MCW
GRADUATE SCHOOL

Doctoral Dissertation Defense Announcement

"Non-Invasive Tracking of Prostate Cancer Risk Assessment Using Radio-Pathomic Mapping"

Savannah R. Duenweg

Candidate for Doctor of Philosophy in Biophysics
School of Graduate Studies
Medical College of Wisconsin

Committee in Charge:
Peter S. LaViolette, PhD (Mentor)
L. Tugan Muftuler, PhD
Adam Greenberg, PhD
William Hall, MD
Radka Stoyanova, PhD

Date: Tuesday, July 2, 2024
Time: 11:00 AM (CST)
Defense Location: HUB – A4520/A4628
Zoom: https://mcw-edu.zoom.us/j/97341910603?pwd=jjOn5OV3qUYSqxcWvVk7hHQy1r292T.1
Meeting ID: 973 4191 0603 Passcode: Duenweg24

Graduate Studies:

Cognitive Neuroscience

Statistical Models & Methods I

Nuclear Magnetic Resonance

Functional MRI Contrast Mechanisms

Introduction to Statistical Machine Learning

Biomedical Applications & Consulting

Ethics & Integrity in Science

Research Ethics Discussion Series

Biophysics Journal Club

Biophysics Seminar Course

Reading and Reading

Doctoral Dissertation

Dissertation

"Non-Invasive Tracking of Prostate Cancer Risk Assessment Using Radio-Pathomic Mapping"

Prostate cancer (PCa) is the most diagnosed cancer among men in the United States, representing 30% of all new male cancer cases. Concerns about PCa typically arise following abnormal digital rectal exam results or elevated prostate-specific antigen (PSA) levels during routine annual exams. If abnormalities are found, patients may undergo biopsies based on findings from multi-parametric magnetic resonance imaging (MP-MRI). For clinically significant cancer, treatment options include radical prostatectomy, which involves the complete removal of the prostate and seminal vesicles, as well as chemotherapy and/or radiation. Although the 5-year survival rate for PCa is nearly 100%, about 30% of men will experience biochemical recurrence, indicated by rising PSA levels after surgery. A significant issue with current treatments is the overtreatment of low-risk patients. PCa treatments can lead to complications such as impotence, incontinence, and infection, which can adversely affect patient quality of life. Therefore, it is essential to develop advanced imaging tools to accurately detect cancer and assess its metastatic potential, ensuring that patients receive the most appropriate treatment and avoid unnecessary procedures and their associated lifelong side effects.

This work uses tissue samples collected following radical prostatectomy aligned to MR imaging acquired prior to treatment to determine the relationships between radiological signatures and the underlying pathology of prostate cancer lesions. Specifically, we hypothesize that clinical MRI couples with machine learning-based predictive models can distinguish regions of aggressive tumors and patients with high metastatic potential by using surgical tissue coupled with pathological cancer annotations as ground truth. The studies involved in this project include validating radio-pathomic modelling potential by 1) comparing standard digital slide scanners to determine if scanner quality impacts pathological findings, 2) MR image normalization techniques to best normalize across a variety of clinical factors, and 3) creating "digital twins" to simulate the biopsy procedure. After validation, we 4) determined pathological features in histology space that can quantitatively characterize regions of cancer tissue and associate with biochemical recurrence risk, 5) correlate these features in MRI space, and 6) develop models that predict prostate cancer in MRI space. These studies have resulted in non-invasive maps of prostate pathology to improve clinical detection of aggressive cancers non-invasively. These maps have the potential to aid in clinical decision making and treatment planning in PCa, therefore improving patient outcomes. Additionally, these maps use quantitative pathomic features and MRI intensity values to mitigate interrater variability that is well known in pathological and radiological studies of Gleason patterns and PI-RADS scores, respectively.

Savannah R. Duenweg
Curriculum Vitae
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EDUCATION

Milwaukee School of Engineering (Milwaukee, WI, Fall 2016- Spring 2020): Bachelor of Science

Major: Biomedical Engineering

Certificate/Minor: User Experience

University Scholars Honor Program (2016)

Medical College of Wisconsin (Milwaukee, WI, Fall 2020 – Current): PhD

Department of Biophysics

RESEARCH EXPERIENCE

PhD Student, Medical College of Wisconsin (Fall 2020 – Current)

Principal Investigator: Dr. Peter LaViolette

Thesis Title: Non-invasive tracking of prostate cancer risk assessment using radio-pathomic mapping

- Developed radio-pathomic machine learning models to detect prostate cancer pathology from MRI intensity values using aligned whole mount tissue samples as ground truth.
- Validated traditional imaging signatures and radiomic texture features using whole mount tissue samples, drawing comparisons across different diagnostic and treatment groups.
- Assessed MRI and histology image standardization methods for analysis generalization.
- Assisted in performing analogous brain cancer radio-pathomic mapping studies, including digital pathology pipeline development and statistical analyses.

Biomedical Research Intern, University of Wisconsin – Madison (Spring 2019 – Fall 2019)

Principal Investigator: Dr. Ari Rosenberg

- Assisted in developing software to create an in-house graphical user interface (GUI) for real-time experimental control.
- Applied User Experience (UX) principles to design GUI with modular style.
- Created supporting documentation and tutorial guides for GUI use and applications.

PROFESSIONAL MEMBERSHIPS

- International Society for Magnetic Resonance in Medicine (ISMRM)
    - MR of Cancer Study Group (ISMRM-MRoC)
    - Body MR Study Group
- Society of Abdominal Radiology
- American Society of Neuroradiology
    - Artificial Intelligence Subgroup
- Society for Neuro-Oncology
- American Urological Association
- Alpha Eta Mu Beta Biomedical Engineering Honor Society
- Society of Women Engineers
- Biomedical Engineering Society
- Engineering World Health

AWARDS

- Top Trainee Presentation, ISMRM MR of Cancer Workgroup, May 2024 (power pitch)
- ISMRM Educational Stipend, May 2024
- GSA Travel Award, November 2023
- Biophysics Scholar Award, MCW Department of Biophysics, June 2023
- The William G. Negendank First Place Award, International Society for Magnetic Resonance in Medicine MR of Cancer Workgroup, November 2022 (poster)
- Top Oral Presentation, MCW Graduate Student Symposium, April 2022 (oral)

VOLUNTEERISM & MENTORING

- MCW Summer Program for Undergraduate Research (SPUR) Mentor
    - Cassandra Naze, Summer 2021
    - Jeff Rodriguez, Summer 2021
    - Alicia Hoefs, Summer 2022
    - Jordyn Hamburger, Summer 2022
    - Sarah Rubenstein, Summer 2023
- MCW 500 Stars Mentor
    - Lily Kriegel, Summer 2023
- BrainExpo 2023, Volunteer

JOURNAL PEER REVIEWS

- The Prostate
- Cancer Epidemiology, Biomarkers & Prevention
- PLoS ONE
- Quantitative Imaging in Medicine and Surgery (QIMS)

PUBLICATIONS

[1] **Duenweg SR**, Bobholz SA, Lowman AK, et.al. Comparison of intensity normalization methods in prostate, brain, and breast cancer multi-parametric magnetic resonance imaging (submitted to *Frontiers*)

[2] Fernandez Gonzalez De La Vega C, **Duenweg S**, Jain P, Rubenstein SI, Bobholz S, Barrett MJ, LaViolette PS, Iczkowski KA. Morphologic features of prostate cancer-encased native vessels: An image analysis study. *Pathol Res Pract*. 2024 Mar 6;256:155239. doi: 10.1016/j.prp.2024.155239.

[3] Bobholz SA, Lowman AK, Connelly JM, **Duenweg SR**, Winiarz A, Nath B, Kyereme F, Brehler M, Bukowy J, Coss D, Lupo JM, Phillips JJ, Ellingson BM, Krucoff M, Mueller WM, Banerjee A, LaViolette PS. Non-invasive tumor probability maps developed using autopsy tissue identify novel regions of tumor beyond the imaging-defined margin. *Neurosurgery*. 2024 Mar 19. doi: 10.1227/neu.0000000000002898

[4] Bobholz SA, Hoefs A, Hamburger J, Lowman AK, Winiarz A, **Duenweg SR**, Kyereme F, Connelly J, Coss D, Krucoff M, Banerjee A, LaViolette PS. Radio-pathomic maps of glioblastoma identify phenotypes of non-enhancing tumor infiltration associated with bevacizumab treatment response. *J Neurooncol*. 2024 Feb 19. doi: 10.1007/s11060-024-04593-7.

[5] **Duenweg SR**, Brehler M, Lowman AK, Bobholz SA, Kyereme F, Winiarz A, Nath B, Iczkowski KA, LaViolette PS. Quantitative histo-morphometric features of prostate cancer differ between patients who exhibit biochemical recurrence following prostatectomy. *Laboratory Investigation*. 2023 Oct 19; 103(12). doi: 10.1016/j.labinv.2023.100269

[6] **Duenweg SR**, Bobholz SA, Barrett MJ, Lowman AK, Winiarz A, Nath B, Stebbins M, Bukowy J, Iczkowski KA, Jacobsohn KM, Vincent-Sheldon S, LaViolette PS. T2-Weighted MRI Radiomic Features Predict Prostate Cancer Presence and Eventual Biochemical Recurrence. *Cancers* (Basel). 2023 Sep 6;15(18):4437. doi: 10.3390/cancers15184437.

[7] **Duenweg SR**, Bobholz SA, Lowman AK, Stebbins MA, Winiarz A, Nath B, Kyereme F, Iczkowski KA, LaViolette PS. Whole slide imaging (WSI) scanner differences influence optical and computed properties of digitized prostate cancer histology. *J Pathol Inform*. 2023 Jul 4;14:100321. doi: 10.1016/j.jpi.2023.100321.

[8] **Duenweg SR**, Brehler M, Bobholz SA, Lowman AK, Winiarz A, Kyereme F, Nencka A, Iczkowski KA, LaViolette PS. Comparison of a machine and deep learning model for automated tumor annotation on digitized whole slide prostate cancer histology. *PLoS One*. 2023 Mar 16;18(3):e0278084. doi: 10.1371/journal.pone.0278084

[9] Shalom E, Kim H, van der Heijden RA, Ahmed Z, Patel R, Hormuth DA, DiCarlo JC, Yankeelov TE, Sisco NJ, Dortch RD, Stokes AM, Inglese M, Grech-Sollars M, Toschi N, Sahoo P, Singh A, Verma SK, Rathore DK, Kazerouni AS, Partridge SC, LoCastro E, Paudyal R, Wolansky IA, Shukla-Dave A, Schouten P, Gurney-Champion OJ, Jiřík R, Macíček O, Bartoš M, Vitouš J, Bharadwaj Das A, Kim G, Bokacheva L, Mikheev A, Rusineck H, Berks M, Cristinacce P, Little RA, Cheung S, O'Connor JPB, Parker GJM, Moloney B, LaViolette PS, Bobholz A, **Duenweg S**, Virostko J, Laue HO, Sung K, Nabavizadeh A, Saligheh Rad H, Hu LS, Sourbron S, Bell LC, Kazerooni AF. The ISMRM Open Science Initiative for Perfusion Imaging (OSIPI): Results from the OSIPI-Dynamic Contrast-Enhanced challege. *Magn Reson Med*. 2023 Dec 19. doi: 10.1002/mrm.29909

[10] Gagandeep Daroach, **Savannah R. Duenweg**, Michael Brehler, Allison K. Lowman, Kenneth A. Iczkowski, Kenneth M. Jacobsohn, Josiah A. Yoder, Peter S. LaViolette. Pathologically meaningful latent space of a prostate histology GAN. Medical Image Computing and Computer Assisted Intervention – MICCAI 2022: 25th International Conference, Singapore, September 18–22, 2022, Proceedings, Part II. Sep 2022. Pages 398–408. https://doi.org/10.1007/978-3-031-16434-7_39

[11] **Duenweg SR**, Fang X, Bobholz SA, Lowman AK, Brehler M, Kyereme F, Iczkowski KA, Jacobsohn KM, Banerjee A, LaViolette PS. Diffusion Restriction Comparison between Gleason 4 Fused Glands and Cribriform Glands within Patient Using Whole-Mount Prostate Pathology as Ground Truth. *Tomography*. 2022 Mar 2;8(2):635-643. doi: 10.3390/tomography8020053.

[12] Bobholz SA, Lowman AK, Brehler M, Kyereme F, **Duenweg SR**, Sherman J, McGarry SD, Cochran EJ, Connelly J, Mueller WM, Agarwal M, Banerjee A, LaViolette PS. Radio-pathomic maps of cell density identify glioma invasion beyond traditional MR imaging defined margins. 2021. *Am J Neuroradiol*. 2022;(May). doi: https://doi.org/10.3174/ajnr.A7477

[13] McGarry SD, Brehler M, Bukowy JD, Lowman AK, Bobholz SA, **Duenweg SR**, Banerjee A, Hurrell SL, Malyarenko D, Chenevert TL, Cao Y, Li Y, You D, Fedorov A, Bell LC, Quarles CC, Prah MA, Schmainda KM, Taouli B, LoCastro E, Mazaheri Y, Shukla-Dave A, Yankeelov TE, Hormuth DA, Madhuranthakam AJ, Hulsey K, Li K, Huang W, Huang W, Muzi M, Jacobs MA, Solaiyappan M, Hectors S, Antic T, Paner GP, Palangmonthip W, Jacobsohn K, Hohenwalter M, Duvnjak P, Griffin M, See W, Nevalainen MT, Iczkowski KA, LaViolette PS. Multi-Site Concordance of Diffusion-Weighted Imaging Quantification for Assessing Prostate Cancer Aggressiveness. *J Magn Reson Imaging*. 2022 Jun;55(6):1745-1758. doi: 10.1002/jmri.27983

PEER REVIEWED PRESENTATIONS

International

[1] Radio-pathomic signatures within and beyond FLAIR hyperintensity predict prognosis in glioblastoma following gross total resection – **Savannah Duenweg**, Michael Flatley, Aleksandra Winiarz, Samuel Bobholz, Allison Lowman, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Anjishnu Banerjee, and Peter LaViolette. ISMRM 2024 (power pitch)

[2] Hist2MRI: a framework for viewing brain autopsy pathology in MRI space – Samuel Bobholz, Allison K. Lowman, Michael J. Barrett, **Savannah R. Duenweg**, Aleksandra Winiarz, Biprojit Nath, Michael T. Flatley, Max Ostrinsky Krucoff, Anjishnu Banerjee, and Peter S. LaViolette. USCAP 2024 (oral)

[3] Autopsy-based radio-pathomic maps reveal demographic factors impact the presence of tumor outside contrast enhancement in glioma patients – Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Margaret A. Stebbins, Aleksandra Winiarz, Michael Flatley, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Wade M. Mueller, Anjishnu Banerjee, Peter S. LaViolette. SNO 2023 (oral)

[4] Association between perfusion imaging metrics and radio-pathomic maps of tumor probability within and beyond the contrast-enhancing volume in glioma patients – Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Margaret A. Stebbins, Aleksandra Winiarz, Michael Flatley, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Wade M. Mueller, Anjishnu Banerjee, Peter S. LaViolette. SNO 2023 (oral)

[5] Comparison of radio-pathomic maps of tumor probability to 5-ALA guided surgical resection cavities in glioblastoma patients – Samuel Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Margaret Stebbins, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee, Max Krucoff and Peter S. LaViolette. ISMRM 2023 (oral)

[6] Radio-pathomic maps of glioblastoma identify phenotypes of non-enhancing infiltration associated with bevacizumab treatment – Samuel Bobholz, Alisha Hoefs, Jordyn Hamburger, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Margaret Stebbins, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee, and Peter S. LaViolette. ISMRM 2023 (oral)

[7] Compartmental analysis of glioblastoma cellularity using autopsy-based radio-pathomic maps identifies IDH1 mutation status – Samuel Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Margaret Stebbins, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee, and Peter S. LaViolette. ISMRM-MRoC 2022 (oral)

[8] Radio-pathomic maps of glioblastoma cellularity highlight regions outside contrast enhancement that recur early – Aleksandra Winiarz, Samuel Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Fitzgerald Kyereme, Dylan Coss, Jennifer Connelly, and Peter S. LaViolette. ISMRM-MRoC 2022 (oral)

[9] Diffusion restriction comparison between Gleason 4 fused and cribriform glands within patients using whole mount prostate pathology – **Savannah R. Duenweg**, Xi Fang, Samuel A. Bobholz, Allison K. Lowman, Michael Brehler, Fitzgerald Kyereme, Kenneth A. Iczkowski, Kenneth Jacobsohn, Anjishnu Banerjee, Peter S. LaViolette. ISMRM 2022 (oral)

[10] Histomorphometric features of prostate cancer identify patients who biochemically recur after prostatectomy – **Savannah R. Duenweg**, Michael Brehler, Allison K. Lowman, Samuel Bobholz, Fitzgerald Kyereme, Kenneth A. Iczkowski, Peter S. LaViolette. USCAP 2022 (oral)

[11] An automated approach for annotating Gleason patterns in whole-mount prostate cancer histology using deep learning – Michael Brehler, Allison Lowman, Samuel Bobholz, **Savannah Duenweg**, Fitzgerald Kyereme, John Sherman, Kenneth Iczkowski, Peter LaViolette. SPIE 2022 (oral)

[12] Radio-pathomic machine learning models trained with autopsy tissue samples aligned to MP-MRI predict histopathological features in brain cancer patients – Samuel Bobholz, Allison Lowman, Michael Brehler, **Savannah Duenweg**, Sean McGarry, Fitzgerald Kyreme, Elizabeth Cochran, Jennifer Connelly, Wade Mueller, Mohit Agarwal, Darren O'Neil, Anjishnu Banerjee, Peter LaViolette. ISMRM 2021 (oral, joint educational session)

[13] Pathological validation of MP-MRI intensity-based signatures in brain cancer patients using autopsy tissue samples – Samuel Bobholz, Allison Lowman, Michael Brehler, **Savannah Duenweg**, Sean McGarry, Fitzgerald Kyreme, Elizabeth Cochran, Jennifer Connelly, Wade Mueller, Mohit Agarwal, Darren O'Neil, Anjishnu Banerjee, Peter LaViolette. ISMRM 2021 (oral)

[14] MRI-based tumor probability maps trained using autopsy tissue samples as ground truth non-invasively predict infiltrative tumor beyond the contrast enhancing region. – Samuel Bobholz, Allison Lowman, Michael Brehler, **Savannah Duenweg**, Sean McGarry, Fitzgerald Kyreme, Elizabeth Cochran, Jennifer Connelly, Wade Mueller, Mohit Agarwal, Darren O'Neil, Anjishnu Banerjee, Peter LaViolette. SNO 2021 (oral)

National

[1] Virtual Prostate Cancer Biopsies Using ADC Targeted Lesions Shows Superior Performance Than T2 and Non-MR Guided Surgical Sampling – **Savannah R. Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Aleksandra Winiarz, Biprojit Nath, Kenneth A. Iczkowski, Kenneth A. Jacobsohn, Peter S. LaViolette. SB^{3}C 2024 (oral)

[2] Increased cell density and heightened tumor probability, as defined by radio-pathomic models, outside the FLAIR hyperintensity is associated with worse overall survival in glioblastoma patients prior to gross total resection – **Savannah R. Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Aleksandra Winiarz, Michael Flatley, Biprojit Nath, Jennifer Connelly, Dylan Coss, Max Krucoff, Wade M. Mueller, Anjishnu Banerjee, and Peter S. LaViolette. ASNR 2024 (oral)

[3] Radio-pathomic signatures predict survival outcomes of gross total tumor resections in glioblastoma patients – Michael Flatley, **Savannah R. Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Aleksandra Winiarz, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Mohit Agarwal, and Peter S. LaViolette. ASNR 2024 (oral)

[4] Autopsy-based radio-pathomic maps of extracellular fluid density associate with fractional anisotropy in glioblastoma patients – Samuel A. Bobholz, Allison K. Lowman, Aleksandra Winiarz, **Savannah R. Duenweg**, Michael Flatley, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Wade M. Mueller, Anjishnu Banerjee, Peter S. LaViolette. ASNR 2024 (oral)

[5] Survival outcomes and glioblastoma locations: a voxelwise survival analysis of white matter tract intersections – Biprojit Nath**,** Aleksandra Winiarz, Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Michael Flatley, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Anjishnu Banerjee, and Peter S. LaViolette. ASNR 2024 (oral)

[6] A comparison of image intensity normalization methods for harmonizing common MRI contrasts in brain cancer imaging studies – **Savannah R. Duenweg**, Samuel Bobholz, Allison K. Lowman, Aleksandra Winiarz, Fitzgerald Kyereme, Jennifer Connelly, Mohit Agarwal, Peter S. LaViolette. ASNR 2023 (oral)

[7] A comparison of radio-pathomic maps of cell density to rCBV for detecting infiltrative tumor outside contrast enhancement in de-novo glioblastoma - Samuel Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Mohit Agarwal, Anjishnu Banerjee, Peter S. LaViolette. ASNR 2023 (oral)

[8] Association between MR spectroscopic imaging and radio-pathomic maps of cell density in a 53-year-old female diagnosed with a glioblastoma – Samuel Bobholz, Janine Lupo, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Mohit Agarwal, Anjishnu Banerjee, Peter S. LaViolette. ASNR 2023 (oral)

[9] Radio-pathomic phenotypes of glioblastoma show different responses to bevacizumab treatment. – Samuel A Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Fitzgerald Kyereme, Elizabeth J. Cochran, Jennifer Connelly, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee, Peter S. LaViolette. ASFNR 2022 (oral)

[10] Glioblastoma survival duration is associated with increased tumor outside of radiological annotations at autopsy. – Samuel Bobholz, Allison Lowman, Michael Brehler, **Savannah Duenweg**, Fitzgerald Kyreme, Elizabeth Cochran, Jennifer Connelly, Wade Mueller, Mohit Agarwal, Darren O'Neil, Anjishnu Banerjee, Peter LaViolette, ASNR 2022 (oral)

Regional

[1] Honoring Choice Wisconsin Quality Improvement – Breanna Palmen, John Zunker, **Savannah Duenweg**, Sabrina Hofmeister, and George Lange. MCW Department of Family & Community Medicine Research Forum 2023 (oral).

Local

[1] T2-weighted MRI radiomic features predict prostate cancer presence and eventual biochemical recurrence – **Savannah R. Duenweg**, Samuel A. Bobholz, Michael J. Barrett, Allison K. Lowman, Aleksandra Winiarz, Biprojit Nath, John Bukowy, Kenneth A. Iczkowski, Kenneth M. Jacobsohn, Stephanie Vincent-Sheldon, Peter S. LaViolette. Olson Radiology Retreat 2023 (oral)

[2] Autopsy-based radio-pathomic maps reveal demographic factors impact the presence of tumor outside contrast enhancement in glioma patients – Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Michael Flatley, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Wade M. Mueller, Anjishnu Banerjee, Peter S. LaViolette. Olson Radiology Retreat 2023 (oral)

[3] Radio-pathomic associations between MRI and complex histomorphometric features of prostate cancer – **Savannah R. Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Michael Brehler, Fitzgerald Kyereme, Kenneth A. Iczkowski, Peter S. LaViolette. MCW GSA Symposium 2022 (oral)

[4] Radio-pathomic mapping in brain cancer using autopsy tissue – Samuel Bobholz, Allison K. Lowman, Michael Brehler, **Savannah R. Duenweg**, Fitzgerald Kyereme, Jennifer Connelly, Elizabeth Cochran, Wade M. Mueller, Anjishnu Banerjee, Peter S. LaViolette. MCW GSA Symposium 2022 (oral)

[5] Investigation of longitudinal functional connectivity changes in glioblastoma patients at the end of life – Aleksandra Winiarz, Samuel Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Michael Brehler, Fitzgerald Kyereme, Dylan Coss, Elizabeth Cochran, Jennifer Connelly, Peter S. LaViolette. MCW GSA Symposium 2022 (oral)

POSTERS

[1] Radio-pathomic maps of complex histo-morphometric features trained with whole mount prostate histology differentiate prostate cancer on MP-MRI – **Savannah Duenweg**, Michael Flatley, Aleksandra Winiarz, Samuel Bobholz, Allison Lowman, Biprojit Nath, Fitzgerald Kyereme, Kenneth Iczkowski, Anjishnu Banerjee, and Peter LaViolette. ISMRM 2024 (power pitch)

[2] Perfusion-cellularity correlation in non-enhancing FLAIR hyperintensity prior to surgery is associated with worse prognosis in glioblastoma patients following gross total resection – Samuel A. Bobholz**,** Allison K. Lowman, Aleksandra Winiarz, **Savannah R. Duenweg**, Michael Flatley, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Wade M. Mueller, Anjishnu Banerjee, Peter S. LaViolette. ASNR 2024 (poster)

[3] Glioblastoma biopsy samples taken during prospective 5ALA-guided surgery from regions outside contrast enhancement identify tumor invasion – Aleksandra Winiarz, Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Michael Flatley, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Anjishnu Banerjee, and Peter S. LaViolette. ASNR 2024 (poster)

[4] Radio-pathomic maps of complex histo-morphometric features trained with whole mount prostate histology differentiate prostate cancer on MP-MRI – **Savannah Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Aleksandra Winiarz, Biprojit Nath, Kenneth Iczkowski, Anjishnu Banerjee, and Peter LaViolette. Southeast Wisconsin Data Science (SEAWINDS) 2024 (poster)

[5] ADC outperforms T2 and non-MR guided surgical sampling in virtual prostate cancer biopsies: a digital twin study – **Savannah R. Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Aleksandra Winiarz, Biprojit Nath, Kenneth A. Iczkowski, Kenneth M. Jacobsohn, and Peter S. LaViolette. SAR 2024 (scientific poster)

[6] Gleason pattern perceptions differ depending on the digitization resolution of whole mount prostatectomy slides – **Savannah R. Duenweg**, Samuel Bobholz, Michael J. Barrett, Allison K. Lowman, Aleksandra Winiarz, Biprojit Nath, Kenneth A. Iczkowski, and Peter S. LaViolette. USCAP 2024 (poster)

[7] Temporal changes in tumor composition differ across tumor grade in glioma – **Savannah R. Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Margaret A. Stebbins, Aleksandra Winiarz, Michael Flatley, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Wade M. Mueller, Anjishnu Banerjee, and Peter S. LaViolette. SNO 2023 (poster)

[8] Autopsy-based radio-pathomic maps of tissue composition delineate IDH1 status in gliomas – Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Margaret A. Stebbins, Aleksandra Winiarz, Michael Flatley, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Wade M. Mueller, Anjishnu Banerjee, Peter S. LaViolette. SNO 2023 (poster)

[9] Radio-pathomic tumor probability maps identify glioblastoma invasion beyond 5-ALA guided resection cavities – Aleksandra Winiarz, Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Margaret A. Stebbins, Michael Flatley, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Wade M. Mueller, Anjishnu Banerjee, and Peter S. LaViolette. SNO 2023 (poster)

[10] A 57-year-old male with primary glioblastoma treated with laser interstitial thermal therapy: imaging and autopsy findings – Allison K. Lowman, Aleksandra Winiarz, Samuel A. Bobholz, **Savannah R. Duenweg**, Margaret Stebbins, Michael Flatley, Biprojit Nath, Fitzgerald Kyereme, Dylan J. Coss, Max Krucoff, Jennifer Connelly, Peter S. LaViolette. SNO 2023 (poster)

[11] AXons Intersecting Tumor Enhancement (AXITE) Radiomics: A Novel predictor for Overall Survival in Glioblastoma – Biprojit Nath, Aleksandra Winiarz, Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Margaret A. Stebbins, Michael Flatley, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Anjishnu Banerjee, and Peter S. LaViolette. SNO 2023 (power pitch and poster)

[12] Diffusion differences in low to high grade glioma transformation – Michael Flatley, **Savannah R. Duenweg**, Allison K. Lowman, Samuel Bobholz, Margaret Stebbins, Aleksandra Winiarz, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Anjishnu Banerjee, and Peter S. LaViolette. SNO 2023 (rapid report and poster)

[13] Radiomic features of contrast enhanced T1 MRI sequences predict survival in primary glioblastoma patients who underwent adjuvant radiation therapy – Michael Flatley, **Savannah R. Duenweg**, Allison K. Lowman, Samuel Bobholz, Margaret Stebbins, Aleksandra Winiarz, Biprojit Nath,

Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Anjishnu Banerjee, and Peter S. LaViolette. SNO 2023 (poster).

[14] SOX2 positive, presumed tumor invasion measured beyond contrast enhancement and FLAIR hyperintensity in both treated and untreated glioblastoma patients assessed at autopsy – Margaret Stebbins, Samuel Bobholz, **Savannah R. Duenweg**, Allison K. Lowman, Aleksandra Winiarz, Michael Flatley, Bijprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Anjishnu Banerjee and Peter S. LaViolette. SNO 2023 (poster)

[15] Radio-Pathomic Maps of Glioblastoma Cellularity Highlight Regions Outside Contrast Enhancement That Recur Early – Aleksandra Winiarz, Samuel Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Michael Flatley, Biprojit Nath, Fitzgerald Kyereme, Dylan Coss, Jennifer Connelly, and Peter S. LaViolette. Olson Radiology Retreat 2023 (poster)

[16] Diffusion differences in low to high grade glioma transformation – Michael Flatley, **Savannah R. Duenweg**, Allison K. Lowman, Samuel Bobholz, Aleksandra Winiarz, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Anjishnu Banerjee, and Peter S. LaViolette. Olson Radiology Retreat 2023 (poster)

[17] Histological signatures of glioblastoma across tumor grades – Michael Flatley, **Savannah R. Duenweg**, Allison K. Lowman, Samuel Bobholz, Aleksandra Winiarz, Biprojit Nath, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Anjishnu Banerjee, and Peter S. LaViolette. Olson Radiology Retreat 2023 (poster)

[18] Use of containers and microservices in supporting dynamic research environments – Michael Barrett, Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Biprojit Nath, and Peter S. LaViolette. Olson Radiology Retreat 2023 (poster)

[19] AXons Intersecting Tumor Enhancement (AXITE) Radiomics: A Novel predictor for Overall Survival in Glioblastoma – Biprojit Nath, Aleksandra Winiarz, Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Margaret A. Stebbins, Michael Flatley, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Max Krucoff, Anjishnu Banerjee, and Peter S. LaViolette. Olson Radiology Retreat 2023 (poster)

[20] Autopsy-based radio-pathomic maps of tumor probability delineate tumor presence within radiological segmentations – Samuel Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Margaret Stebbins, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee and Peter S. LaViolette. ISMRM 2023 (poster)

[21] Slide scanner differences influence optical and computed properties of digitized prostate cancer histology – **Savannah R. Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Aleksandra Winiarz, Margaret Stebbins, Fitzgerald Kyereme, Kenneth A. Iczkowski, and Peter S. LaViolette. USCAP 2023 (poster)

[22] An analysis of optical and computed properties of prostate cancer histology digitized on multiple slide scanners – **Savannah R. Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Aleksandra Winiarz, Margaret Stebbins, Fitzgerald Kyereme, Kenneth A. Iczkowski, and Peter S. LaViolette. MCW Graduate School Poster Session 2022 (poster)

[23] Multi-scanner T2-weighted imaging normalization methods comparison in prostate cancer MRI – **Savannah R. Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Margaret Stebbins, Aleksandra Winiarz, Fitzgerald Kyereme, and Peter S. LaViolette. ISMRM-MRoC 2022 (power pitch and poster)

[24] T2-weighted image intensity normalization methods comparison in prostate cancer MRI with and without the use of an endorectal coil – **Savannah R. Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Margaret Stebbins, Aleksandra Winiarz, Fitzgerald Kyereme, and Peter S. LaViolette. ISMRM-MRoC 2022 (power pitch and poster)

[25] Hypocellular regions on radio-pathomic maps of glioma pathology are associated with bevacizumab treatment response – Samuel Bobholz, Alisha Hoefs, Jordyn Hamburger, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Margaret Stebbins, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee, and Peter S. LaViolette. ISMRM-MRoC 2022 (power pitch and poster)

[26] Tumor probability maps derived from conventional MRI and machine learning predict the location of glioblastoma invasion beyond contrast enhancement confirmed with 5-ALA-guided resection – Aleksandra Winiarz, Samuel Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Fitzgerald Kyereme, Dylan Coss, Max Krucoff, Jennifer Connelly, and Peter S. LaViolette. ISMRM-MRoC 2022 (power pitch and poster)

[27] SOX2 positive glioblastoma invasion beyond contrast enhancement detected with radio-pathomic maps of cell density – Margaret Stebbins, Samuel Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Fitzgerald Kyereme, Jennifer Connelly, Dylan Coss, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee, and Peter S. LaViolette. ISMRM-MRoC 2022 (power pitch and poster)

[28] Phenotypic analysis of radio-pathomic maps in de-novo glioblastoma identifies differences in bevacizumab treatment response – Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz,

Fitzgerald Kyereme, Elizabeth J. Cochran, Jennifer Connelly, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee, Peter S. LaViolette. SNO 2022 (poster)

[29] Radio-pathomic maps of de-novo glioblastoma identify phenotypes of tumor invasion associated with prognosis – Samuel A. Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Aleksandra Winiarz, Fitzgerald Kyereme, Elizabeth J. Cochran, Jennifer Connelly, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee, Peter S. LaViolette. SNO 2022 (poster)

[30] Overall survival variation due to the timing of post-surgical radiation in high-grade gliomas - Allison K. Lowman, Samuel Bobholz, Michael Brehler, **Savannah R. Duenweg**, Fitzgerald, Kyereme, Elizabeth J. Cochran, Dylan Coss, Jennifer Connelly, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee, Peter S. LaViolette. SNO 2022 (poster)

[31] A 44-year old female with DICER1-mutant primary intracranial sarcoma with imaging near end of life - Allison K. Lowman, Aleksandra Winiarz, Samuel Bobholz, Michael Brehler, **Savannah R. Duenweg**, Fitzgerald, Kyereme, Elizabeth J. Cochran, Dylan Coss, Jennifer Connelly, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee, Peter S. LaViolette. SNO 2022 (poster)

[32] A ground truth comparison of pathologically confirmed glioblastoma margins to contrast enhancement at autopsy – Allison K. Lowman, Samuel Bobholz, Michael Brehler, **Savannah R. Duenweg**, Fitzgerald, Kyereme, Elizabeth J. Cochran, Dylan Coss, Jennifer Connelly, Wade M. Mueller, Mohit Agarwal, Anjishnu Banerjee, Peter S. LaViolette. SNO 2022 (poster)

[33] Investigation of longitudinal functional connectivity changes in glioblastoma at the end of life. – Aleksandra Winiarz, Samuel Bobholz, Allison K. Lowman, **Savannah R. Duenweg**, Fitzgerald Kyereme, Dylan Coss, Elizabeth Cochran, Jennifer Connelly, Peter S. Laviolette. ASFNR 2022 (virtual case report)

[34] Radio-pathomic associations between MRI and complex histomorphometric features of prostate cancer – **Savannah R. Duenweg**, Samuel A. Bobholz, Allison K. Lowman, Michael Brehler, Fitzgerald Kyereme, Kenneth A. Iczkowski, Peter S. LaViolette. ISMRM 2022 (power pitch)

[35] Tumor infiltration beyond contrast enhancement and FLAIR hyperintensity at autopsy predicts survival in glioblastoma patients. - Samuel Bobholz, Allison Lowman, Michael Brehler, **Savannah Duenweg**, Fitzgerald Kyreme, Elizabeth Cochran, Jennifer Connelly, Wade Mueller, Mohit Agarwal, Darren O'Neil, Anjishnu Banerjee, Peter LaViolette. ISMRM 2022 (digital poster)

[36] Radio-pathomic tumor probability maps in glioma patients using autopsy tissue samples as ground truth. - Samuel Bobholz, Allison Lowman, Michael Brehler, **Savannah Duenweg**, Fitzgerald Kyreme, Elizabeth Cochran, Jennifer Connelly, Wade Mueller, Mohit Agarwal, Darren O'Neil, Anjishnu Banerjee, Peter LaViolette. ISMRM 2022 (power pitch)

[37] Measurement of treatment dependent glioblastoma cell density in T1-weighted contrast enhancement at autopsy – Allison Lowman, Samuel Bobholz, Jennifer Connelly, Elizabeth Cochran, Wade Mueller, Michael Brehler, Fitzgerald Kyreme, John Sherman, **Savannah Duenweg**, Peter LaViolette. ASCO 2021 (e-Abstract)

[38] Pathological validation of contrast enhancement at autopsy between patients treated and untreated with chemotherapy and radiation – Allison Lowman, Samuel Bobholz, Jennifer Connelly, Elizabeth Cochran, Wade Mueller, Michael Brehler, Fitzgerald Kyreme, John Sherman, **Savannah Duenweg**, Peter LaViolette. SNO 2021 (poster)

[39] Effect of tumor treating fields treatment duration on cellularity distributions beyond T1w MRI contrast enhancing margin at autopsy in glioma patients: preliminary results – Samuel Bobholz, Allison Lowman, Michael Brehler, **Savannah Duenweg**, Sean McGarry, Fitzgerald Kyreme, Elizabeth Cochran, Jennifer Connelly, Wade Mueller, Mohit Agarwal, Darren O'Neil, Anjishnu Banerjee, Peter LaViolette. SNO 2021 (poster)

[40] Histomorphometric features of prostate cancer identify patients who biochemically recur after prostatectomy - **SR Duenweg**, M Brehler, S Bobholz, AK Lowman, F Kyereme, K Iczkowski, and PS LaViolette. MCW Graduate School Poster Session 2021 (poster)

[41] Development of customized software for transferring pathologist annotations between high-resolution histology digitized on two different slide scanners – **SR Duenweg**, M Brehler, S Bobholz, AK Lowman, F Kyereme, K Iczkowski, and PS LaViolette. MCW Graduate School Poster Session 2020 (poster)