Derek J. Bivona, PhD

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EDUCATION

PhD in Biomedical Engineering Aug. 2016 – Dec. 2021
University of Virginia (UVA) Charlottesville, VA
GPA: 3.96 (Relevant Coursework: Machine Learning, Soft Tissue Biomechanics)

BS in Biomedical Engineering Aug. 2012 – May 2016
Tulane University New Orleans, LA
GPA: 3.97 (Summa Cum Laude)
Relevant Coursework: Honors Linear Algebra, Mathematical Modeling of Biological Systems

RESEARCH INTERESTS

Application of data science, machine learning, and artificial intelligence to physiological systems & baseball
Growth and remodeling of soft tissues such as cardiovascular & female reproductive systems

SKILLS

Key Skills: Machine Learning, Statistical Modeling, Clustering & Classification, Dimensionality Reduction, Signal Processing, Biomechanics, Finite Element Modeling

Technical Skills: Python (with NumPy, SciPy, Pandas & Sci-Kit Learn), MATLAB, FEBio Suite (Finite Element Solver), C++, UNIX/Linux/Mac, SuiteHeart (Cardiac MRI Analysis Software)

RESEARCH/WORK EXPERIENCE

Data Scientist/Biomedical Engineer | Clinical Cardiac Electrophysiology Jan. 2023 – Present
Cardiovascular Medicine | UVA

- Gathering and analyzing data from a variety of sources and procedures within the clinical cardiac electrophysiology program (i.e., patient medical charts, cardiac MRI, cardiac echocardiography, and ECGs)
- Developing and employing appropriate statistical tests and predictive/machine learning models (functional principal component analysis, XGBoost/random forest, CNN, linear and logistic regression) to improve patient outcomes to pace-maker therapy
- Summarizing findings in peer-reviewed journal articles
- Managing collaborations among (and presenting findings to) industry partners such as Medtronic and Siemens Healthineers along with other non-technical stakeholders
- Mentoring engineering undergraduate and medical students

Research Partner/Data Science Consultant | Reboot Motion June 2022 – Nov. 2022

Project: Machine Learning Models to Give Pitcher-Specific Advice to Improve Fastball Velocity

Link to Summary Article: https://learnyourkeep.substack.com/p/building-on-top-of-reboot-motion

- Pre-processed dataset, which consisted of 12,000 fastballs (observations) each with around 70 biomechanics-based proprietary parameters, to eliminate correlated features and impute missing values

- Project A. Velocity Improvement: Quick Fixes with Stepwise Linear Regression
    1. Utilized motion-captured data from a specific pitcher as input
    2. Identified the top five features that influenced the velocity of the given pitcher
    3. Displayed (a) the distribution of each of the significant parameters during the outing, as well as (b) scatterplots that mark parameter values versus fastball velocity
    4. Output advice on whether to increase or decrease a certain parameter to increase velocity

- Project B. Velocity Improvement: Long-Term Adjustments
    1. Optimized random forest and XGBoost models to fit available fastball data
    2. Created partial dependence plots (PDPs) to uncover 8 significant features along with the overall relationship between parameters and velocity based on the random forest/XGBoost models
    3. Demonstrated shortcomings of a given pitcher by overlaying the distribution of parameters of a specific pitcher on the distribution of the same parameters from the MLB
    4. Quantified shortcomings by calculating deviations in the means of the parameters between the specific pitcher and MLB cohort
    5. Suggested specific adjustment based on the tree-based model and PDPs

Postdoctoral Research Associate | Cardiovascular Medicine | UVA Jan. 2022 – Dec. 2022
Advisor: Ken Bilchick, MD, MS

Project: Statistical and Machine Learning Models to Improve Patient Outcome in Clinical Cardiac Electrophysiology

- Collaborated with an interdisciplinary team (physicians, engineers, nurses, and clinical research coordinators) to collect clinical and imaging-based parameters from more than 200 human patients with heart failure who received cardiac resynchronization therapy (CRT) at the UVA Health System
- Developed raw data from multiple modalities (cardiac magnetic resonance [CMR], echocardiography, cardiac angiograms/X-rays, electrocardiograms [ECG]) into curated, well-structured data utilized to train statistical and machine learning models
- Built and optimized the following models:
    1. Multivariate multiple linear regression to evaluate the associations among 39 clinical parameters and 3 CRT response measures
    2. Gaussian mixture model (GMM) to stratify patients into 3 clusters, which resulted in one group with poor long-term survival, one group with intermediate survival, and another group with excellent survival
    3. Logistic regression with cross-validation to predict 4-year survival with an average area under the ROC curve of 0.86 ± 0.01
    4. Linear regression models with interaction terms to demonstrate that females with non-ischemic cardiomyopathy and extensive ventricular dyssynchrony have the most-favorable outcome to CRT
    5. Robust linear regression models to highlight the utility of novel electrical activation parameters in predicting CRT outcome
- Created a web-based application (which can be accessed at http://gmmxcrt.pythonanywhere.com/ with username tester and password BilchickCRT) to allow physicians to utilize the GMM to identify patients who may benefit from advanced heart failure therapy
- Communicated key findings to broad audience including physicians, professors, and biotechnology companies

- Managed multiple projects/collaborations with industrial (Siemens Healthineers, Medtronic) and academic (Fred Epstein, PhD in Biomedical Engineering @ UVA & Amit Patel, MD in Cardiovascular Medicine @ UVA) partners
- Trained and supervised 4 medical students in patient chart review, CMR/echocardiography analysis, and ECG reading and exportation

Graduate Research Assistant | Cardiac Biomechanics Group | UVA Aug. 2016 – Dec. 2021
Advisor: Jeffrey W. Holmes, MD, PhD

Dissertation Title: "Biophysical and Statistical Modeling for Predicting the Progression and Regression of Cardiac Growth"

Project 1: A Comprehensive Finite-Element Model of Changes in Mechanics, Composition, and Growth during Post-Infarction Healing

- Constructed a biomechanics-based, finite-element (FE) model of the rat left ventricle (LV) after processing physiological signals from rat experiments
- Optimized the parameters of multiple constitutive equations based on experimental data using Monte Carlo simulations and genetic algorithms to accurately model the material behavior of both healthy and damaged cardiac tissue
- Wrote a custom material plug-in in C++ for the FEBio software to model volume loss within the FE model
- Accurately simulated the cardiac cycle while evaluating changes in LV geometry and growth due to perturbations in pressure and stiffness
- 3D models can be found at https://derekbivona.github.io/DerekBivona/ARmodels.html and seen in augmented reality [AR] on mobile devices

Project 2: Predicting Patient Response to CRT with Machine Learning

- Employed logistic regression, random forest, and support vector machine models with nested cross-validation and accurately classified patient response to CRT with an area under the ROC curve of 0.9
- Performed penalized linear discriminant analysis on cardiac strain curves (discretized functional data) derived from patient MRI and differentiated CRT responders from non-responders with 80% accuracy

Undergraduate Research Assistant Aug. 2014 – May 2016
Biomechanics of Growth and Remodeling Lab | Tulane University
Advisor: Kristin S. Miller, PhD

Experimental & Computational Approaches to Quantifying Regional Variations of Residual Strain Within the Murine Female Reproductive System

- Performed opening angle experiments on the murine female reproductive system before and after exposure to elastase
- Developed MATLAB program to analyze biaxial mechanical testing data of the murine female reproductive system
- Explored the use of a four-fiber family constitutive model (considering collagen, elastin, and smooth muscle) to describe the mechanical behavior of the murine female reproductive system

PEER-REVIEWED JOURNAL ARTICLES

1. Bivona, D. J., Ghadimi, S., Wang, Y., Oomen, P. J. A., Malhotra, R., Darby, A. E., Mangrum, J. M., Mason, P. K., Mazimba, S., Patel, A.R., Epstein, F. H., & Bilchick, K. C. (2024 – Under Review). Machine learning of ECG waveforms and cardiac magnetic resonance for response and survival After cardiac resynchronization therapy. *Computers in Biology and Medicine*.

2. Bivona, D. J., Tallavajhala, S., Abdi, M., Oomen, P. J. A., Gao, X., Malhotra, R., Darby, A. E., Monfredi, O. J., Mangrum, J. M., Mason, P. K., Mazimba, S., Salerno, M., Kramer, C. M., Epstein, F. H., Holmes, J. W., & Bilchick, K. C. (2022). Machine learning for multidimensional response and survival after cardiac resynchronization therapy using features from cardiac magnetic resonance. *Heart rhythm O2*, *3*(5), 542–552. https://doi.org/10.1016/j.hroo.2022.06.005
3. Bivona, D. J., Oomen, P. J., Wang, Y., Morales, F. L., Abdi, M., Gao, X., ... & Bilchick, K. C. (2023). Cardiac Magnetic Resonance, Electromechanical Activation, Kidney Function, and Natriuretic Peptides in Cardiac Resynchronization Therapy Upgrades. *Journal of Cardiovascular Development and Disease*, *10*(10), 409. https://doi.org/10.3390/jcdd10100409
4. Bivona, D. J., Tallavajhala, S., Abdi, M., Oomen, P. J. A., Gao, X., Malhotra, R., Darby, A., Monfredi, O. J., Mangrum, J. M., Mason, P., Mazimba, S., Salerno, M., Kramer, C. M., Epstein, F. H., Holmes, J. W., & Bilchick, K. C. (2022). Cardiac magnetic resonance defines mechanisms of sex-based differences in outcomes following cardiac resynchronization therapy. *Frontiers in cardiovascular medicine*, *9*, 1007806. https://doi.org/10.3389/fcvm.2022.1007806
5. Morales, F. L.*, Bivona, D. J.*, Abdi, M., Malhotra, R., Monfredi, O., Darby, A., Mason, P., Mangrum, J. M., Epstein, F. H., Bilchick, K. C., & Oomen, P. J. A. (2023). Noninvasive Electrical Mapping Compared with the Paced QRS Complex for Optimizing CRT Programmed Settings and Predicting Multidimensional Response. *Journal of Cardiovascular Translational Research*, *16*(6), 1448-1460. https://doi.org/10.1007/s12265-023-10418-1
6. Bivona, D.J., Estrada, A. C., Yoshida, K., & Holmes. J. W. (2024 – In Preparation) A Comprehensive Finite-Element Model of Changes in Mechanics, Composition, and Growth During Post-Infarction Healing. *Journal of biomechanical engineering.*
7. Capone, D. J., Clark, G. L., Bivona, D. J., Ogola, B. O., Desrosiers, L., Knoepp, L. R., Lindsey, S. H., & Miller, K. S. (2019). Evaluating residual strain throughout the murine female reproductive system. *Journal of biomechanics*, *82*, 299–306. https://doi.org/10.1016/j.jbiomech.2018.11.001

CONFERENCE PRESENTATIONS

Postdoctoral Research

- "Cardiac Magnetic Resonance Demonstrates Key Differences in Patients Undergoing De Novo Cardiac Resynchronization Therapy (CRT) Versus CRT Upgrades" | American Heart Association Scientific Sessions (Poster) | November 2022
- "Novel Cardiac Electrical Activation Parameters Associated with Cardiac Resynchronization Therapy Response" (Poster) | American Heart Association Scientific Sessions | November 2022
- "Machine Learning Analysis of Clinical and CMR Features Predicts Long-term Survival After Cardiac Resynchronization Therapy" (Poster) | Heart Rhythm Society Annual Meeting | April 2022

Graduate Research

- "Cluster Analysis of Cardiac Resynchronization Response Parameters Predicts Long-Term Survival with Heart Failure" | American Heart Association Scientific Sessions (Virtual) | November 2020
- "Machine Learning vs. Medical Doctor: Predicting Patient Response to Cardiac Resynchronization Therapy Using Machine Learning" | TomTom Applied Machine Learning Conference (Oral) | April 2019
- "A Volumetric Growth Model with Unstressed Configuration Updates for Healing Post-Infarction Scar" | Summer Biomechanics, Bioengineering, and Biotransport Conference (Virtual) | June 2020
- "A Volumetric Growth Model for Healing Post-Infarction Scar" | Summer Biomechanics, Bioengineering, and Biotransport Conference (Oral) | June 2019
- "A Volumetric Growth Model for Healing Post-Infarction Scar" | NIH Interagency Modeling and Analysis Group: Multiscale Modeling Consortium Meeting (Poster) | March 2019

Undergraduate Research

- Summer Biomechanics, Bioengineering, and Biotransport Conference (Oral) | National Harbor, MD | June 2016
- Health Science and Research Day (Poster) | Tulane University School of Medicine | April 2016
- School of Science and Engineering Research Day (Poster) | Tulane University | April 2016
- Biomedical Engineering Society Annual Meeting (Oral) | Oct. 2015

AWARDS

Biomedical (Big) Data Science Training Grant Appointment July 2017 – July 2019

- Selected among all graduate students in the School of Science and Engineering to receive training in biomedical data science under an NIH funded program for two consecutive years; acted as social media chair for the program (@uva_biodatasci)

Image-Based Biomedical Modeling Summer Fellowship June 2018

- Chosen for an international program to receive training in modeling biomedical systems in Park City, Utah

National Science Foundation Graduate Research Fellowship Program – Honorable Mention April 2018

School of Science and Engineering Poster Competition, 1st Place, Tulane University April 2016

Phi Kappa Beta Honor Society, Tulane University Chapter Inducted March 2016

Tulane University Honor's Program Summer Research Grant Summer 2015

- Awarded a grant from the Honor's Program at Tulane University to conduct research on women's reproductive health

Tau Beta Pi Engineering Honor Society, Tulane University Chapter Inducted Nov. 2014

- Inducted into society for having a GPA within the top 5% of all engineering students at Tulane University; served as president

Paul M. Pope, Jr. Engineering Scholarship, Tulane University Aug. 2014 – May 2016

School of Science and Engineering Honor Society, Tulane University Inducted Aug 2013

Distinguished Scholar Scholarship, Tulane University Aug. 2012 – May 2016

Tulane University's Louisiana High School Valedictorian Scholarship Aug. 2012 – May 2016

TEACHING EXPERIENCE

Teaching Assistant | Physiology for Engineers I | UVA Jan. 2019 – May. 2019

- Created and delivered weekly lectures translating complex topics in human physiology to 65 undergraduate students
- Selected student feedback:
  1. "Derek was an amazing TA… He knows every single person's name, so when he was asked to give a presentation, he called on everyone by name. He understands the material and was great at simplifying the information for everyone..."
  2. "Derek was a wonderful TA that really aided in my understanding of the course material. He was very responsive to emails and was willing to go out of his way to meet before classes and discuss material that I didn't quite understand..."
  3. "Derek had a very relaxed and engaging teaching style that made him very approachable and helped initiate good discussions."

Teaching Assistant | Biomechanics | UVA Aug. 2018 – Dec. 2018

- Held weekly two-hour long sessions to aid 63 undergraduate students with their problem-solving skills in classic engineering subjects such as statics, dynamics, and mechanics of materials
- Developed homework and exam problem sets and provided students with solutions using a variety of multimedia sources

Guest Lecturer | BME8550 Soft Tissue Mechanics | UVA Nov. 2018

- Taught one class to graduate students about how to correctly model growth within the heart under different pathologic loading conditions
- Created in-class problems that gave the students hands on experience with calculating heart growth using an analytical slab of myocardium (heart tissue)

Grader | Biofluid Mechanics | Tulane University Aug. 2015 – Dec. 2015

- Designed and graded homework, quizzes, and exams
- Provided coursework help for students during office hours

Math and Science Tutor Aug. 2013 – May 2014
The New Orleans Charter Science and Mathematics High School | New Orleans, LA

- Tutored math and science to students from disadvantaged backgrounds

RELEVANT COURSEWORK

Undergraduate (Tulane University)
Modern Physics
Biomedical Electronics
Biomaterials & Tissue Engineering
Anatomy and Physiology with Cadaver Lab
Biomechanics
Vascular Bioengineering
Soft Tissue Biomechanics
Linear Algebra (Honors)
Mathematical Modeling of Biological Systems

Graduate (UVA)
Machine Learning
Soft Tissue Mechanics
Continuum Mechanics
Finite Element Analysis
Systems Bioengineering and Multi-Scale Modeling
Quantitative Biological Reasoning

VOLUNTEER

Baseball Buddy, Louisiana's Special Olympics Spring 2010 – Spring 2014

HOBBIES & PERSONAL INTERESTS

Baseball, iced coffee, wake surfing, Pixar movies, flag-football, strength & conditioning training, ultimate frisbee