A national infrastructure for sharing AI solutions in medical imaging for radiotherapy of cancer diseases

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Abstract

Radiotherapy (RT) is a resource-intensive process, with considerable variation in practice across centers. Artificial intelligence (AI) presents a means of automation and increased consistency in RT workflows, thereby reducing the burden on clinical staff and supporting more uniform, equitable care. We demonstrate a national data science infrastructure that enables secure medical image data upload, automated curation, ontology mapping, and standardized model deployment. By building on existing healthcare communication networks and adhering to FAIR principles, the infrastructure allows validated AI models to be trained and applied across institutions. Segmentation of organs at risk in CT-scans serves as one example of AI-supported automation, but the framework is designed to accommodate a wide range of applications including treatment planning and quality assurance.

Keywords: Image data infrastructure; Medical image analysis; Radiation Oncology; Image segmentation

1 Introduction

Radiotherapy (RT) is a cornerstone in modern cancer treatment, used in the management of more than half of all cancer patients. The workflow leading from diagnostic imaging to treatment delivery is, however, resource-intensive, requiring highly trained personnel and significant amounts of clinical time. In particular, delineation of organs at risk and tumor volumes and radiation dose optimization remain the most time-consuming steps in treatment planning. In recent years, artificial intelligence (AI) has shown great potential to accelerate these clinical workflows, increase consistency between institutions, and free up valuable clinical resources (Nielsen et al. [2023]). Nevertheless, the transition from proof-of-concept to clinical practice has proven difficult. Implementing AI models requires not only computational infrastructure, but also expertise in data curation, integration into clinical IT systems, and ongoing monitoring of performance. Smaller RT centers, which would stand to benefit the most from automation, are often the least equipped to take on this challenge. This

AI in Science
Conference 2025
EU2025DK

uneven distribution of capacity risks widening the gap between well-resourced academic hospitals and smaller regional clinics. From a policy perspective, this raises important concerns about equity of access and uniformity of care across a national healthcare system. It also hampers the ability to generate robust multi-center evidence. To address these challenges, we present the Danish Data Science Infrastructure in Radiotherapy - 'DESIRE'. The infrastructure is designed to support medical image data curation and standardization according to FAIR principles, enable multi-center AI training and deployment, and provide seamless integration of AI tools into clinical workflows (Krogh et al. [2023]). By building on existing national IT networks and healthcare communication standards, it demonstrates a scalable and generalizable approach that can be applied beyond RT to other data-intensive areas of medicine.

2 Objectives of the Infrastructure

Overall, the scientific motivation is to provide a robust, standardized, and scalable infrastructure that enables multi-center research in radiotherapy including a data storage hub - 'DcmCollab' - while also ensuring equitable clinical access to AI-driven automation. The infrastructure was designed with three main objectives contributing to this:

- **Data curation and FAIR compliance.**
  Data are automatically uploaded and mapped to standard ontologies, enabling large-scale reuse for both clinical and research purposes.

- **Support for clinical trials.**
  Although not the focus here, the infrastructure provides a framework for managing RT trial quality assurance across multiple centers.

- **Training and deployment of AI at national scale.**
  The infrastructure enables the training of AI models on diverse, multi-institutional data, and ensures that validated models can be deployed nationally.

3 Methods

The infrastructure builds on existing national healthcare IT networks and standards for Digital Imaging and Communications in Medicine (DICOM) to enable seamless data flow between radiotherapy (RT) centers and shared AI applications. Clinical data can be exported to DcmCollab using standard DICOM workflows, requiring only minimal changes at local sites and thus lowering the threshold for adoption. Once submitted, the data undergoes automated quality control procedures, including checks for completeness, metadata integrity, and parameter consistency. Potential anomalies may be flagged before integration, ensuring robustness of the shared dataset.

To guarantee interoperability across diverse institutions and vendors, all data are mapped to a structured ontology. This step harmonizes otherwise heterogeneous inputs and ensures that the infrastructure adheres to FAIR principles, making datasets findable, accessible, interoperable, and reusable for both clinical and research purposes.

User access to data stored in DcmCollab is governed per protocol. The legal status of the infrastructure is that of a ‘data processor’ rather than a ‘data controller’. The role of ’data controller’ lies with the researchers using the infrastructure, and they hold the legal obligations in relation to a specific research protocol. To support the researcher’s use, legal framework agreements with all regions of Denmark have been negotiated. These frameworks address all the security and access issues related to the fulfillment of GDPR requirements. The infrastructure is legally handling data on the users’ behalf and use of the data for any purpose other than those stated by the data controllers is not allowed. All negotiations about reuse of data for other projects will take place between the relevant researchers, but access can be immediately granted from DcmCollab once permission is achieved.

On top of this curated data foundation, AI applications are deployed as remote services. Imaging studies can be submitted to the infrastructure and processed by AI models hosted at national nodes, with results returned in standard formats that integrate directly into existing clinical workflows. For example, segmentation of organs at risk has been implemented as an initial application building on validated segmentation models (nnU-Net from Isensee et al. [2021], TotalSegmentator from Wasserthal et al. [2023]), but the framework is designed to support a broad range of tasks, including treatment planning and quality assurance. All model executions are logged with metadata on model version, processing times, and flagged anomalies, enabling continuous monitoring of performance across sites and populations. By enforcing standardized interfaces for input and output, the infrastructure ensures that new AI tools can be integrated in a modular, plug-and-play manner.

4 Current status

The infrastructure is now operational across all national radiotherapy (RT) centers, involving both major university hospitals and smaller regional clinics. Several thousand patient images have already been uploaded into the system, and the user base includes clinicians and researchers distributed across institutions, with participation steadily increasing.

Automated pipelines for curation and standardization are in production use. These pipelines incorporate ontology mapping, ensuring that the data integrated into the infrastructure is consistent and usable across heterogeneous sites and vendors. This has allowed the system to move beyond proof-of-concept stage and into routine use for clinical and research applications.

Six AI segmentation models are currently implemented and running within the infrastructure. A head-and-neck organ-at-risk delineation model based on nnU-Net, validated on a national dataset and actively used in clinical workflows. As a second example, the TotalSegmentator whole-body model, which has been integrated at a separate site and is now supporting multi-center studies in lung cancer radiotherapy as well as exploratory clinical use. Both models demonstrate the feasibility of deploying validated AI applications at national scale, with consistent performance across multiple institutions. A national randomized trial for autosegmentation of target structures in breast cancer radiotherapy is currently being prepared to run within the infrastructure.

Feedback from pilot centers has been positive. Although a formalized comparison study has not been conducted, smaller RT departments report efficiency gains with time savings of 30–40% in head-and-neck organs-at-risk delineation tasks compared to manual-only workflows. Importantly, these benefits are reported to be achieved without compromising clinical quality, underscoring the potential of national-level infrastructures to make AI more accessible and impactful.

5 Future perspectives

The infrastructure forms the foundation for a broader national strategy in AI-enabled RT. Planned developments include:

- **Extension to additional data modalities**
  Beyond image based RT data (CT, MR, PET), the system may be expanded to include multimodal data sources. This will enable the development of multi-parametric AI models for both diagnosis and treatment planning.

- **Expansion of AI applications**
  While segmentation has been the initial focus, the infrastructure can support other applications, such as automated treatment planning, dose prediction, adaptive RT, and quality assurance tools.

- **Integration with national and international initiatives**
  The infrastructure will serve as the backbone for the launch of a new large-scale research project - '**AIM@CANCER**' - to build vision foundation models for medical image analysis, and will interface with European efforts to build federated AI resources for cancer research.

From a policy perspective, the infrastructure represents a model for how healthcare systems can adopt AI responsibly. By ensuring equitable access to validated models, enforcing FAIR principles, and maintaining central oversight, it addresses concerns of fragmentation, bias, and unequal distribution of technological benefits.

6 Conclusions

The presented infrastructure demonstrates that it is possible to deploy AI applications for RT on a national scale, leveraging existing healthcare IT systems and a centralized governance model. It ensures that all centers, regardless of size or resources, can benefit from automation, thereby supporting equity of care. At the same time, it provides a robust research platform, facilitating reproducibility, alignment with clinical guidelines, and large-scale evidence generation.

For policymakers, this case illustrates how national-level investments in infrastructure can accelerate the safe and equitable adoption of AI in healthcare. For the scientific community, it highlights the importance of standardized, interoperable, and monitored deployment strategies. Together, these perspectives underline the potential of AI not merely as a collection of isolated tools, but as a shared infrastructure that can transform clinical research and practice at scale.

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