Network Visualization and Analysis of Pregnant Uterine Contractions

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Abstract

Premature births are often caused when uterine muscles sychronously contract too early, precipitating expulsion of the fetus. To analyze patterns in such contractions, we explored the use of networks to visualize and quantify uterine contractions based on activation of sensors on the abdomen surface. The results provide proof-of-concept that a unipartite network of sensor-sensor correlations, combined with the concept of modularity, can be used to visualize and quantify the degree of synchronous muscle contraction. Such an approach could be used for the early warning and prevention of premature births.

Introduction

Almost 10% of all US births are premature resulting in long-term medical complications for the new born. A common cause of premature deliveries is the early synchronization of uterine muscles resulting in the expulsion of an immature fetus. To address this problem, recent research[1] has begun to use sensors on the abdomen surface to record and analyze electrical fields generated by uterine contractions. Given the complex nature of the contractions, we posed the question: *Can networks help to visualize and quantitatively analyze uterine muscular contractions recorded by sensors on the abdomen?*

Method

Using data of a normal delivery collected in an earlier study[1], we generated a fully-connected sensor network where nodes represented 148 sensors on the abdomen surface, and edge weights between pairs of nodes represented the Pearson's correlation in electrical activity of those sensors. As shown in Figure 1, the network was laid out using the x-y coordinates of each sensor (ranging from the breast area at the top, to the uterus area at the bottom), with edge thickness proportional to the strength of the correlation. To reduce the effect of noise, only edge weights above 0.5 correlations were included in the analysis.

To quantify the degree of synchronization between sensors, we used the CNM modularity algorithm[2] for weighted networks to (1) identify clusters of nodes that have similar edge weights, and (2) calculate the maximum cluster modularity, which measures (in a range from -1 to +1) the quality of the clusters; good divisions have high edge weights between the nodes in a cluster, and low edge weights across the clusters.

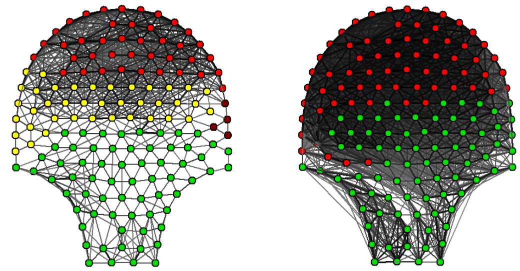

Figure 1. The sensor networks of a normal delivery subject at (A) -22 days before delivery showing 4 clusters of sensors with high modularity (0.43), and (B) -2 days before delivery showing 2 clusters with relatively low modularity (0.16).

Low synchronization of muscles should therefore lead to more clusters (due to heterogeneous sensor activation) and correspondingly high modularity values; high synchronization of muscles should lead to fewer clusters, and low modularity values.

Results and Conclusion

Figure 1A and 1B show the sensor networks of a normal subject at -22 days, and at -2 days before delivery respectively. The different colors represent highly correlated clusters of sensors identified by the CNM algorithm. As shown in Figure 1A, there are 4 sensor clusters at -22 days with relatively high modularity (0.43) representing low synchronization of uterine muscles. In contrast, there are only 2 clusters at -2 days before delivery and relatively low modularity (0.16) representing high synchronization of muscles. Our current research is analyzing how this longitudinal pattern of a normal delivery, at different noise thresholds, compares to those in premature deliveries, and whether modularity can be used for the early warning and prevention of such unfortunate occurrences.

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