Probabilistic Graphical Modelling of Intracranial Aneurysm Rupture Risk Factors

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Intracranial aneurysms (IA) are balloon-shaped expansions of cerebral arteries which are often asymptomatic and unrecognized. However, sudden rupture of IA leads to aneurysmal subarachnoid haemorrhage (aSAH), a severe form of stroke with often poor functional outcome and high mortality. Therefore, a better understanding of rupture risk factors to guide clinical decision support is required to improve treatment.

To construct an explainable model for medical decision support, we learned two Bayesian network (BN) models for clinical evidence structuring. We found novel interdependencies among the risk factors and onto rupture, leading to new potential causalities. Discrete and additive BNs were compared to conventional clinical data analysis methods on a retrospectively collected, single-centric patient-level set (n=799) of the 9 major IA rupture risk factors.

Discrete BN models with heuristic structure learning and non-parametric bootstrapping resulted in a sparse BN. Mixed additive BN estimated with structural Markov chain Monte Carlo presented the same associations and some additional ones that highly improved clinical interpretability. Systematically restricting physically impossible associations favoured the detection of a high number of causal relations supporting existing and proposing new theories of IA rupture risk factor interdependencies. For example, IAs in females are known to rupture at smaller size and later in life compared to males. Both BNs found this relation as an indirect association with females showing less chance of hypertension and thus being more likely to develop individual IAs, which tend to be smaller and less likely to rupture.

The present study proposes BN models' feasibility to quantify existing associations and detect novel disease pathways to enable patient-specific decision support for IA treatment.