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Improving MRI Access and Efficiency through Changeover-Aware Sequencing

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ABSTRACT

Purpose: To evaluate drivers of MRI procedure duration and exam-to-exam changeover time and to estimate whether optimization-guided MRI scheduling policies can increase usable appointment capacity without adding scanners.

Methods: Historical MRI data from an 11-site oncology-focused imaging center network were analyzed from June 2025 through March 2026. The dataset included 77,087 MRI records, of which 64,929 examinations and 54,934 same-scanner exam-to-exam pairs were retained after validation. Statistical testing, regression, and random forest permutation importance were used to identify timing drivers. Empirical timing distributions informed a discrete-event digital twin of a representative four-scanner clinic. First-come-first-served sequencing was compared with greedy changeover minimization and mixed-integer linear programming across 256 paired simulated clinic days.

Results: Mean network changeover time was 35.9 minutes. Scanner site and hour of day were the dominant changeover drivers, with random forest permutation importance values of 0.422 and 0.128, respectively. Procedure duration was more predictable than changeover time, with random forest R-squared values of 0.746 versus 0.382. In simulation, greedy and mixed-integer linear programming policies increased freed 15-minute appointment slots by approximately 75.9% and 90.2%, respectively, relative to first-come-first-served sequencing, corresponding to 8.5 and 10.1 additional 15-minute slots per simulated clinic day.

Conclusion: Dynamic, data-driven MRI sequencing policies can improve operational efficiency using existing scanner resources. Greedy and mixed-integer linear programming approaches increased modeled free appointment capacity, supporting prospective workflow testing across clinical imaging centers.

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INTRODUCTION

Timely MRI access is a persistent operational challenge for radiology practices.[1-2] Scanner availability, protocol complexity, staffing limits, and day-to-day workflow variation constrain schedulable capacity, while adding scanners or expanding hours can be costly and difficult to sustain. A complementary strategy is to use existing scanner time more efficiently.

This study evaluates **whether optimization-guided sequencing can recover usable appointment capacity without adding scanners**, while also **identifying the timing factors** that matter most for MRI scheduling.

METHODS AND MATERIALS

MRI records were extracted from DICOM metadata and EHR imaging orders across an 11-site oncology-focused imaging network from June 2025 through March 2026 using Quantivly (Quantivly Inc., Somerville, MA). Validation retained 64,929 clinical examinations and 54,934 consecutive same-scanner exam pairs from 77,087 raw records across 148 procedure codes.

Procedure duration was measured as the interval between the time of the first acquired image and the time of the last acquired image. Changeover time was measured from the time of the last acquired image of one examination to the time of the first acquired image of the next examination on the same scanner. Timing drivers were evaluated using statistical testing, multivariable regression, and random forest permutation importance.

Empirical procedure-duration and changeover distributions informed a discrete-event digital twin of a representative four-scanner clinic. First-come-first-served (FCFS) sequencing was compared with greedy changeover minimization and mix-integer linear programming (MILP) policy across 256 simulated clinic days, using free 15-minute appointment slots as the primary outcome.

RESULTS

Mean changeover time across the MRI network was 35.9 minutes. Table 1 summarizes the main factors associated with changeover time and procedure duration. **Overall, procedure duration was more predictable than changeover time.**

Outcome	Model	R-squared	Leading drivers
Changeover time	Random forest	0.382	Site, hour of day, next examination duration, appointment duration
Procedure duration		0.746	Acquisition count, procedure code, appointment duration, coil count

Table 1. Timing Predictability and Leading Drivers

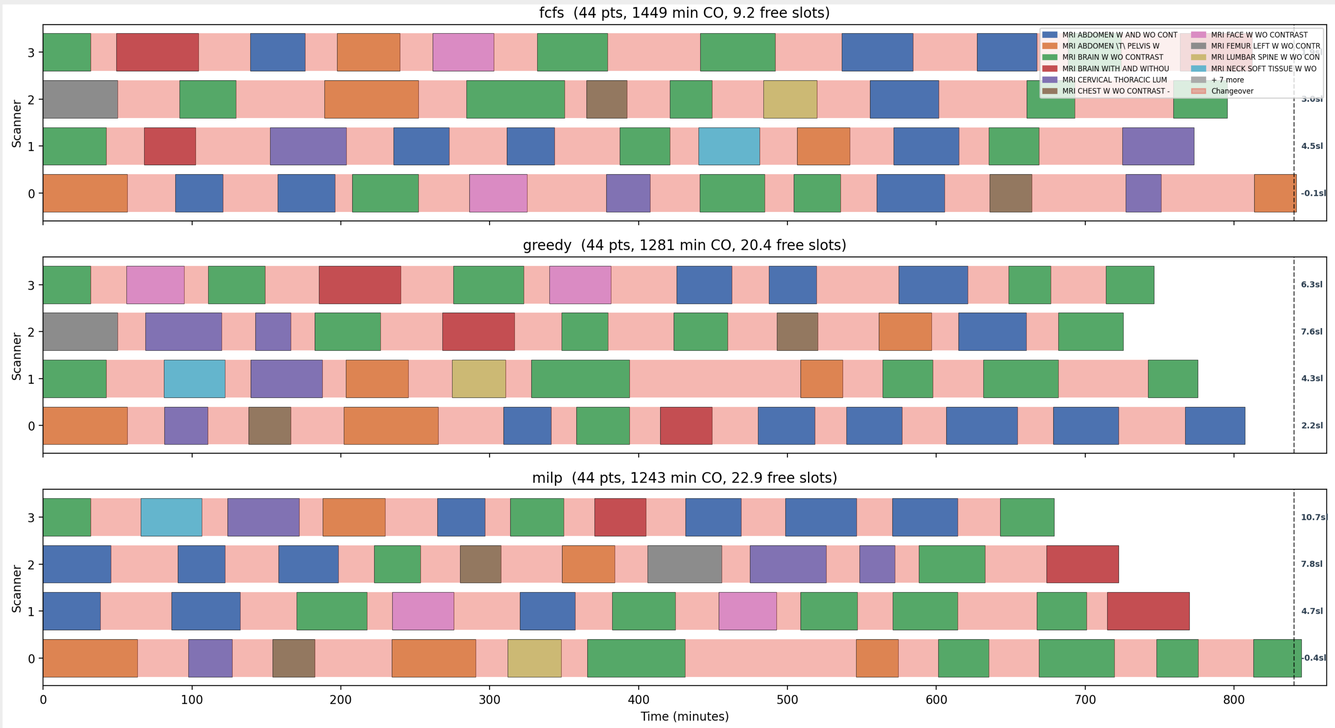

Figure 3. Representative 44-patient simulated clinic day comparing FCFS, greedy, and MILP sequencing. Rows are scanners, colored blocks are examinations, pink gaps are changeovers, and the dashed line marks the 840-minute horizon.

Changeover time varied by schedule structure, with longer morning than afternoon changeovers (34.5 vs. 30.3 minutes; Figure 1) and higher Friday changeovers than Monday–Thursday levels (38.2 vs. 30.7–31.8 minutes).

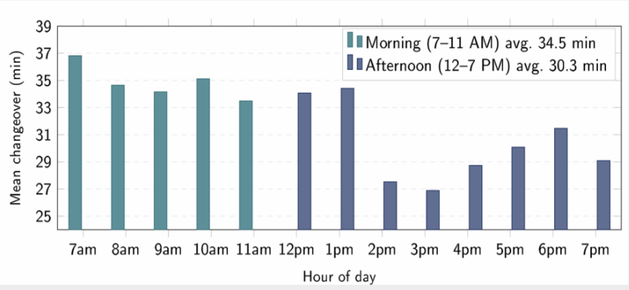

Figure 1. Morning versus Afternoon Mean MRI Changeover Time at a Single Network Site

Calibrated input distributions showed acceptable agreement with observed data. Procedure duration and changeover fits had median absolute relative errors of 0.05% and 2.1%, median Q-Q R-squared values of 0.943 and 0.906, and KS pass rates of 81% and 88%, respectively. Using these inputs, the four-scanner digital twin showed that greedy and MILP sequencing freed 8**.5 and 10.1 additional 15-minute slots** per simulated clinic day versus FCFS, equal to approximately 128–152 minutes of scanner time (Figure 2).

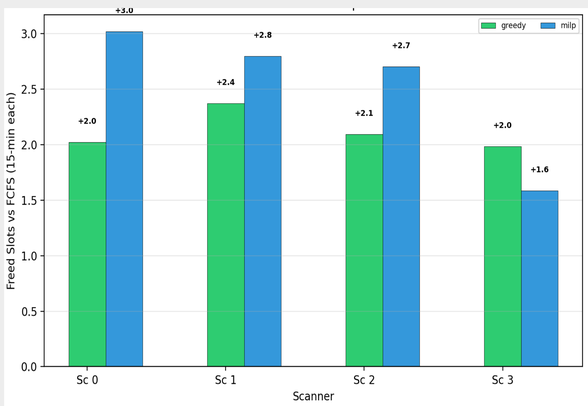

Figure 2. Additional 15-minute appointment slots freed by the greedy sequencing policy (green) and MILP sequencing policy (blue) compared with first-come, first-served sequencing.

To illustrate how sequencing creates this added capacity in practice, Figure 3 shows a representative simulated clinic day as a Gantt chart under different sequencing policies. Each policy schedules the same patients; only the order of patients and scanner assignment are changed. The optimized sequencing policies reduce idle gaps between examinations and consolidate available scanner time into usable appointment slots.

DISCUSSION

Procedure duration can be predicted from information available before or at scheduling. Changeover time was less predictable

Greedy sequencing is a practical near-term decision-support policy because it captured much of the modeled MILP benefit without requiring specialized optimization software or complex solver infrastructure.

CONCLUSIONS

Optimization-guided MRI sequencing increased modeled free appointment capacity in a representative four-scanner clinic without adding scanners. Estimated gains of **8.5–10.1 additional 15-minute slots per simulated day** suggest a meaningful opportunity to recover usable scanner time by providing a decision-support recommendation for scheduling.

These results support prospective workflow testing of greedy and MILP-based sequencing policies across clinical imaging centers.

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