Project Details	
Project Code	CMD27Br Caputo
Title	Understanding the role of immunometabolic changes and immune exhaustion during recovery of paediatric cardiac bypass surgery
Research Theme	Cardiometabolic Disease
Project Type	Wet lab
Summary	1 in 300 babies born in the UK will require surgery for congenital heart disease. Although cardiopulmonary bypass has transformed survival, recovery varies considerably, with some children developing significant complications. This project will investigate how the immune system responds to surgery by examining changes in immune cell function, metabolism and gene regulation before and after the operation. Using a unique multi-centre biobank of patient samples integrated with electronic health records, the student will identify biological signatures associated with recovery, with the aim of improving risk prediction and supporting more personalised care for children undergoing cardiac surgery.
Description	Congenital heart disease (CHD) is the most common congenital anomaly, affecting around 1% of live births, and approximately 1 in 300 babies born in the UK will require cardiac surgery during infancy or childhood. The introduction of cardiopulmonary bypass (CPB) has transformed outcomes for these patients, enabling increasingly complex surgical procedures with excellent survival. However, CPB also induces a profound systemic inflammatory response through blood contact with artificial surfaces, ischaemia-reperfusion injury, and tissue damage. While many children recover rapidly, others develop significant complications including prolonged intensive care admission, organ dysfunction, post-operative infection, and acute kidney injury. Despite countless clinical trials, clinicians remain unable to accurately predict which children are at greatest risk, highlighting the need for further research. The immune response to CPB has traditionally been viewed as an acute inflammatory process. However, emerging evidence suggests that surgery also induces substantial changes in immune cell metabolism and function, including immune exhaustion, altered cellular bioenergetics, and long-lasting epigenetic remodelling. These processes may influence the ability of immune cells to respond appropriately to injury and infection and may contribute to the marked variation in clinical recovery observed between patients. Understanding these mechanisms could reveal novel biomarkers for patient stratification and identify new therapeutic targets to improve outcomes following congenital heart surgery. This PhD will leverage the OMACp biobank; a BHF funded multi-centre prospective biobank of thousands of paediatric patients undergoing cardiac procedures. The biobank includes serial peripheral blood samples collected before and after surgery alongside detailed perioperative clinical data and long-term electronic health record (EHR) follow-up. The project combines state-of-the-art immune phenotyping, epigenetic profiling and statistical modelling to investigate how immunometabolic and epigenetic changes influence recovery after CPB.

	Central research question: How do immunometabolic and epigenetic changes within circulating immune cells influence recovery following paediatric cardiopulmonary bypass, and can these biological signatures be used to predict postoperative outcomes? To address this question, the student will work towards three integrated objectives. Objective 1: Characterise the dynamic peripheral immune response following cardiopulmonary bypass. The student will perform high-dimensional immune phenotyping of serial blood samples using spectral flow cytometry to define changes in circulating immune cell populations before and after surgery. Particular focus will be placed on markers of immune activation, immune exhaustion and cellular metabolism to understand how immune function evolves during recovery and how these responses differ between patients with uncomplicated and complicated postoperative courses. Objective 2: Define the epigenetic landscape associated with recovery following cardiac surgery. The student will investigate epigenetic changes within circulating immune cells using next-generation sequencing approaches. These analyses will identify alterations in chromatin accessibility and gene regulatory networks associated with immune activation, exhaustion and metabolic adaptation following CPB. Comparisons between patients with favourable and adverse clinical outcomes will provide insight into biological mechanisms underpinning differential recovery. Objective 3: Integrate biological signatures with electronic health records to identify predictors of postoperative outcome. The student will integrate immune phenotyping and epigenetic datasets with detailed perioperative variables and longitudinal electronic health records. Using statistical modelling and machine learning approaches, they will identify biological signatures associated with complications such as prolonged intensive care stay, acute kidney injury, infection and delayed recovery. This systems-level approach aims to improve patient stratification and establish foundations for future precision medicine approaches in paediatric cardiac surgery. Throughout the studentship, the candidate will receive multidisciplinary training spanning immunology, cardiovascular medicine, molecular biology, computational biology and clinical data science. They will gain expertise in advanced flow cytometry, multi-omic data analysis, bioinformatics, statistical modelling and integration of large clinical datasets, providing a strong platform for future careers in academia, translational research or clinical science. Importantly, although the overall scientific aims are well defined, the project provides substantial flexibility for the student to shape its direction. Following completion of the core immune phenotyping, the student will have the opportunity to develop their own hypotheses, explore additional immune or metabolic pathways identified within the data, refine computational approaches for multi-omic integration, and undertake mechanistic follow-up analyses. They will also have opportunities to collaborate with clinicians, bioinformaticians and laboratory scientists across the multi-centre consortium, helping them

	develop an independent research profile while contributing to a programme of research with clear translational potential. Ultimately, this project seeks to improve our understanding of the biological mechanisms that drive recovery following paediatric cardiac surgery. By identifying immunometabolic and epigenetic signatures that predict postoperative outcomes, the work has the potential to enable earlier identification of children at greatest risk of complications and support the future development of personalised therapeutic strategies to improve recovery after congenital heart surgery.
Can be completed part time?	Yes
Supervisory Team	
Lead Supervisor	
Name	Professor Massimo Captuto
Affiliation	Bristol
College/Faculty	Medical School
Department/School	Cardiac Surgery
Email Address	m.caputo@bristol.ac.uk
Co-Supervisor 1	
Name	Dr Francesca Bartoli-Leonard
Affiliation	Bristol
College/Faculty	Immunology
Department/School	Medical School
Co-Supervisor 2	
Name	Dr Kristin Ladell
Affiliation	Cardiff
College/Faculty	Medical School
Department/School	Medical School
Co-Supervisor 3	
Name	
Affiliation	
College/Faculty	
Department/School	