

Doctoral Dissertation Defense Announcement

Mohamed Khalil

“Defining Memory NK cell development and functions following cytomegalovirus infection”



Candidate for Doctor of Philosophy in Microbiology and Immunology
School of Graduate Studies
Medical College of Wisconsin

Committee in Charge:

Subramaniam Malarkannan, PhD (Thesis Advisor)

Scott Terhune, PhD (Thesis Advisor)

Joseph T. Barbieri, PhD

Sridhar Rao, MD PhD

Ravit Boger, MD

Colleen Lau, PhD (Cornell University)

Tuesday, May 21st, 2024

12:00 PM – 1:00 PM CST

BRI Conference Room

Zoom Meeting ID: 965 7893 5827 Passcode: vt6GAR8j

<https://mcw-edu.zoom.us/j/96578935827?pwd=VWZ2NFizZUNLM3Y2UnY5dVBTODBUdz09>

Coursework completed

Introduction to Biomedical Research

Foundations of Clinical Medicine

Clinical Human Anatomy I

Molecules to Cells

Physiology

Bioethics

Clinical Human Anatomy II

Medical Neuroscience

Clinical Apprenticeship

Bench to Bedside

Infectious Agents and Host Immunology

Principles of Drug Action

Foundations of Human Behavior

Foundations of Pathological Principles

Techniques in Molecular and Cell Biology

Microbiology and Immunology Seminar

Team Science (CTSI)

Cardiovascular

Renal/Respiratory

Hematology/Lymph

Molecular and Cellular Research

Gastrointestinal/Nutrition

Endocrine/Reproduction

Neurology/Psychiatry

Symptoms

Foundational Capstone

Readings and Research

Foundations in Biomedical Science III

Tumor Immunology

Methods in Grant Preparation (CTSI)

Ethics & Integrity in Science

Research Ethics and Discussion Series

Doctoral Dissertation

Dissertation Summary

Defining Memory NK cell development and function following cytomegalovirus infection

Human cytomegalovirus (HCMV) is a β -herpesvirus that is highly prevalent in the adult population and has the ability to establish lifelong latency in healthy individuals. The innate and adaptive immune systems work closely to control viral replication, leading to a dynamic interaction between the virus and the host immune system. This interplay leads to the development of distinct immune-cell repertoires in HCMV seropositive (HCMV⁺) individuals. Natural killer (NK) cells are cytotoxic lymphocytes that are required to manage and control HCMV infections and possess strong anti-tumor activity. NK cells utilize their activating NKG2C/CD94 receptor complex to mount a response to HCMV-infected cells that present HLA-E molecules loaded with the HCMV UL40-derived peptide. As a result, HCMV⁺ individuals possess higher levels of NKG2C⁺ NK cells that contract to form a subset of memory-like cells. These NKG2C⁺ memory NK cells have enhanced anti-tumor and cytotoxic characteristics and therefore can be utilized in a variety of anti-tumor cellular therapies. However, the development and the underlying transcriptional mechanisms maintaining and sustaining these memory cells are not well understood. Given their potent cancer immunotherapeutic potential, my PhD thesis primarily aims to transcriptionally define this memory NK cell subset and explore their developmental origins.

Recent work by our lab and others have demonstrated that HCMV⁺ individuals exhibit significantly higher proportions of NKG2C⁺ memory NK cells in their peripheral blood. We found NKG2C⁺ memory NK cells have elevated transcriptional levels of *CD3*, *CD52* and *KLRC2*. To expand on these findings, we isolated NK cells from the human spleen, a secondary lymphoid organ crucial for initiating memory immune responses. To investigate if the human spleen is serving as one of the sites involved in housing and sustaining NKG2C⁺ memory NK cells, we obtained eight healthy adult human spleens from four HCMV seronegative (HCMV⁻) and four HCMV⁺ donors. Donor median age was 52 [IQR 47.5-56.5], 50% (n=4) were identified as female and 50% (n=4) were identified as male, and 50% (n=2) of females were HCMV⁻ and 50% (n=2) of females were HCMV⁺. The human spleens were provided by the Versiti Organ Donor Center of Wisconsin and were processed to a single cell suspension. In line with previous findings in the peripheral blood of HCMV⁺ individuals, we observed significantly elevated proportions of NKG2C⁺ NK cells in the spleens of HCMV⁺ donors. This observed significance of higher NKG2C⁺ NK cells was consistent across all HCMV⁺ donors when compared to our HCMV⁻ donors.

To investigate the molecular mechanisms involved in the maintenance and persistence of memory NKG2C⁺ NK cells, we performed single-cell RNA sequencing (scRNA-seq), using the sorted NK cells from all eight donors. Using unbiased clustering analysis, we identified and characterized four distinct NKG2C⁺ splenic NK cell subsets. Our findings indicated that the relative composition of these NKG2C⁺ subsets was highly influenced by the HCMV serostatus of the donors. Specifically, we observed that HCMV⁺ donors had significantly higher levels of NKG2C^{Hi} memory NK cells when compared to the HCMV⁻ donors. Our findings indicated that the relative composition of these NKG2C⁺ subsets was highly influenced by the HCMV status of the donors. Specifically, we observed that HCMV⁺ donors had significantly higher levels of NKG2C^{Hi} memory NK cells when compared to the HCMV⁻ donors. This NKG2C^{Hi} memory NK subset had significantly higher expression of *NKG2C*, *CD52*, *CD3 ϵ* , and *IL7R* and significantly lower expression of *FCER1G*, *KLRC1*, *CD247*, *ZBTB16*, *SYK*, and *SH2D1B*. These findings suggest NKG2C^{Hi} memory NK cells possess unique transcriptional and molecular mechanisms that may contribute to their ability to persist over time.

To explore the developmental cell fate of NKG2C^{Hi} memory NK, we utilized computational modeling from both the Monocle 2 and Monocle 3 software's to track how NKG2C⁺ cells transition between transcriptomic states. Monocle 3 analysis yielded a simple early-to-late cell fate trajectory that was projected onto our UMAP plot. We found that NKG2A^{Hi} NKG2C⁺ subset served as the early timepoint Khalil

in the developmental trajectory, ultimately leading to the development of NKG2C^{Hi} memory NK. The Monocle 2 analysis produced unique developmental trajectory plots, allowing us to visualize distinct developmental pathways and transitions. Interestingly, we observed a unique branch-point exclusive to the HCMV⁺ donors that expressed significantly higher transcriptional levels of *CD3ε* and *IL7R*. These data collectively demonstrate that HCMV exposure impacts the developmental trajectories of NK cells and influence the developmental origins of NKG2C^{Hi} memory NK cells.

Together, the work presented in this dissertation demonstrates that HCMV infection can promote the formation of NKG2C^{Hi} memory NK cells in the human spleen that displays a unique transcriptional and developmental profile. These findings may ultimately prove useful in the future isolation and application of memory NK cells in cellular immunotherapies.

Education

- August 2018 – present MD/PhD Candidate (anticipated May 2026)
Medical College of Wisconsin, Milwaukee, WI
- August 2014 – May 2016 B.S. Molecular and Cellular Biology
Illinois State University, Normal, IL
- January 2012 – May 2014 A.A.S Applied Sciences
Harry S. Truman College Chicago, IL

Research Experience

- August 2020 – present Antiviral functions of NK cells, characterizing memory NK cells following HCMV infection, congenital CMV
MCW/BRI (Malarkannan & Terhune labs)
- August 2018 – March 2020 Short-term morbidity and mortality outcomes in CRS/HIPEC in patients with appendiceal cancers
MCW Department of Surgery (Dr. Harveshp Mogal)
- January 2015 – May 2016 Utilizing the nematode *C. elegans* as a model to study the molecular and neurological basis of Angelman Syndrome
Illinois State University (Dr. Andres Vidal-Gadea)
- October 2014 – January 2015 Molecular machinery involved in *C. elegans* magnetotaxis behavior and function
Illinois State University (Dr. Andres Vidal-Gadea)

Grant Funding

- July 2022 – present **TL1-TR001437**
“Defining the immunological consequences of congenital cytomegalovirus infection”

Publications

1. **Khalil M**, Terhune SS, Malarkannan S. Characterizing the single-cell transcriptomes of fetal NK cells isolated from the umbilical cord of fetuses exposed to human cytomegalovirus during gestation. *Journal of Clinical and Translational Science*, 2024;8(s1) 113-114. doi: 10.1017/cts.2024.333.
2. **Khalil M**, Terhune SS, Malarkannan S. Human Cytomegalovirus Infection Promotes the Formation of NKG2C^{Hi} Memory NK Cells That Express Elevated Levels of IL-7R and Cyto-CD3ε. *Blood* 2023;142 (Supplement 1): 2554. <https://doi.org/10.1182/blood-2023-174570>.
3. **Khalil M**, Terhune SS, Malarkannan S. Single cell transcriptomes from HCMV⁺ donors reveal a unique NKG2C^{Hi} subset that represents true memory NK cells. *Journal of Immunology* 2023;244.01 doi: 10.104049/jimmunol.210.Supp.244.01.
4. **Khalil M**, Terhune SS, Malarkannan S. Defining the single-cell transcriptomes of splenic adaptive Natural Killer cells in donors with latent human cytomegalovirus infection. *Journal of Clinical and Translational Science* 2023;80. doi: 10.1017/cts.2023.326. PMID: PMC10129496

5. **Khalil M** & Malarkannan S. Innatus Immunis: Evolving paradigm of adaptive NK cells. *Journal of Experimental Medicine* 2022;1254. doi: 10.1084/jem.20221254. PMID: 36066493.
6. **Khalil M**, Mei A, Hashemi E, Wang D, Schumacher M, Terhune S, Malarkannan S. Method to Study Adaptive NK Cells Following MCMV Infections. *Methods in Molecular Biology* 2022;2463:195-204. doi: 10.1007/978-1-0716-2160-8_14. PMID: 35344176.
7. Wang D, Burns R, **Khalil M**, Mei A, Hashemi E, Malarkannan S. Methods to Analyze the Developmental Trajectory of Human Primary NK Cells Using Monocle and SCENIC Analyses. *Methods in Molecular Biology* 2022;2463:81-102. doi: 10.1007/978-1-0716-2160-8_7. PMID: 35344169.
8. Mei A, Hashemi E, **Khalil M**, Wang D, Malarkannan S. Isolation of Innate Lymphoid Cells from Murine Intestinal Lamina Propria. *Methods in Molecular Biology* 2022;2463:3-9. doi: 10.1007/978-1-0716-2160-8_1. PMID: 35344163.
9. Hashemi E, Mei A, Wang D, **Khalil M**, Malarkannan S. Methods for Isolating and Defining Single-Cell Transcriptomes of Tissue-Resident Human NK Cells. *Methods in Molecular Biology* 2022;2463:103-116. doi: 10.1007/978-1-0716-2160-8_8. PMID: 35344170.
10. **Khalil M**, Wang D, Hashemi E, Terhune SS, Malarkannan S. Implications of a 'Third Signal' in NK Cells. *Cells*. 2021 Jul 31;10(8):1955. doi: 10.3390/cells10081955. PMID: 34440725.

Abstracts

Oral presentations

1. **Khalil M**, Terhune SS, Malarkannan S. Single cell transcriptomes from fetuses exposed to HCMV during gestation reveals a distinct subset of memory-like NKG2C⁺ fetal NK cells. American Association of Immunologist 2024. Chicago, IL. May 2024
2. **Khalil M**, Terhune SS, Malarkannan S. Characterizing the single-cell transcriptomes of fetal NK cells isolated from the umbilical cord of fetuses exposed to human cytomegalovirus during gestation. Association for Clinical and Translation Sciences. Las Vegas, NV. April 2024
3. **Khalil M**, Terhune SS, Malarkannan S. Memory NK cells are regulated by a unique transcriptional program allowing for their persistence in HCMV⁺ individuals. Autumn Immunology Conference. Chicago, IL. November 2023
4. **Khalil M**, Terhune SS, Malarkannan S. Cytomegalovirus infection induces the generation of NKG2C^{Hi} fetal NK cells in the umbilical cord. Midwest TL1 Summit. Wauwatosa, WI. September 2023
5. **Khalil M**, Terhune SS, Malarkannan S. Interleukin-7 Receptor (IL-7R) and CD3 ϵ are necessary components for the development and function of NKG2C^{Hi} adaptive NK cells during HCMV infections. 13th Annual Immunology Scientific Retreat, Center for Immunology. Wauwatosa, WI. June 2023
6. **Khalil M**, Terhune SS, Malarkannan S. Single cell transcriptomes from HCMV⁺ donors reveal a unique NKG2C^{Hi} subset that represents true memory NK cells. American Association of Immunologist 2023. Washington, D.C. May 2023
7. **Khalil M**, Terhune SS, Malarkannan S. Single-cell transcriptome of human adaptive NK cells reveal a unique transcriptional program that governs its development and function. Autumn Immunology Conference. Chicago, IL. November 2022
8. **Khalil M**, Patel J.J, Baruah D, Rein L.R, Tsai S, Clarke C, T. Gamblin C, Mogal H. Association of Muscle Quantity and Frailty on Short-term Outcomes of CRS/HIPEC in Patients with Appendiceal cancer. SSO 2020 International Advanced Cancer Therapies. Orlando, Florida. February 2020 [Trainee Travel Award]
9. **Khalil M**, Vidal-Gadea AG. Impairment in the nematode *UBE3A* ortholog leads to neurological and molecular impairments in a *C. elegans* model of Angelman syndrome. Phi Sigma Research Symposium, Normal, IL. May 2016

10. **Khalil M**, Vidal-Gadea AG. Loss of function in the nematode *UBE3A* ortholog leads to neurological impairments in a *C. elegans* model of Angelman Syndrome. Animal Behavior Conference at Indiana University, Bloomington, IN. March 2016
11. **Khalil M**, Vidal-Gadea AG. The *C. elegans UBE3A* ortholog, *herc-1* is required for normal development and muscular functions. Molecular and Cellular Biology Seminar. Normal, IL. December 2015

Poster presentations

1. **Khalil M**, Terhune SS, Malarkannan S. Single cell transcriptomes from fetuses exposed to HCMV during gestation reveals a distinct subset of memory-like NKG2C⁺ fetal NK cells. American Association of Immunologist 2024. Chicago, IL. May 2024
2. **Khalil M**, Terhune SS, Malarkannan S. The single-cell transcriptomes of fetal NK cells unveil a distinctive subset crucial for the management of congenital cytomegalovirus infection. All Things Data Science Symposium. Milwaukee, WI. April 2024
3. **Khalil M**, Terhune SS, Malarkannan S. Characterizing the single-cell transcriptomes of fetal natural killer cells isolated from the umbilical cord of fetuses exposed to human cytomegalovirus during gestation. Association for Clinical and Translation Sciences. Las Vegas, NV. April 2024
4. **Khalil M**, Terhune SS, Malarkannan S. Single-cell transcriptomes of fetal NK cells reveal a unique NKG2C^{Hi} population that helps fetus manage congenital cytomegalovirus infection. MCW Research Week. Wauwatosa, WI. March 2024
5. **Khalil M**, Terhune SS, Malarkannan S. Transcriptomic profiling of fetal NK cells derived from the umbilical cord of fetuses exposed to human cytomegalovirus during gestation. Department of Medicine. Wauwatosa, WI. March 2024
6. Ishaq A, **Khalil M**, Terhune SS, Malarkannan S. Single cell profiling reveals a unique Ly49H^{Hi} memory-like NK subset during MCMV infection. Cancer Center Trainee Symposium. Milwaukee, WI. March 2024
7. **Khalil M**, Terhune SS, Malarkannan S. Human cytomegalovirus infection promotes the formation of NKG2C^{Hi} memory NK cells that express elevated levels of IL-7R and cyto-CD3 ϵ . American Society of Hematology. San Diego, CA. December 2023
8. **Khalil M**, Terhune SS, Malarkannan S. Single-cell transcriptome of HCMV seropositive fetuses reveals a unique subset of NKG2C⁺ cells that represent adaptive NK cells. 33rd Annual Graduate School Poster Session. Milwaukee, WI. December 2023
9. Ishaq A, **Khalil M**, Terhune SS, Malarkannan S. Single-cell transcriptomes of NK cells responding to MCMV infection reveal a distinct Ly49H^{Hi} memory subset emerging 7 days post-infection. Autumn Immunology Conference. Chicago, IL. November 2023
10. **Khalil M**, Terhune SS, Malarkannan S. Memory NK cells are regulated by a unique transcriptional program allowing for their persistence in HCMV⁺ individuals. Autumn Immunology Conference. Chicago, IL. November 2023
11. **Khalil M**, Terhune SS, Malarkannan S. Fetal NK Cells: Identifying Their Role During Congenital Cytomegalovirus Infection. 12th Annual CTSI Milwaukee Regional Research Forum. Milwaukee, WI. October 2023
12. **Khalil M**, Terhune SS, Malarkannan S. Cytomegalovirus infection induces the generation of NKG2C^{Hi} fetal NK cells in the umbilical cord. Midwest TL1 Summit. Wauwatosa, WI. September 2023
13. **Khalil M**, Terhune SS, Malarkannan S. Infection by human cytomegalovirus (HCMV) stimulates the development of memory NK cells characterized by increased expression of cyto-CD3 ϵ . 38th Annual MD-PhD National Student Conference. Copper Mountain, CO. July 2023
14. **Khalil M**, Terhune SS, Malarkannan S. Interleukin-7 Receptor (IL7R) and CD3 ϵ are necessary components for the development and function of NKG2C^{Hi} adaptive NK cells during HCMV

- infections. 13th Annual Immunology Scientific Retreat, Center for Immunology. Wauwatosa, WI. June 2023
15. **Khalil M**, Terhune SS, Malarkannan S. Single cell transcriptomes from HCMV⁺ donors reveal a unique NKG2C^{Hi} subset that represents true memory NK cells. American Association of Immunologist 2023. Washington, D.C. May 2023
 16. **Khalil M**, Terhune SS, Malarkannan S. Defining the single-cell transcriptomes of splenic adaptive Natural Killer cells in donors with latent human cytomegalovirus infection. Association for Clinical and Translation Sciences. Washington, D.C. April 2023
 17. **Khalil M**, Terhune SS, Malarkannan S. Interleukin-7 Receptor (IL7R) and CD3 ϵ are necessary for the development and function of NKG2C⁺ memory-like NK cells during HCMV infections. 6th Annual Graduate School Symposium. Milwaukee, WI. April 2023
 18. **Khalil M**, Terhune SS, Malarkannan S. Single-cell transcriptomes reveal a unique NKG2C^{Hi} population representing memory NK cells. MCW Research Week. Wauwatosa, WI. March 2023
 19. **Khalil M**, Terhune SS, Malarkannan S. Single-cell transcriptome from the spleen of HCMV⁺ donors reveal a unique subset of NKG2C⁺ population that represent true memory NK cells. Department of Medicine. Wauwatosa, WI. March 2023
 20. **Khalil M**, Terhune SS, Malarkannan S. Single-cell transcriptome of human adaptive NK cells reveal a unique transcriptional program that governs its development and function. Autumn Immunology Conference. Chicago, IL. November 2022
 21. **Khalil M**, Terhune SS, Malarkannan S. Single-cell transcriptome of HCMV seropositive individuals reveals a unique subset of NKG2C⁺ cells that represent adaptive NK cells. 32nd Annual Graduate School Poster Session. Wauwatosa, WI. October 2022
 22. **Khalil M**, Terhune SS, Malarkannan S. Transcriptome of human adaptive NK cells reveal a unique transcriptional program that governs its development and function. 11th Annual CTSI Milwaukee Regional Research Forum. Milwaukee, WI. October 2022
 23. **Khalil M**, Terhune SS, Malarkannan S. Transcriptomic profiling of human Adaptive NK cells derived from HCMV seropositive individuals. 1st Annual Midwest TL1 Research Summit. Madison, WI. September 2022
 24. **Khalil M**, Terhune SS, Malarkannan S. Defining the Human Cytomegalovirus manipulation of NK cells at a single-cell resolution. 12th Annual Immunology Scientific Retreat, Center for Immunology. Wauwatosa, WI. June 2022
 25. **Khalil M**, Patel J.J, Baruah D, Rein L.R, Tsai S, Clarke C, T. Gamblin C, Mogal H. Association of Muscle Quantity and Frailty on Short-term Outcomes of CRS/HIPEC in Patients with Appendiceal cancer. SSO 2020 International Advanced Cancer Therapies. Orlando, Florida. February 2020
 26. **Khalil M**, Vidal-Gadea AG. Impairment in the nematode *UBE3A* ortholog leads to neurological impairments in a *C. elegans* model of Angelman syndrome. Phi Sigma Research Symposium, Normal, IL. May 2016
 27. **Khalil M**, Vidal-Gadea AG. Loss of function in the nematode *UBE3A* ortholog leads to neurological impairments in a *C. elegans* model of Angelman Syndrome. Animal Behavior Conference at Indiana University, Bloomington, IN. April 2016 [Undergraduate Presentation Award]
 28. **Khalil M**, Vidal-Gadea AG. *C. elegans* as a potential model to study the molecular and neuronal aspects of Angelman syndrome. Angelman Syndrome Foundation Scientific Symposium, Schaumburg, IL. July 2015
 29. **Khalil M**, Vidal-Gadea AG. Molecular machinery responsible for *C. elegans* detection of earth's magnetic fields. Phi Sigma Research Symposium, Normal, IL. May 2015
 30. **Khalil M**, Vidal-Gadea AG. Investigation of the role of the nematode *UBE3A* ortholog leads to severe neurological impairments in a *C. elegans* model of Angelman syndrome. Annual Animal Behavior Symposium, Indiana University, Bloomington, IN. April 2015

Journal Reviewer

1. Journal of Experimental Medicine
2. Frontiers in Immunology
3. iScience
4. Scientific Reports

Awards and Honors

May 2024	Top Abstract , American Association of Immunologist
April 2024	Outstanding Abstract , Association for Clinical and Translational Science
January 2024	Heath Foundation Travel Award , Department of Medicine MCW
November 2023	John Wallace Diversity Award , Autumn Immunology Conference
October 2023	Center for Immunology Travel Award , C4I MCW
September 2023	Graduate School 2023-2024 Diversity Award , MCW
July 2023	Diversity Travel Award , National MD-PhD Student Conference
June 2023	Top Abstract Award , Annual Immunology Scientific Retreat MCW
May 2023	Trainee Abstract Award , American Association of Immunologist
April 2023	Outstanding Trainee Award , Association for Clinical and Translational Science
March 2023	Best Poster Presentation , MCW Department of Medicine
December 2021	Graduate Student Travel Award , MCW
June 2020	Medical Student Summer Research Program , MCW
February 2020	Outstanding Medical Student Presentation Award , Society of Surgical Oncology International Conference
August 2018 – 2020	Medical Student Presidential Scholar Award , MCW
May 2016	Outstanding Undergraduate Oral Presentation , Phi Sigma Symposium
March 2016	Undergraduate Oral Presentation Award , Animal Behavior Conference

Invited Talks

January 2024	“Fetal NK cells: Unraveling Their Role During Congenital Cytomegalovirus Infection” Illinois State University Molecular Immunology Seminar
September 2023	“Human cytomegalovirus infection drives the formation of NKG2C^{Hi} memory NK cells that express elevated levels of IL-7R and cyto-CD3ϵ” Component & Module Leaders CTSI
August 2022	“Immunological Consequences of Congenital Cytomegalovirus Infection” TL1 Predoctoral Training Grant NIH Renewal Review Board
September 2021	“Single cell transcriptomes of Natural Killer Cells during viral infections” Illinois State University School of Biological Sciences Seminar

Leadership Positions

February 2024 – present	Student Ambassador - MCW Social Media Team
December 2023 – present	Admissions Committee Student Chair - Medical College of Wisconsin Medical Scientist Training Program
November 2023 – present	MSTP Student Council G4/5 Representative - Medical College of Wisconsin Medical Scientist Training Program
January 2023 – present	Mentorship Chair - Mentoring and Advocating for Diverse Physician Scientist (MAPS)
August 2023 – present	Founder & President - Muslim Professionals Mentoring Program
September 2020 – present	Medical Student Interviewer - Medical College of Wisconsin Medical School Admissions Committee
September 2020 – present	MD-PhD Student Interviewer - Medical College of Wisconsin Medical Scientist Training Program

January 2023 – June 2023	Co-President- Mentoring and Advocating for Diverse Physician Scientist (MAPS)
August 2022 – August 2023	Pre-health Advisor- Illinois State University School of Biological Sciences
December 2021 – August 2022	Pre-health Advisor- Illinois State University School of Biological Sciences
December 2020 – May 2021	MSTP Student Assembly Executive Board Representative- Medical College of Wisconsin
April 2019 – May 2022	Co-founder & President- Weightlifting and Fitness Interest Group, Medical College of Wisconsin
April 2019 – April 2020	Treasure- Muslim Medical Association, Medical College of Wisconsin
March 2019 – March 2020	Vice President- Global Health Organization, Medical College of Wisconsin
January 2019 – December 2020	Executive Board- Medical School Oath Committee, Medical College of Wisconsin
August 2018 – March 2020	Medical Student Tour Guide- Medical College of Wisconsin Medical School Admissions Office
August 2018 – December 2018	Molecules to Cells Student Liaison- Medical College of Wisconsin
June 2016 – August 2018	Founder & President- Redbird Red Cross, Illinois State University

Professional Development

Teaching and tutoring

July 2022 – present	Tutor- SEA literacy Milwaukee
August 2021 – August 2022	Small Group Facilitator- M1 physiology Case Based Discussions, Medical College of Wisconsin
August 2020 – May 2022	Tutor- USMLE-STEP1, MedSchoolCoach
August 2020 – May 2021	Small Group Instructor- Academic Enhancement USMLE-STEP1 Prep, Medical College of Wisconsin
October 2018 – March 2020	Cadaver Educator- Cadavers as Educators, Medical College of Wisconsin

Conference judge

March 2024	Poster Judge- Department of Medicine Research Retreat
April 2023	Poster Judge- Association of Clinical and Translational Sciences
November 2022	Poster Judge- Autumn Immunology Conference

Clinical engagement

September 2018 – present	Volunteer- Saturday Clinic for the Uninsured, Medical College of Wisconsin
July 2020 – July 2023	Clinical Continuity Track- Saturday Clinic for the Uninsured, Medical College of Wisconsin
October 2018 – March 2020	Phlebotomist- Saturday Clinic for the Uninsured, Medical College of Wisconsin
August 2018	Adult & Pediatric CPR/AED & First Aid- American Red Cross

Mentorship

June 2023 – present	Mentoring and Advocating for Diverse Physician Scientist, Medical College of Wisconsin
July 2022 – present	SEA Literacy Milwaukee
October 2018 – present	Pre-med Pair Up (PMPU), Medical College of Wisconsin

Khalil

August 2018 – May 2023	Pre-health Student Organization, Illinois State University School of Biological Sciences
May 2022 – August 2022	Summer Program for Undergraduate Research (SPUR), Medical College of Wisconsin

Students Mentored

October 2023 – present	Ahmad Farooq, Loyola University Chicago, pre-med undergraduate student
July 2023 – present	Ali Ishaq, University of Wisconsin-Milwaukee, undergraduate student in the Malarkannan lab
June 2023 – present	Manaar Jan, University School of Milwaukee, highschool student in the Malarkannan lab
December 2022 – present	Tariq Abdelhamid, Illinois State University, pre-med undergraduate student
September 2022 – present	Mohammed Hommedia, Medical College of Wisconsin, <i>current</i> medical student
June 2023 – August 2023	Manaar Jan, University School of Milwaukee, highschool student in the Malarkannan lab
December 2021 – July 2022	Abraham Valazquez, Rush Medical College, <i>current</i> medical student
June 2021 – August 2021	Blessed Ikuobolati, Summer Program for Undergraduate Research, SPUR student
July 2020 – July 2022	Belal Abuzir, Rosalind Franklin University of Medicine and Science, podiatry student
June 2018 – May 2020	Andrew Schuler, University of Chicago Medical School, medical student

Community Outreach

July 2022 – present	Science Tutor- SEA Literacy Milwaukee
June 2021 – present	Tour Guide- Alumni Center, MCW
January 2019 – present	Veteran Interviewer- My life My story for Veterans, MCW
September 2018 – present	Annual Science Fair Judge- Heritage Christian Private School
October 2018 – July 2022	Youth Volunteer Coordinator- Islamic Society of Milwaukee
August 2018 – August 2020	Volunteer- Student Health Initiative Pipeline Program, MCW
September 2016 – July 2018	Tutor- YWCA Smart Sprouts

Service Trips

May 2018	Volunteer- Zaatari Refugee Camp, Mafraq, Jordan
December 2017	Clinical Volunteer- Medlife Movement, Lima, Peru
March 2017	Site Leader- Our House Shelter, Little Rock, AR
April 2016	Service Leader- Habitat for Humanity, Winder, GA
November 2015	Volunteer- Camp Cedar Lodge, Lawrence, MI

Memberships and Professional Societies

American Association of Immunologist (**AAI**)
 American Society of Hematology (**ASH**)
 Association of Clinical and Translational Science (**ACTS**)
 American Physician Scientist Association (**APSA**)
 Wisconsin Medical Society (**WMS**)
 American Medical Association (**AMA**)
 American College of Physicians (**ACP**)
 American College of Surgeons (**ACS**)