Detection and Measurement of Lymph Nodes Using Artificial Intelligence

The Effect of Artificial Intelligence on Patient-Radiologist Dynamic

A Thesis Prospectus
In STS 4500
Presented to
The Faculty of the
School of Engineering and Applied Science
University of Virginia
In Partial Fulfillment of the Requirements for the Degree
Bachelor of Science in Biomedical Engineering

By
Nathan Patton

Fall, 2023

Technical Team Members:
Kaya Oguz
Daniel Song

On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

ADVISORS

Benjamin Laugelli, Department of Engineering and Society

Xue Feng, M.D. Department Biomedical Engineering

Introduction

Head and neck squamous cell carcinoma (HNSCC) encompasses a group of malignancies affecting the oral cavity, pharynx, hypopharynx, larynx, nasal cavity, and salivary glands, ranking as the seventh most frequently diagnosed tumor type. Incidence and mortality rates for HNSCC exhibit geographical and demographic variations, with a higher prevalence in men and older adults. The developing world anticipates a 30% annual increase in global HNSCC incidence by 2030, attributed in part to lifestyle changes like elevated alcohol consumption, tobacco use in developing nations, and the rising incidence of human papillomavirus (HPV)-related oropharyngeal cancer (Barsouk et al., 2023, p. 1). Given these escalating trends, there is a critical need to enhance the diagnosis and treatment not only for HNSCC but for all cancers.

To address this, the technical project focuses on assessing the application of artificial intelligence (AI), specifically deep learning, in precisely detecting and measuring lymph nodes in the head and neck region. The research seeks to answer a pivotal question in the realm of patient care and radiology: How does the integration of AI impact the dynamic between patients and radiologists concerning autonomy and trust in lymph node detection and measurement? This inquiry holds significant implications for cancer diagnosis and treatment, as AI technologies continue to play an increasingly prominent role in healthcare.

Detection and Measurement of Lymph Nodes Using Artificial Intelligence

Lymph node metastasis stands out as a crucial prognostic factor in cancer staging, significantly influencing clinical staging and treatment decisions for patients. Unfortunately, the manual microscopic review of lymph nodes by pathologists for metastatic tumor cells is a laborious, time-consuming, and potentially error-prone process (Caldonazzi et al., 2023, p. 1).

Once identified, assessment of the change in tumor burden is an important feature of the clinical evaluation of cancer therapeutics: both shrinkage (objective response) and time to the development of disease progression are useful endpoints in clinical trials (Eisenhauer et al., 2009, p. 2). Current methods of assessment including calipers, rulers, X-rays, CT, MRI, ultrasound, endoscopy, laparoscopy, tumor markers, cytology, and histology exhibit error rates and limitations (Brady, 2017, p. 1). Radiologists face a demanding environment, with an average daily error rate of 3-5% and a retrospective error rate of 30% from radiological studies (Alexander et al., 2022, p. 1).

Recognizing these challenges, the objective of this technical project is to develop an automated and user-friendly AI-based tool for lymph node detection and measurement. The aim is to streamline the radiological workflow, reduce human error, and enhance diagnostic accuracy for cancer patients undergoing CT and/or MRI. The rapid evolution of AI in radiology and the broader medical industry introduces questions and risks, underscoring the need for continuous improvement in radiologic techniques.

The approach involves developing, implementing, and evaluating an AI algorithm integrating convolutional neural networks, filters, and pooling for intricate tasks like image recognition and segmentation. The model will undergo training on datasets, optimizing tools, and fine-tuning hyperparameters using validation sets to achieve the highest accuracy and F1 score. Continuous analysis and comparison with existing lymph node detection techniques, as outlined by RECIST, will guide feedback and improvements in the model's performance.

This work has the potential to revolutionize radiology by: 1) Enhancing the efficiency of lymph node detection while matching or surpassing current methodologies, 2) Improving the quality of life for radiologists by reducing mental fatigue and exhaustion associated with manual image analysis, and 3) Setting a new standard for medical image analysis, thereby advancing the existing clinical workflow. The developed tool holds promise not only for radiologists but also for integration into various clinical workflows, thereby contributing to the broader field of medical image analysis.

The Effect of Artificial Intelligence on the Patient-Radiologist Dynamic

Artificial Intelligence (AI), a dynamic subset of information technology (IT), is rapidly evolving and holds promise in addressing critical challenges faced by health organizations. Understanding the current state of AI technologies and their applications is essential for health leaders navigating the complex landscape of healthcare IT. In the healthcare environment, where diverse groups employ various technologies, the transmission of information through IT transforms inputs into complex outputs, fostering improved information flow and ultimately enhancing the quality of care (Cresswell et al., 2010, p. 1). AI's potential to enhance efficiency, safety, and access in health services positions it as a catalyst for the overall digital transformation of healthcare. Its impact is already tangible across various healthcare domains, from providing clinical decision support at the point of care to empowering patients for self-management of chronic conditions at home and influencing real-world drug research.

This paper specifically focuses on the application of AI in radiology, as outlined in the technical report. The current methodology for detecting and measuring lymph nodes relies on trained physicians visually assessing medical images, a process prone to subjectivity based on education and experience. In contrast, AI excels at recognizing complex patterns in image data, offering automated and quantifiable assessments. Integrating AI into the radiology clinical workflow has the potential to enhance the accuracy and reproducibility of assessments, marking a significant advancement in diagnostic capabilities (Hosny et al., 2018, p. 2). However, achieving successful AI integration poses challenges for health organizations: (1) lack of understanding about the uses of a particular AI technology; (2) lack of clear strategies for integrating different AI technologies into existing healthcare systems; (3) shortage of experienced workforce for AI implementation; (4) the incompatibility of AI technologies with old infrastructure; (5) a lack of access to "good" and diverse medical data (Chen & Decary, 2020, p. 1).

Addressing the challenges in integrating AI into healthcare not only provides an opportunity for technological advancement but also opens a rich field for research on the ethical and societal implications of AI-predictive analytics in healthcare. Trust and autonomy, repeatedly discussed in literature, stand as key ethical principles that require careful examination.
In the clinical field, autonomy signifies the ability of doctors to make clinical decisions without constraints from external factors like organizational procedures, financial concerns, performance measurement systems, or managerial control (Lombi, L., & Rossero, 2023, p. 4). The central question arises: How does the implementation of AI into the radiological clinical workflow impact the decision-making ability of physicians and/or patients? Does it detract from it? Additionally, trust is identified as a prerequisite for the successful implementation of AI systems in medical practice that makes decision making more efficient by simplifying the acquisition and interpretation of information (Goisauf & Cano, 2022, p. 8). To thoroughly examine these implications and the effect that they have on the patient-radiologist relationship, the paper will employ the Actor Network Theory (ANT) framework.

ANT provides a powerful analytical tool to understand the complex interactions among various actors, including AI technologies, healthcare professionals, and patients. It facilitates an in-depth exploration of how these actors influence decision-making processes and shape trust dynamics within the radiological clinical workflow. ANT challenges the technological determinism/social constructivism dichotomy prevalent in technology studies. Scholars adopting this approach align with the social constructivist perspective, asserting that sociotechnical systems evolve through negotiations involving people, institutions, and organizations. Beyond this, proponents argue that artifacts play a pivotal role in these negotiations, asserting influence through their physical structure and design. Artifacts, intentionally designed to replace human actions, can shape the behavior of individuals, allowing people to "act at a distance" through the technologies they create. This construction and employment of technologies become instrumental in achieving specific values and political goals (Latour, 1992, p. 1). ANT conceives the world as a complex network, comprising humans, things, ideas, and concepts, all referred to as "actors" within the network. The central activity of ANT involves tracing relationships and understanding how each actor interacts within this intricate web (Cresswell et al., 2010, p. 2). In the context of autonomy and trust in radiology, key stakeholders and artifacts within this network include AI medical devices, manufacturers, developers, doctors, patients, and insurance companies.

This theoretical framework will undergo further analysis in the complete research paper, exploring the intricate dynamics of actor relationships (patients and radiologists) and shedding light on how the integration of AI in radiology shapes autonomy and trust. The examination facilitated by ANT aims to contribute valuable insights to the ongoing discourse surrounding responsible and ethical AI implementation in healthcare.

Research Question and Methods

This study investigates the impact of AI on the patient-radiologist dynamic by combining documentary research and interviews that explore themes of autonomy and trust. Documentary research involves literature, journals, and studies. Interviews are designed to gauge participants' trust in AI accuracy, comfort in decision-making based on AI recommendations, and their value of making healthcare decisions. Participants will be presented with insights from the documentary research to assess potential shifts in their perspectives. The study aims to blend theoretical insights from documentary research with real-world experiences, guiding further exploration of dynamics in the patient-radiologist relationship during AI integration in radiology diagnostics. Leveraging ANT and the chosen research methods will uncover the potential effects of AI on trust and autonomy, offering insights that can lead to solutions ensuring that stakeholders retain their trust and autonomy in radiological studies.

Conclusion

In the pursuit of advancing healthcare through technology, the technical project aims to develop a revolutionary AI-based lymph node detection and measurement tool. This tool, designed to be automated and user-friendly, promises increased efficiency and accuracy compared to current assessment methods. The potential impact is significant, as it not only expedites disease diagnosis and monitoring but also contributes to a reduction in human error. By integrating artificial intelligence into clinical workflows, this project seeks to enhance the overall effectiveness of radiological practices.

Simultaneously, the Science, Technology, and Society (STS) research component delves into the broader implications of AI in healthcare, specifically examining its effects on autonomy and trust in radiology. The research methodology, involving documentary research and interviews with key stakeholders, aims to provide a comprehensive understanding of how AI shapes the patient-radiologist relationship.

Both the technical and STS research components align with the overarching goal of improving radiological outcomes. The technical project addresses a specific aspect of medical diagnostics, offering a solution that combines efficiency and precision. On the other hand, the STS research explores the ethical dimensions of AI implementation, ensuring that advancements in technology are made in a way that upholds and respects autonomy and trust. Together, these initiatives contribute to the ongoing transformation of healthcare through responsible and innovative applications of artificial intelligence.

References

Alexander, R., Waite, S., Bruno, M. A., Krupinski, E. A., Berlin, L., Macknik, S., & Martinez-Conde, S. (2022). Mandating Limits on Workload, Duty, and Speed in Radiology. *Radiology*, *304*(2), 274–282. https://doi.org/10.1148/radiol.212631

Barsouk, A., Aluru, J. S., Rawla, P., Saginala, K., & Barsouk, A. (2023). Epidemiology, Risk BrockFactors, and Prevention of Head and Neck Squamous Cell Carcinoma. *Medical Sciences*, *11*(2), 42. https://doi.org/10.3390/medsci11020042

Brady, A. P. (2017). Error and discrepancy in radiology: Inevitable or avoidable? *Insights into Imaging*, *8*(1), 171–182. https://doi.org/10.1007/s13244-016-0534-1

Caldonazzi, N., Rizzo, P. C., Eccher, A., Girolami, I., Fanelli, G. N., Naccarato, A. G., Bonizzi, G., Fusco, N., d'Amati, G., Scarpa, A., Pantanowitz, L., & Marletta, S. (2023). Value of Artificial Intelligence in Evaluating Lymph Node Metastases. *Cancers*, *15*(9), 2491. https://doi.org/10.3390/cancers15092491

Chen, M., & Decary, M. (2020). Artificial intelligence in healthcare: An essential guide for health leaders. *Healthcare management forum*, *33*(1), 10–18. https://doi.org/10.1177/0840470419873123

Cresswell, K. M., Worth, A., & Sheikh, A. (2010). Actor-Network Theory and its role in understanding the implementation of information technology developments in healthcare. *BMC Medical Informatics and Decision Making*, *10*(1), 67. https://doi.org/10.1186/1472-6947-10-67

Eisenhauer, E. A., Therasse, P., Bogaerts, J., Schwartz, L. H., Sargent, D., Ford, R., Dancey, J., Arbuck, S., Gwyther, S., Mooney, M., Rubinstein, L., Shankar, L., Dodd, L., Kaplan, R., Lacombe, D., & Verweij, J. (2009). New response evaluation criteria in solid tumours:

Revised RECIST guideline (version 1.1). *European Journal of Cancer*, *45*(2), 228–247. https://doi.org/10.1016/j.ejca.2008.10.026

Goisauf, M., & Cano Abadía, M. (2022). Ethics of AI in Radiology: A Review of Ethical and Societal Implications. *Frontiers in Big Data*, *5*, 850383. https://doi.org/10.3389/fdata.2022.850383

Hosny, A., Parmar, C., Quackenbush, J., Schwartz, L. H., & Aerts, H. J. W. L. (2018). Artificial intelligence in radiology. *Nature Reviews Cancer*, *18*(8), 500–510. https://doi.org/10.1038/s41568-018-0016-5

Latour, B. (1992). Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts. In W. E. Bijker & J. Law (ed.), *Shaping Technology / Building Society: Studies in Sociotechnical Change* (pp. 225-258) . The MIT Press.

Lombi, L., & Rossero, E. (2023). How artificial intelligence is reshaping the autonomy and boundary work of radiologists. A qualitative study. *Sociology of Health & Illness*, 1467-9566.13702. https://doi.org/10.1111/1467-9566.13702