Project Details	
Project Code	CMD27Br Biglino
Title	Novel dynamic shape atlasing of cardiovascular structures in congenital heart disease
Research Theme	Cardiometabolic Disease
Project Type	Dry lab
Summary	Congenital heart disease (CHD) affects 1 in 110 births and causes significant long-term morbidity, yet identifying anatomical sub-phenotypes remains difficult. Structural changes over time—enlargement, narrowing, remodelling—are key markers of disease progression, but current shape analysis largely relies on static, cross-sectional snapshots. This project will pioneer a dynamic shape atlasing framework, extending statistical shape modelling (SSM) into the temporal domain to capture continuous growth and remodelling trajectories of cardiac chambers and vessels. Built on a unique longitudinal biobank, this work will generate the first 4D (3D + time) population atlases for tetralogy of Fallot and bicuspid aortic valve disease.
Description	Background. Congenital heart disease (CHD) affects 1 in 110 births and causes significant long-term morbidity, yet identifying anatomical sub-phenotypes remains challenging, with treatments ineffective in up to half of cases. Structural changes over time — chamber enlargement, vessel narrowing, progressive remodelling — are key indicators of disease trajectory, but current computational shape analysis largely relies on static, cross-sectional snapshots. Statistical shape modelling (SSM) has advanced cardiovascular morphology research by generating population "atlases" — average shapes with quantified variability — enabling more objective, 3D assessment than traditional 2D qualitative review. However, treating each scan as an isolated observation obscures the trajectory of remodelling: two patients with near-identical shape at one timepoint may be following entirely different growth paths, with very different clinical implications. Aim. This project will develop a dynamic (spatiotemporal) shape atlasing framework — extending SSM from static shape description into the temporal domain — to characterise cardiovascular growth and remodelling trajectories in CHD, rather than isolated shape states. This represents a methodological shift from asking "What does this heart look like now?" to "How is this heart changing and how does that compare to expected/known trajectories?" Objectives. 1) Develop the core methodology for dynamic shape atlasing, extending correspondence and variability-modelling techniques (e.g. principal component analysis) from static shapes to time-resolved trajectories, including handling irregular scan timing and varying image quality across a longitudinal dataset. 2) Apply trajectory-based (rather than single-timepoint) unsupervised clustering to automatically identify sub-groups of patients following distinct remodelling paths, using appropriate distance metrics that capture trajectory shape and rate of change, not just endpoint morphology. 3) Construct the first spatiotemporal normative atlases of growth/remodelling for two clinically important scenarios — ventricular remodelling in tetralogy of Fallot (the most common cyanotic CHD) and aortic growth in bicuspid

	aortic valve disease, with and without coarctation — against which individual patient trajectories can be compared to flag early deviation. 4) Explore whether early-trajectory shape features have predictive value for later adverse outcomes such as aortic dilatation or ventricular enlargement or other clinically relevant outcomes, positioning the atlas as a predictive rather than purely descriptive tool. Approach. Methodological development will use the Bristol biobank generated through OMACp (Outcome Monitoring After Cardiac Procedure), a multicentre prospective cohort with repeated 3D imaging per patient — an unusually well-suited dataset for trajectory modelling given most published SSM work in CHD remains cross-sectional. Work is structured in three stages. First, the student will establish robust spatiotemporal correspondence across sequential scans and extend PCA-style variability frameworks to trajectory data, building the technical foundation for dynamic atlasing. Second, trajectory-clustering methods will be applied to identify natural remodelling sub-groups within the two clinical scenarios, comparing individual patients against the derived normative dynamic atlas to detect early adverse trajectories. Third, having established methodology and initial findings on OMACp data, the student will test generalisability of key trajectory markers in an independent, larger dataset, treating this as confirmatory validation rather than the project's central focus. Methodological considerations. Where deep-learning-based shape representations are explored, the project will remain attentive to concerns — highlighted in recent methodological literature — that such approaches can establish opaque, potentially spurious associations between shape inputs and clinical outputs. Dynamic shape atlasing, by contrast, offers an interpretable alternative grounded in explicit statistical trajectory modelling, with clinical meaning attributable to specific, visualisable modes of shape change over time. A structured approach to anticipating and auditing potential sources of methodological error will be incorporated throughout. Innovation. Static shape atlases are increasingly established in cardiovascular imaging research; dynamic, trajectory-based shape atlasing remains a genuinely underdeveloped methodological frontier, particularly in congenital heart disease, where longitudinal 3D imaging datasets of sufficient scale have only recently become available. This project's core contribution is therefore methodological: building the statistical and computational machinery required to model shape change as a first-class object, rather than inferring change indirectly from repeated static analyses. Successful development of this framework would provide a transferable approach applicable beyond CHD to other progressive structural diseases where longitudinal imaging is available, and would generate one of the first published dynamic cardiovascular shape atlases in the paediatric/congenital literature.
Can be completed part time?	Yes
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