PROJECT REPORT

Investigating the molecular cause of hypermobile Ehlers-Danlos syndrome

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1 Introduction

Ehlers-Danlos syndromes are a group of heritable connective tissue disorders that can be classified into multiple subtypes. The current classification proposed in 2017 describes 13 subtypes [1] and was later extended by one additional type [2]. The most common type is hypermobile EDS (hEDS) which is also the only subtype with an unknown molecular cause, leading to a diagnosis based on clinical presentation. Identifying the molecular cause is crucial to improve the diagnosis process, the understanding of the disease and finding potential treatment options [3].

Although many studies investigated several genes, no clear molecular cause with a connection to connective tissue has been established yet [4]. While an ongoing study aims to find the genetic cause of hEDS by analysing the genes of around 1000 affected individuals, results are not expected before 2025 [5]. Until then, it is essential to utilise the already collected data to understand more about hEDS. One problem with this is that the diagnosis criteria changed with the new subtype classification in 2017, resulting in data from before the change not being usable anymore [6, 7].

This project aims to investigate the molecular cause of hypermobile EDS by studying the influence of differentially expressed genes in hEDS patients. It particularly tries to find pathways and biological processes affected by differentially expressed genes that are similar to the ones affected by the molecular cause of other EDS types. This analysis eventually aims to find genes differentially expressed in hEDS that are candidates of being the molecular cause of hEDS and to relate the findings to existing research.

2 Methods

To answer the research question, the following steps will be performed:

2.1 Analysis of Differentially Expressed Genes and Network Creation

A dataset of gene expression profiles from dermal fibroblasts from patients with hEDS and healthy controls is used. It is available at the NCBI GEO database with the accession number GSE218012 [3]. The analysis is performed with the R-package DeSeq2 based on the analysis script exported from GEO2R to identify up-regulated and down-regulated genes [8]. Genes with a log2-fold change $> \pm 0.5$ and a p-value < 0.05 after adjustment based on False-Discovery-Rate using the Benjamin-Hochberg procedure were considered. The cut-offs were chosen based on similar research [9, 10].

The Protein-protein interaction (PPI) network is then created in Cytoscape [11] by querying the before identified differentially expressed genes from the STRING database with an interaction score > 0.4 which reflects medium confidence [12]. Since hEDS belongs to the family of Ehlers-Danlos syndromes its molecular cause is most likely closely related to other EDS types. The PPI network of the differentially expressed genes is therefore expanded by additionally querying genes related to other EDS types. The genes are retrieved from Disease ontology with Disease Ontology ID 13359 [13] and similarly queried from STRING with a medium confidence threshold as well. The resulting network is annotated with the data from the analysis of the differential expression of the genes.

2.2 Gene Ontology and Clustering

To gain insight about affected [TODO: by what] biological processes, molecular functions and pathways, the R-package clusterProfiler [14] is used for GeneOntology (GO) enrichment [15, 16].

- large network, thus cluster before to get better insights for specific parts
- two different cluster methods used with a different resulting cluster structure

- create subnetworks for clusters with more than 15 nodes [TODO: why this threshold? to focus on more relevant because many in MCODE between 10 and 15 nodes, for community clustering smaller ones probably found by MCODE]

MCODE

MCODE is a clustering algorithm designed to find highly connected regions in larger PPI networks [17]. Such regions might represent molecular complexes which makes MCODE a suitable algorithm to analyse the molecular function of the resulting clusters that are mostly small because of MCODE's search for dense regions. MCODE was applied in Cytoscape with the clusterMaker2 app using the default parameters [18].

On the resulting clusters, GO-enrichment is performed to find over-represented molecular functions that might be involved in causing hEDS, considering results with $p < 0.05$ as significant. Additionally, it is investigated whether genes are clustered together with genes known to cause other EDS types and whether the resulting clusters consist of upregulated or downregulated genes or a combination of both.

Community Clustering

To analyse the biological processes and pathways involved in the differential expressed genes, larger clusters are required. GLay, a community clustering algorithm was designed to be used for a functional interpretation of clusters in networks [19]. Analogous to the MCODE, clustering was performed with clusterMaker2 and Cytoscape using the default parameters [11, 18].

The GO enrichment on the resulting clusters focuses on biological processes instead of molecular function. [TODO: pathway enrichment]

3 Results

3.1 Differentially Expressed Genes and Network creation

Under the chosen thresholds discussed in 2.1 908 genes were found to be differentially expressed. Around half of them (495) are upregulated, the remaining 413 are downregulated. STRING was able to query 828 of them; using other ID types did not change this. After querying the additional EDS-related genes the resulting network consists of 847 nodes and 6129 edges.

The position of the known EDS genes in the network is on average more central than expected by chance based on degree, clustering coefficient, betweenness centralitiy and closeness centrality. This supports the close relationship between hEDS and other EDS types.

3.2 Enrichment analysis and clustering

3.2.1 MCODE

- 3 clusters with more than 15 nodes (first with 66 nodes & 1953 connections, second with 44 nodes & 686 connections, third with 16 nodes & 114 connections)
- first and largest cluster upregulated only
- second one as well
- 3rd MCODE cluster, shown in figure 1, is mostly upregulated with 2 downregulated nodes, some not relevantly differentially expressed, also only 9/16 are not known eds genes, 8 are

- the eds genes are all below the threshold of |log2FoldChange| > 0.5, 1 of them is 1 of the two down-regulated genes
- quite interesting to see genes closely related to other eds genes, COL21A1 is also strongly upregulated (log2FoldChange > 2)
- all known EDS genes with ADAMTS2 as an exception have a high Closeness Centrality
- regarding the enrichment of this cluster: not surprising to see the extracellular matrix in two GO-Terms when testing for over-representation of molecular functions
- first go term: GO:0005201 - The action of a molecule that contributes to the structural integrity of the extracellular matrix. overall 13 of the 16 genes in this GO-Term, 6 are known eds genes, the other six differentially expressed (COL10A1, COL15A1, PCOLCE, COL5A3, COL18A1, COL21A1, COL27A1)
- second go term: GO:0030020 - A constituent of the extracellular matrix that enables the matrix to resist longitudinal stress, and is a subtype of the first. Same EDS genes and same genes as in the first term, except PCOLCE, PCOLE is also the only downregulated gene [TODO: interprete]

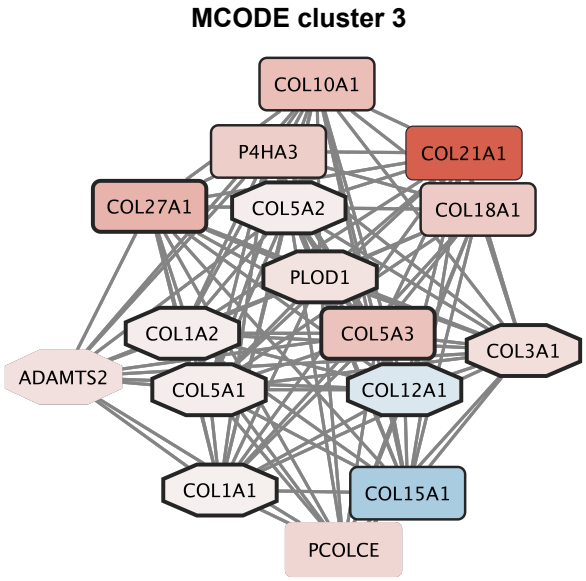

Figure 1: The MCODE cluster contains many genes known to cause other types of EDS. [TODO: add legend for shape and colour]

- mcode cluster 2: GO:0030527 - structural constituent of chromatin enriched, downregulated genes involved in processes related to chromatin in vEDS [20]

3.2.2 Community Clustering

- 6 clusters with more than 15 nodes
- 3 very small loosely connected clusters (18 nodes & 17 connections, 29 nodes & 32 connections, 29 nodes & 29 connections), two medium-sized highly interconnected (76 nodes & 1000 connections and 105 nodes & 2330 connections) and one very large cluster (363 nodes & 1661 connections)
- especially medium-sized clusters highly interconnected
- biggest one mix of up-regulated and down-regulated genes, contains all 21 genes known to cause other EDS types
- both medium-sized clusters mostly upregulated $\rightarrow$ interesting!
- smallest cluster with 18 nodes to small for meaningful enrichment analysis regarding processes

4 Discussion

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