Quantitative MRI Evidence for Diffuse White Matter Injury and Reduced Deep Gray MatterVolumes In Extremely Preterm Infants With Major Neonatal Morbidities

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Introduction

Pre-term infants are at risk for many diseases since their immune system, as well as many other systems, have not fully developed yet. An association between major pre-term infants and major morbidities such as bronchopulmonary dysplasia (BPD – lung problems), patent ductus arteriosus (PDA – heart problems), retinopathy of prematurity (ROP – eye problems), intraventricular haemorrhage (IVH – bran bleed), and sepsis (blood infection) have all been linked to adverse neurological outcomes (Bassler, 2009). As such, the degree of association is important in being able to predict the outcome of these pre-term infants. This will allow for early treatment of the neurological outcome.

The diseases stated have been shown to reduce white matter injury in previous studies (Bassler, 2009). This reduction in white matter (WM) has also been associated with adverse long term neurological outcomes. A study done by Northam et al. found that WM abnormalities found on MRI in pre-term infants were associated with lower IQ scores (2011). They looked at a group of adolescents (mean age 16 years) that were all pre-term births. Some had brain injury when born, some did not, and a few others were born at term as a control group. They found that just the fact that some of these adolescents were pre-term lead to lower IQ scores, even without any brain injury.

Another study done by Bruïne et al. (2011) wanted to determine if diffuse excessive high signal intensity (DEHSI) was associated with punctate WM lesions and ventricular dilation (which are both related to adverse neurological outcomes such as motor delay and cerebral palsy). This study is very similar to the one being reported here in that they wanted to use an imaging modality to predict neurological outcome. They found that DEHSI was not a good
indicator of neurological outcomes as it was not associated with the WM lesions or ventricular dilation.

The studies mentioned show how clinicians are trying to use imaging modalities to predict neurological outcomes in these pre-term infants. If this is possible, it would allow early treatment and therapeutic remedies for these babies. The first objective of this study was to test multiple hypotheses related to the pre-term infants and the morbidities commonly present with them. H1 to H4 represent the first four hypotheses that related to this first objective:

H1. There is a mean difference between deep gray matter (DGM) volume and being positive or negative for the five different morbidities

H2. There is mean difference between WM volume and being positive or negative for the five different morbidities

H3. There is an association between having one morbidity and having another (i.e. if you have sepsis you are more likely to have IVH etc.)

H4. IVH leads to a lower mean motor score

The overall goal of this study was to determine if quantitative MRI is a valid tool in predicting adverse neurological outcomes, specifically, adverse motor function.

H5. There is a correlation between DGM volume and motor function

H6. There is a correlation between WM volume and motor function

**Theory**

The brain is composed of two main types of tissue, gray matter and white matter. Gray matter is a major part of the central nervous system consisting of different types of nerve cells
that all relate to parts of the brain involved in muscle control, and the senses. In essence, gray matter is associated with perception and cognition. White matter on the other hand is involved in intra-communication within the brain, connecting areas of gray matter to each other via special neurons. White matter also carries nerve impulses between neurons. It would seem then that reduced gray matter volume would result in cognitive issues, including motor developmental issues. This is the original thought for this study because if these common pre-term infant morbidities cause a lowering of DGM volume, we should expect developmental issues. The same idea applies to white matter volume.

In essence, these two ideas are the underlying concepts of the first two hypotheses (H1 and H2) and how those two connect to H5 and H6. If we were able to see that there is an association between having the diseases and a lower DGM volume or WM volume, and an association between lower DGM/WM volume and motor function, we could potentially predict the outcome of these pre-term infants, or at least, have some idea of the developmental issues to come.

Different statistical tests were used depending on the hypotheses. The basic concept of each is what will be discussed.

Two basic statistical concepts must be understood first. The first is the meaning of a “p-value.” It is easy to just think that if our test results in a lower p-value than the critical (rejection) p-value, we just reject the null, but an understanding of why this occurs is needed. The p-value represents the chance that we will make a type 1 error meaning we will reject the null when the null is true. This would lead to saying there is a difference between two populations or there is an association between two variables when there is not.
The second statistical concept that is inherent in any clinical study is the idea of confounders. Triola and Triola (2006) explain the idea of confounding as “when [the] effects of variables are somehow mixed so that the individual effects of the variables cannot be identified” (12). This can make determining disease associations and causalities difficult. Triola and Triola give a good example of how confounders can be related to clinical studies:

“Suppose we treat 1000 people with a vaccine designed to prevent Lyme disease caused by ticks. If an early onset of cold weather causes the ticks to hibernate and the 1000 vaccinated subjects subsequently experience an unusually low incidence of Lyme disease, we don’t know if the lower disease rate is the result of an effective vaccine or the early onset of cold weather” (13).

This was prevalent in the study being conducted because all the conditions for these morbidities could not be controlled for. For example, the effects of head volume have been known to affect the amount of DGM volume but the head volume cannot be controlled for. Thus, we have something that could potentially confound our results by adding a significant difference in DGM volume when really it is just the random effects of larger and smaller head volumes. Linked to this is birth weight, another condition that cannot be controlled for. Confounders are present in most clinical studies like this, but tests have been developed to alleviate some of the problems associated with this, such as ANCOVA.

In testing for differences in the means of populations, a standard statistical test is ANOVA (and related ANCOVA). In simplest terms, this test works similar to a t-test. The differences lay in the distribution it uses (the f-distribution rather than the t-student distribution) and it allows for more than two populations to be compared. In essence, ANOVA is a
generalized t-test. Another significant difference is that ANOVA tests the equality of different population means by analysing the sample variance. ANCOVA is similar to ANOVA but instead it allows for a correction of a confounder. Simply, it removes the variance explained by covariates, i.e. head volume was associated with DGM so they would be covariates. When corrected for head volume, the variation explained by head volume in DGM is removed.

Another test that was used was the Pearson Chi Square test. This test was used as a test for independence. This means that the null hypothesis was that there is no association between the different disease states. The mechanics of the test are simple; based on the counts of positives and negatives, a contingency table (or four way frequency table) is set up. Next, expected counts for each contingency are calculated using

\[ \text{Expected} = \frac{\text{Row total} \times \text{Column total}}{\text{Grand Total}} \] (1)

This expected count for each contingency is compared to the actual count of each part of the table, and a chi statistic is calculated and compared to a critical p value on the chi distribution using

\[ \chi^2 = \sum \frac{(\text{Observed} - \text{Expected})^2}{\text{Expected}} \] (2)

This allowed for determination if there is an association between different disease states, meaning that if the infants had one morbidity, they are at an increased risk in having another. A more concrete example of this would be the idea that people with diabetes are at a higher risk for circulatory problems, but it is not necessarily the fact that diabetes causes circulatory problems, there could be other factors involved.
A third test used was bivariate correlations. This test uses the Pearson product moment correlation \((r^2)\) to test the linear correlation between two variables. The \(r^2\) value is between -1 and +1 where +1 indicates a perfect, positive slope, linear correlation between the two variables and -1 indicates a perfect, negative slope, linear correlation between the two variables. This test was needed to determine the association between continuous variables such as DGM volume and motor function. The designation of what \(r^2\) value gives a significant association between the two variables is somewhat arbitrary and multiple texts by different authors have been made arguing for certain criteria. For this study, a correlation of somewhere above 0.5 was needed at least to consider an association between the two variables due to all of the additional effects of different variables.

A related test for this is the Spearman correlation. This is another bivariate test but it is not sensitive to outliers like the Pearson product. The value obtained for the Spearman correlation coefficient can be read exactly like the Pearson product coefficient. The idea for when you use one or the other is if what you are looking for is linearity between two variables, you use the Pearson product. If you are looking for general trends for populations that may not be normally distributed, you use the Spearman as it can detect correlations in higher orders of degree (instead of just linear i.e. one degree).

This study was interested in the motor functions of these major pre-term infants and thus, a scale in which to measure the motor function was needed. There were a few scales that could have been used, but the one selected was the Baley’s score of Infant development. This assesses multiple areas of child development, but the one focused on was motor functions. An observer assesses a child on certain tasks and rates the child on how well they did compared to a normal child. This score can be likened to that of an IQ test. There are issues with this score however.
What has to be kept in mind is that this score is an assessment of *current functioning*. What this means is that while the child may be behind in their motor functions at this point, there is still development occurring since all children develop at different rates. Thus, this score should not be used as a diagnostic tool of neurological developmental issues but rather as an indicator of areas that might require further evaluation. This score does help with this study though in giving an idea of how development may be affected by different pre-term conditions.

**Methods**

A wide amount of information was needed to start testing our hypotheses. Initially we needed to determine the WM volume, DGM volume, and any other functional characteristics of the brain tissue. To do that, a quantitative MRI was used. This allowed accurate measurement of WM volume, DGM volume, T2*, as well as many other characteristics of the brain tissue as opposed to conventional MRI which would only allow qualitative assessment (i.e. this infant has larger DGM volume than another, rather than giving specific numbers).

The selection criteria was stringent; the gestational age of the pre-term infants had to be ≤ 30 weeks (major pre-term), they had to survive until discharge and they had to be clinically stable for MRI. The reasoning behind this selection criteria is that since this is a prospective study, the babies had to be able to be studied for motor functions after a couple years (hence, survival until discharge).

Exclusion criteria were also present; the infants could not have major congenital anomalies, chromosomal disorders, and could not have cystic periventricular leukomalacia. This allowed for selection of the five morbidities discussed above. This allowed for control of the five morbidities and reduced effects from other confounding diseases.
Analysis was done using SPSS, a standard in inferential statistical software. ANOVA was used to test the mean difference in WM volume between the positive and negative populations of each morbidity and most other tests. ANCOVA was used to test the mean difference in DGM volume between the positive and negative populations of each morbidity. This was due to the confounder of head volume present in DGM. Finally, the Pearson chi squared test was used to determine the association between the different disease states. SPSS had all these functions built in.

Results

There were a total of 48 infants. Data for some was lost, corrupted, or not obtained for some infants, leading to these tests not having a total count of 48. Babies which did not have data for a portion of a test were omitted from that test. The diseases analyzed were: bronchopulmonary dysplasia (BPD), patent ductus arteriosus (PDA), retinopathy of prematurity (ROP), intraventricular haemorrhage (IVH), and sepsis.

H1 (there is a mean difference between DGM volumes depending on whether you have a morbidity or not) is summarized in Table 1:
DGM vs. Disease (Controlling for head volume)

<table>
<thead>
<tr>
<th>Disease</th>
<th>Mean Volume for Positive (cm$^3$)</th>
<th>Mean Volume for Negative volume (cm$^3$)</th>
<th>Significance ($\alpha = 0.05$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sepsis</td>
<td>18.13 (n = 17)</td>
<td>19.25 (n = 20)</td>
<td>0.877</td>
</tr>
<tr>
<td>IVH</td>
<td>17.34 (n = 14)</td>
<td>19.58 (n = 23)</td>
<td>0.072</td>
</tr>
<tr>
<td>ROP</td>
<td>17.52 (n = 14)</td>
<td>19.47 (n = 23)</td>
<td>0.007*</td>
</tr>
<tr>
<td>PDA</td>
<td>18.28 (n = 29)</td>
<td>20.38 (n = 8)</td>
<td>0.031*</td>
</tr>
<tr>
<td>BPD</td>
<td>18.21 (n = 29)</td>
<td>20.62 (n = 8)</td>
<td>0.002*</td>
</tr>
</tbody>
</table>

Table 1 - ANOVA results for each test comparing positive and negative populations of each morbidity against DGM volume. Head volume was used as a covariate. The cells contain the mean DGM volume along with the population from which that mean was calculated. The significance level was evaluated at $\alpha = 0.05$ and only two were found to be not significant (sepsis and IVH). * indicates that the finding was significant.

Interestingly, even when there was no significance, the mean values of the positive population for each morbidity was lower than the mean for the negative population.

H2 (there is a mean difference between WM volumes depending on whether you have a morbidity or not), is summarized in Table 2:

<table>
<thead>
<tr>
<th>WMV vs. Disease</th>
<th>Mean Volume for Positive (cm$^3$)</th>
<th>Mean Volume for Negative (cm$^3$)</th>
<th>Significance ($\alpha = 0.05$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sepsis</td>
<td>144.30 (n = 16)</td>
<td>156.05 (n = 19)</td>
<td>0.174</td>
</tr>
<tr>
<td>IVH</td>
<td>141.46 (n = 14)</td>
<td>156.82 (n = 21)</td>
<td>0.077</td>
</tr>
<tr>
<td>ROP</td>
<td>144.12 (n = 14)</td>
<td>155.05 (n = 21)</td>
<td>0.214</td>
</tr>
<tr>
<td>PDA</td>
<td>147.58 (n = 28)</td>
<td>163.07 (n = 7)</td>
<td>0.149</td>
</tr>
<tr>
<td>BPD</td>
<td>146.22 (n = 28)</td>
<td>168.53 (n = 7)</td>
<td>0.034*</td>
</tr>
</tbody>
</table>

Table 2 - ANOVA results for each test comparing positive and negative populations of each morbidity against DGM volume. The cells contain the mean DGM volume along with the population from which that mean was calculated. The significance level was evaluated at $\alpha = 0.05$ and four for them were found to be insignificant but by very narrow margins. * indicates a significant finding. Only BPD and WM were found to be significant between positive and negative populations.

Similar to the preceding table, the mean values for the positive population was lower for all morbidities than for the negative population even though the difference was not significant.
Furthermore, the significance levels were somewhat close to the critical p-value (where rejection of the null hypothesis would occur).

H3 (there is an association between having one disease and another), is presented in Table 3.

Only the significant associations are shown.

<table>
<thead>
<tr>
<th>Diseases Compared</th>
<th>Expected Count (positive for both diseases)</th>
<th>Actual count</th>
<th>Significance ($\alpha = 0.05$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BPD and IVH</td>
<td>12.4</td>
<td>15</td>
<td>0.044</td>
</tr>
<tr>
<td>PDA and IVH</td>
<td>12.4</td>
<td>16</td>
<td>0.005</td>
</tr>
<tr>
<td>Sepsis and IVH</td>
<td>7.6</td>
<td>11</td>
<td>0.028</td>
</tr>
<tr>
<td>ROP and IVH</td>
<td>6</td>
<td>9</td>
<td>0.046</td>
</tr>
<tr>
<td>Sepsis and ROP</td>
<td>7.1</td>
<td>11</td>
<td>0.011</td>
</tr>
</tbody>
</table>

Table 3 - Chi squared test results comparing morbidities associations. All other permutations of compared diseases were deemed insignificant.

These results show that there is an association between having IVH and all the other morbidities, i.e. if the infant has IVH, that infant has an increased risk of getting one of the other morbidities.

For H4 (IVH is correlated with motor scores), an ANOVA test was done and it was found to be insignificant. This means we fail to reject the null hypothesis that there is no difference in mean motor function between the infant having had IVH or not. This was unexpected as a brain bleed would be thought to lead to neurological development issues later on.
For H5 (there is an association between DGM and motor function), it was found to not be correlated.

Figure 1 - $r^2$ (Pearson correlation) was 0.104 indicating very little association between the two variables. The association was found to be insignificant. The sample size was 29 infants.

The Pearson correlation was small (0.104) and found to be insignificant.
For H6 (there is a correlation between WM volume and motor function), it was found to not be correlated.

Figure 2 - $r^2$ (Pearson correlation coefficient) was 0.130 indicating very little association between the two variables. The association was found to be insignificant. The sample size was 27.

**Discussion**

The study on these pre-term infants is a prospective one and has been through multiple stages. The results obtained here were compared against the 2009 analysis on almost the same data. The 2009 analysis did not test as much here, but rather only looked at DGM volume and its association between the different disease states. The comparison is presented in Table 4.
### 2009 Study (DGM)

<table>
<thead>
<tr>
<th>Disease</th>
<th>Mean of Negatives</th>
<th>Mean of Positives</th>
<th>Significance $(\alpha = 0.05)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sepsis</td>
<td>19.2 n = 20</td>
<td>18.1 n = 17</td>
<td>0.205</td>
</tr>
<tr>
<td>BPD</td>
<td>19.6 n = 24</td>
<td>7.1 n = 13</td>
<td>0.005*</td>
</tr>
<tr>
<td>IVH</td>
<td>19.6 n = 23</td>
<td>17.3 n = 14</td>
<td>0.011*</td>
</tr>
<tr>
<td>ROP</td>
<td>19.5 n = 23</td>
<td>17.5 n = 14</td>
<td>0.028*</td>
</tr>
<tr>
<td>PDA</td>
<td>20.28 n = 12</td>
<td>18.1 n = 22</td>
<td>0.021*</td>
</tr>
</tbody>
</table>

### 2012 study (DGM)

<table>
<thead>
<tr>
<th>Disease</th>
<th>Mean of Negatives</th>
<th>Mean of Positives</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sepsis</td>
<td>19.25 n = 20</td>
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<tr>
<td>IVH</td>
<td>19.47 n = 23</td>
<td>17.52 n = 14</td>
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<tr>
<td>ROP</td>
<td>20.38 n = 23</td>
<td>18.28 n = 14</td>
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<td>PDA</td>
<td>20.62 n = 29</td>
<td>18.21 n = 8</td>
<td>0.002*</td>
</tr>
</tbody>
</table>

Table 4 - Comparison of the 2009 study results and the 2012 results. Only the BPD and sepsis results were changed between the 2 analyses. * indicates a significant result.

The difference between the two studies is that two of the morbidity were found to be insignificant in comparison to the 2009 study which only had one insignificant morbidity.

This is due to an updated database that contained more accurate measurements of DGM volume.

Another reason for the changes was that some data was lost and replaced by newer infants.

Regardless of these changes, the direction of each test was the same, meaning that the means of the positive sample for each disease was lower than the negative sample population for each disease.

Issues arose with this study concerning sample size. Due to the nature of the study, obtaining a large enough sample size was difficult. As such, this could result in misleading results especially in regards to the chi square test. One of the requirements for the chi squared test is that there is an expected count of at least five in each contingency. Some of the tests did result in counts less than five. In this sense, we have to question the validity of these findings as applying to the population. A larger sample size is needed to confirm these findings.

For H1, which was that there is a mean differences in DGM volume between positive or negative diagnosis of a morbidity the results found them all to be associated with reduction in
volume between the positive and negative populations for each morbidity. Some reductions in mean volume were found to be insignificant, like IVH and sepsis, but this could be due to sample size errors as the p-values were close to the critical alpha level of 0.05.

H2 found that there were no significant mean differences between WM volumes of the positive and negative populations of morbidities. Upon further investigation, not only were the mean volumes of positive diagnosis for each morbidity lower, but the significance values were close to the critical alpha level (0.05 < p-value for each morbidity < 0.2 roughly with the majority being between 0.05 and 0.1). This shows the need for a larger sample size to further confirm the insignificance of each test. If a larger sample size were to give a mean that was even slightly lower than the positive population has now, it could make the findings significant. As such, further research has to be done with a larger cohort of infants.

H3 was to determine an association between having one morbidity and having another. An interesting outcome of this hypothesis was the apparent association between IVH and the other complications. IVH and PDA have been linked due to the treatment for PDA. In this study, PDA was treated with indomethacin but as with most drugs, there are side effects. Ohlsson and Shah (2011) explained that indomethacin is linked to cerebral side-effects including IVH. This could explain the link between IVH and PDA. Tests have been done on this link and a study done by Ohlsson and Shah concluded that ibuprofen decreased the incidence of PDA and decreased the need for surgical intervention, but due to the long term effects of using ibuprofen (such as gastrointestinal issues), it should not be used. As such, indomethacin would still have to be used. Further tests should be done on whether it is the drug that causes the increase in risk for IVH, or whether the two diseases are actually associated.
The link between sepsis and IVH has also been investigated. This link is due to the fact that the pre-term infants have weak immune systems and cannot fight off infection (Behrman & Butler, 2007) or contain the infection from where they arise. As such, the blood infection spreads and often moves toward the brain. It has been shown that sepsis causes meningitis (an infection of the membrane surrounding the brain) and can cause intraventricular bleeds. The association between sepsis and ROP, which was shown in Table 3, is also well-documented (Behrman & Butler, 2007).

Further investigation needs to be done into the association between IVH and the other diseases as to the exact mechanism that causes this relation. A higher sample size is also desired so as to validate the associations presented here.

H4 was interesting in the fact that the mean of the motor scores were not changed between having IVH and not. A brain bleed would be thought to cause more problems with neurological development but the tests show this is not the case. Due to the nature of the Baley’s score though, we cannot say they will not have neurological issues down the line. Northern et al. (2011) did find though that WM injury caused by IVH did lead to cognitive and behavioural issues in 16 year olds so these findings suggest that not enough development has occurred for effects on the brain to be seen.

H5 were dealing with the main objective of this study which investigated whether there is an association between Baley’s score of infant development motor rating and DGM volume. Referring to Figure 1, there was no association with an $r^2$ value of only 0.104. The problem with this is the fact that the Pearson correlation coefficient is sensitive to outliers. By looking at the scatter plot for DGM volume versus motor function (Figure 1), we can see that there are five
points of data that seem to be extraneous from the rest. Removal of these outliers cannot be done based on observing the graph; a different test has to be used that is not sensitive to outliers. To test to see if removal of the five data points from DGM volume is justified, a Spearman correlation test was conducted, which is not as sensitive to outliers and can determine higher degrees of correlation (such as quadratic, cubic, etc.). The results are displayed in Table 5.

<table>
<thead>
<tr>
<th>DGM Volume (cm³) vs. Motor Function</th>
<th>Sample size</th>
<th>Spearman Coefficient</th>
<th>Significance (α = 0.05)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>27</td>
<td>0.105</td>
<td>0.588</td>
</tr>
</tbody>
</table>

Table 5 - Results of the Spearman test of the DGM versus motor function variables. The spearman coefficient showed that there is not much association between the variables and this small association is not significant.

The Spearman shows that removing the outliers is not the correct solution. This is because the Spearman is not sensitive to outliers and it is still not a significant correlation between the two variables with the outliers present. Still, a higher sample size is needed to further confirm this.

**Conclusion**

This study was concerned with predicting neurological outcomes of pre-term infants with different morbidities. There were two objectives. The first was to test certain hypotheses of the effects of morbidities on brain matter. The second was to determine if there was an association between changes in DGM volume or WM volume and motor function. The hypotheses for the first objective were: there is a mean difference in volume of DGM between positive and negative sample sizes of each morbidity, there is a mean difference in volume of WM between positive and negative sample sizes of each morbidity, there is an association between having one morbidity and having another (i.e. if you have sepsis, this leads to an increase in getting ROP, etc.), and IVH leads to adverse neurological outcomes.
The first two hypotheses were tested using ANOVA. For DGM volume, the morbidities that lead to a significant lower DGM volume were ROP, PDA, and BPD. This was different than the 2009 study that found sepsis and IVH also to lead to lower mean volumes. This was attributed to an updated database that contained different measures for DGM volume. For WM volume, only BPD lead to a significant lower volume. All the other morbidities had lower volumes and were above the significance level by a small margin. As such, a higher sample size is needed to confirm the insignificance of those tests.

The third hypothesis lead to IVH being associated with the other four diseases and ROP being associated with sepsis. The latter is well established within the literature but the fact that IVH was associated with the four other diseases was not expected. IVH and BPD have been known to be correlated and IVH and Sepsis have also been correlated before but not the other two. Further research is required to determine why this occurs.

The fourth short term hypothesis was determined to not be associated. This means that even though an infant may have IVH (a brain bleed), it does not determine lower motor outcome.

The second objective involved two ideas; to see if DGM volume and WM volume could be used to predict if there will be neurological developmental issues in the long run. Two hypotheses were generated on these questions: DGM volume and motor function are associated and WM volume and motor function are associated.

The results for these hypotheses showed they were not significantly correlated. The $r^2$ value obtained for DGM versus motor function was 0.104 and the $r^2$ value for WM volume versus motor function was 0.130. Observation of Figure 1 indicated that there may be outliers present in the data so a Spearman correlation test was done. This was done because the
Spearman correlation coefficient is not as sensitive to outliers as the Pearson product. The results of the Spearman also showed no correlation between the two variables. Thus, those points cannot be considered outliers.

The main issue with this study was the limited sample size. Even though 48 sets of infant data were acquired, many infants had incomplete data i.e. one infant might be missing WM volume measurements and another missing DGM volume measurements. As such most tests were run with a sample size of roughly 30. Statistical tests are used to generalize to the population but with this limitation, we cannot be certain that the findings are true. For example, it did seem that having the morbidity lead to a lower WM/DGM volume measurement for all morbidities. Not all were found significant though, so a higher sample size may lead to it becoming significant.

Addressing the initial idea of being able to predict motor function of major pre-term infants using quantitative MRI data, the results show that DGM volume and WM volume should not be used as a diagnostic tool in outcome prediction.
References


