforward with our current tools
- WS — Writable scripting tools could help solve this issue
- A robust solution to this issue has already been implemented
- A solution that partially solves this issue has already been implemented



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- Is the modulation going to be ok? Do I trust the dose? Does QA have a good chance of passing? Is the field width ok? Should jaw tracking be on?
- How does the fluence look? Is it deliverable?
- Are all the correct documents there? IGRT? Setup sheet? Move sheet? Calypso? SBRT IGRT?
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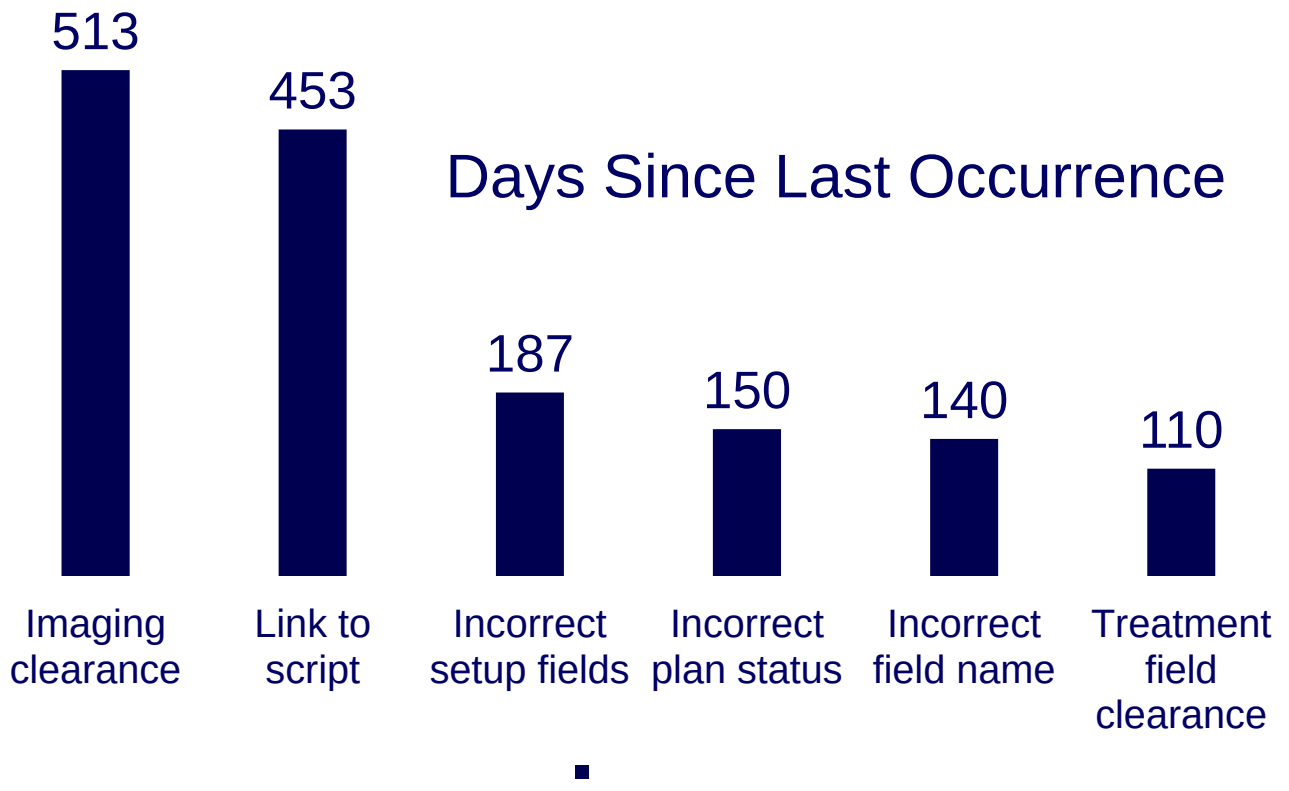
Clinical Results

- Treatment unit delays (due to upstream errors) reduced from ~20 / month to < 5
- Certain categories of errors greatly reduced



Conclusion

- Remove the human element by implementing automation and hard safety barriers
- Many aspects of treatment plan QA are ideally suited for automation
- Automation allows team members to focus their expertise
- Prioritization of automation should be driven by ILS and other data-tracking efforts