International Survey Results on Current Adaptive Radiotherapy Implementation

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Adaptive Radiotherapy (ART)

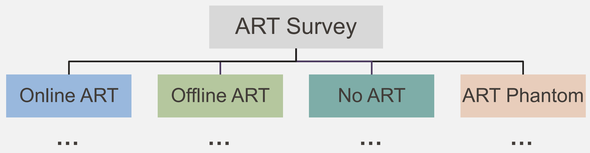
- ART is a closed-loop feedback process utilizing serial on-board imaging (CBCT, MRI) to systematically re-optimize plans mid-course, correcting for temporal anatomical/biological variations to maximize target coverage and minimize normal tissue toxicity.[1]
- Automated segmentation and advanced imaging have accelerated clinical translation, but treatment planning, delivery, dose accumulation, and clinical trial quality assurance (QA) remain unstandardized nationally.
- Formal consensus recommendations are actively under development:
  - **TG-384:** Clinical implementation of automated segmentation for ART
  - **TG-395:** CT-guided online adaptive RT – QA and clinical implementation
  - **TG-441:** CT-based adaptive proton therapy – clinical implementation and QA
  - **TG-442:** Online ART on MR-guided systems
  - **TG-443:** Safe practice of adaptive treatment management and dose reporting
- Current clinical implementations remain highly vendor-specific, creating unquantified variations in contouring, adaptation triggers, and QA thresholds across multi-institutional trial sites.

Objective

To globally characterize current ART implementation pathways, quantify operational variability across delivery modalities and disease sites, evaluate active quality assurance methodologies, and identify technological gaps to guide IROC ART clinical trial credentialing resource development.

Methods

Survey Design: A branching questionnaire was built and hosted on REDCap, followed by pilot-testing with 10 physicists representing diverse delivery platforms and adaptive subfields.



Distribution: Sent to primary medical physicists at 1,903 radiation oncology clinics worldwide. Data collection conducted between August 20 and October 21, 2025.

Statistical Analysis:

- Independent Categorical Associations: Evaluated using Pearson's Chi-square (χ^2) or Fisher's Exact tests to identify institutional trends. Bonferroni corrections were applied to maintain strict family-wise error rates (α_{adj}) across multi-group comparisons.
- Paired Categorical Evaluations: To assess patient-specific quality assurance (PSQA) habits within the same online programs, McNemar's exact binomial tests on discordant pairs were executed to evaluate calculation-based vs. measurement-based QA utilization rates.

Results

- A total of N=384 unique institutions completed the questionnaire (87% USA, 6% Canada, 7% International). Overall, 56.8% (n=218) of clinics currently perform some form of ART.

Landscape of Global ART Adoption

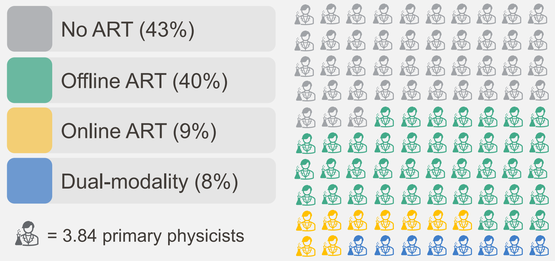


Figure 1: Distribution of ART implementation.

ART Adoption Stratified by Institution Type

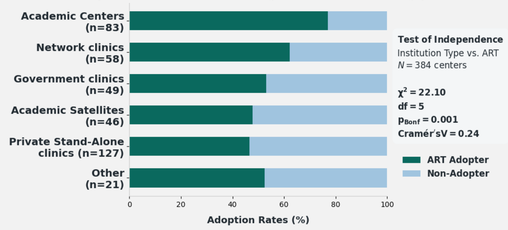


Figure 2: Absolute share of ART adopters versus non-adopters evaluated across six distinct institutional classifications. An Omnibus Pearson's Chi-square test reveals that clinical implementation is heavily dependent on institution type. Academic centers demonstrate the highest rate of adaptive workflows (~77%), while academic satellites, network clinics, and private stand-alone centers rely significantly more on non-adaptive modalities. A Cramer's V of 0.24 indicates a moderate operational effect size, confirming that institution type plays a meaningful role in dictating an organization's capacity to implement adaptive workflows.

Multivariable Logistic Regression of Clinical ART Adoption Odds

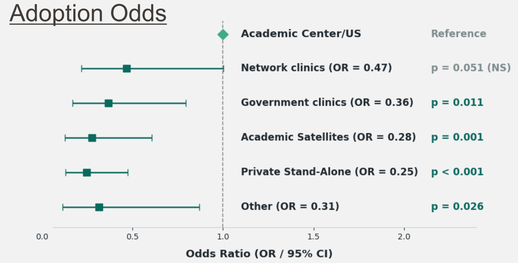


Figure 3: Forest plot of adjusted Odds Ratios (OR) and 95% Confidence Intervals (CI) relative to Academic Centers (OR = 1.0). Wald p-values indicate whether the odds of adoption for each facility type differ significantly from the academic baseline ($p < 0.05$). All non-academic sectors show a significant reduction in adoption odds, with private stand-alone clinics and academic satellites showing the lowest likelihood of clinical implementation.

Multi-Fraction Dose Accumulation Tracking Across Workflow Pathways

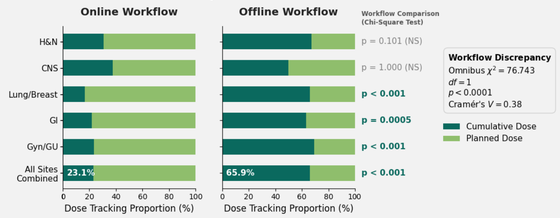


Figure 4: Comparison of dose accumulation tracking frequencies between online and offline adaptive pathways across site-specific clinical protocols. Offline regimes track cumulative dose significantly more often than rapid online pathways. Row-wise p-values demonstrate that this tracking deficit remains highly pronounced in Lung/Breast, GI, and Gyn/GU protocols ($p < 0.001$).

Paired PSQA Modality Use in Online Photon ART

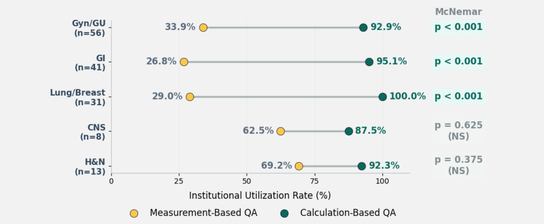
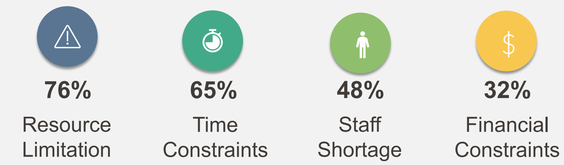


Figure 5: Paired evaluation of measurement-based versus calculation-based QA utilization rates across online photon adaptive protocols. A paired McNemar's exact binomial test on discordant pairs reveals a massive systematic reliance on calculation software over physical measurement. This utilization gap is highly pronounced and statistically significant for high-volume sites including Gyn/GU, GI, and Lung/Breast, whereas low-sample protocols (CNS and H&N) show no statistical difference (NS) after Bonferroni correction.

Barrier for ART implementation



Need for ART Phantom Support

- Active ART adopters are significantly more likely to express an urgent need for independent IROC phantom credentialing systems (70.2% vs. 56.0%, $p = 0.0058$).
- Across the entire survey sample, clinics overwhelmingly state that a next-generation QA phantom must be capable of auditing Dose Accumulation software (73.2%) and Deformable Image Registration (DIR) algorithms (68.0%).

Conclusions

- Clinical ART adoption is expanding rapidly but remains highly stratified; resource-heavy online workflows are predominantly concentrated within academic environments.
- Online adaptive clinics systematically substitute physical dosimetry measurements with secondary calculation software. Furthermore, they fail to track multi-fraction cumulative delivered doses.
- Because clinics are heavily relying on secondary software calculations and DIR algorithms without physical, experimental verification, independent end-to-end credentialing is paramount. To guarantee clinical trial data integrity, dose accuracy, and multi-institutional safety, an independent physical auditing system is essential.

Future Work

- These survey results establish the requirements for IROC's upcoming ART program development. Active development is currently focused on an anthropomorphic head-and-neck adaptive phantom for institutional credentialing and a standardized clinical trial case review protocol, both of which will be implemented and made available in the future.

References

1) Yan D, et al. Adaptive radiation therapy. Phys Med Biol. 1997;42(1): 123-132.