Objective: Few tools have been optimised for use over the entire spectrum of neonatal morbidity and standardised for use in perinatal population and community health studies. The objective of this study was to determine the performance profile of the recently developed morbidity assessment index for newborns (MAIN score). This score was designed as a discriminative index of morbidity for the entire population of babies delivered >28 weeks gestation without a major congenital anomaly.

Design and setting: MAIN score items were extracted retrospectively from the health records of 2892 consecutively born babies delivered beyond 28 weeks gestation in Edmonton area hospitals between June and December of 1999.

Main results: The mean MAIN score in the general newborn population was 70.3 (95% confidence intervals 64.2 to 76.4). With the MAIN score tool, 84.6% of newborns scored from 0 to 150 (no/minimal morbidity), 11.3% from 151 to 500 (mild), 3.1% from 501 to 800 (moderate), and 1% had >800 (severe) score. The MAIN score tool was sufficiently sensitive to detect significant effects of low gestational age, low birth weight, male sex, caesarean delivery, tertiary hospital delivery, twins/triplets, non-vertex presentation, prenatal illicit drug use, and medical complications of pregnancy.

Conclusion: The MAIN score fulfills the need for a simple, universal, yet sensitive and robust tool to provide a numerical index of early neonatal outcomes of prenatal care and adverse prenatal exposures in babies delivered beyond 28 weeks gestation. The performance of the MAIN score agrees well with the current medical awareness regarding the impact of adverse prenatal exposures on newborn morbidity.
births, malpresentation, maternal medical complications, prenatal adverse exposures, etc). These analyses have provided evidence for validity of the MAIN score as a discriminative tool of newborn morbidity.

**METHODS**

The Health Research Ethics Board of the University of Alberta approved this study for data collection by chart review at three Edmonton hospitals: Royal Alexandra (RAH), Grey

<table>
<thead>
<tr>
<th>Table 1</th>
<th>MAIN score morbidity items with their scale values and goodness of fit parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Item</td>
<td>Morbidity attribute</td>
</tr>
<tr>
<td><strong>Within 24 hours of birth</strong></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Cord blood pH</td>
</tr>
<tr>
<td>2</td>
<td>Resuscitation at birth</td>
</tr>
<tr>
<td>3</td>
<td>Intubation</td>
</tr>
<tr>
<td>4</td>
<td>Meconium</td>
</tr>
<tr>
<td>5</td>
<td>Meconium below cords</td>
</tr>
<tr>
<td>6</td>
<td>Apgar score (5 min)</td>
</tr>
<tr>
<td>7</td>
<td>score 1–3</td>
</tr>
<tr>
<td>8</td>
<td>score &lt;1</td>
</tr>
<tr>
<td>9</td>
<td>Apgar score (10 min)</td>
</tr>
<tr>
<td>10</td>
<td>score 1–3</td>
</tr>
<tr>
<td><strong>Within seven days of birth</strong></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Heart rate/min*</td>
</tr>
<tr>
<td>12</td>
<td>&gt;200 beat</td>
</tr>
<tr>
<td>13</td>
<td>&lt;100 beat</td>
</tr>
<tr>
<td>14</td>
<td>Hypotonia*</td>
</tr>
<tr>
<td>15</td>
<td>Present at 1–120 h of age</td>
</tr>
<tr>
<td>16</td>
<td>Present beyond 120 h of age</td>
</tr>
<tr>
<td>17</td>
<td>Altered colour*</td>
</tr>
<tr>
<td>18</td>
<td>Dusky/central cyanosis</td>
</tr>
<tr>
<td>19</td>
<td>Respiratory rate/min*</td>
</tr>
<tr>
<td>20</td>
<td>Heart rate/min*</td>
</tr>
<tr>
<td>21</td>
<td>&gt;200 beat</td>
</tr>
<tr>
<td>22</td>
<td>&lt;100 beat</td>
</tr>
<tr>
<td>23</td>
<td>Hypotension*</td>
</tr>
<tr>
<td>24</td>
<td>Present at 1–120 h of age</td>
</tr>
<tr>
<td>25</td>
<td>Present beyond 120 h of age</td>
</tr>
<tr>
<td>26</td>
<td>Altered colour*</td>
</tr>
<tr>
<td>27</td>
<td>Dusky/central cyanosis</td>
</tr>
<tr>
<td>28</td>
<td>Respiratory rate/min*</td>
</tr>
<tr>
<td>29</td>
<td>Heart rate/min*</td>
</tr>
<tr>
<td>30</td>
<td>&gt;200 beat</td>
</tr>
<tr>
<td>31</td>
<td>&lt;100 beat</td>
</tr>
<tr>
<td>32</td>
<td>Hypotension*</td>
</tr>
<tr>
<td>33</td>
<td>Present at 1–120 h of age</td>
</tr>
<tr>
<td>34</td>
<td>Present beyond 120 h of age</td>
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<td>35</td>
<td>Altered colour*</td>
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<td>36</td>
<td>Dusky/central cyanosis</td>
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<td>37</td>
<td>Respiratory rate/min*</td>
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<td>38</td>
<td>Heart rate/min*</td>
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<td>39</td>
<td>&gt;200 beat</td>
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<tr>
<td>40</td>
<td>&lt;100 beat</td>
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<tr>
<td>41</td>
<td>Respiratory rate/min*</td>
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<tr>
<td>42</td>
<td>Heart rate/min*</td>
</tr>
<tr>
<td>43</td>
<td>&gt;200 beat</td>
</tr>
<tr>
<td>44</td>
<td>&lt;100 beat</td>
</tr>
</tbody>
</table>

* = circle all items that apply between birth and discharge from the hospital or up to seven days of life, whichever is earlier. ‡ = 2 consecutive readings.
Nuns (GNH), and Misericordia (MH). In addition to a community maternal-child health service, the RAH is the regional tertiary care facility for high risk deliveries. The GNH and MH are community hospitals. Data on the MAIN score morbidity items were obtained from the health records of 2892 newborns delivered at the three hospitals from June to December 1999, born at ≥ 28 weeks’ gestation with no major life threatening anomaly at birth. The MAIN score for each recruited newborn was calculated by retrospective review of the hospital chart. Relevant maternal data (see later) were collected retrospectively from the chart of each newborn’s mother.

For designing the MAIN score, innovative item response theory (IRT)13–14 and dimensionality testing techniques15 were used for structural validation and item analysis, as published previously.10–12 Structural validation techniques helped evaluate relation between the morbidity items and the underlying construct of newborn morbidity by determining the goodness of fit of items included in the MAIN score inventory. Item analysis provided scale values or weights that were assigned to each morbidity item contained in the MAIN score inventory. The scale values are relative values that provide weighting to the item(s) reflecting its contribution to the overall morbidity score. The statistical parameters of goodness of fit, including the discriminatory capabilities of an item to capture various grades of morbidity on the morbidity continuum. The discrimination statistic in conjunction with the ICCs provided evidence regarding information function of an individual item and the goodness of fit of items in the MAIN score. In brief, after a number of iterations and re-evaluations of goodness of fit of different combinations of items, an inventory containing 47 binary items representing 24 different grades of morbidity on the morbidity continuum. The prevalence of uncommon morbidity items may be as low as 0.2% (for example, bacterial culture or urine output assessment) at birth before discharge from the hospital.

Sample size considerations
Sample size calculations were based on the probability of occurrence of 47 morbidity items contained in the MAIN score. Measurement theories advise that to provide stable parameter estimates for the measurement tool, at least five participants per item need to be recruited.10 Considering that the prevalence of uncommon morbidity items may be as low as 0.2%, a sample size of 2500 newborns was required for providing stable parameter estimates of morbidity items in the MAIN score. A total of 2892 eligible newborns were recruited to this study.

Newborn data collection
Data were collected for 2892 infants. Of these, 1405 (48.5%) newborns were recruited from the RAH, 875 (30.3%) from the GNH, and 606 (21%) from the MH. Depending on the complexity of morbidity, it takes from 2 to 15 minutes per chart to extract data for the MAIN score from hospital records. Customised electronic forms were prepared using Microsoft Access (version 5.0) for data entry and computation of the MAIN score. Three research assistants were trained using 20 charts each to extract morbidity data from the health records. Inter-rater reliability among the three data abstractors was tested on other sets of 20 charts for each pair—that is, a total of 40 charts. Inter-rater reliability between two raters in each pair was greater than 98%.

Maternal data collection
In all three hospitals there is a standardised nursing assessment of maternal risk indicators for both antepartum and intrapartum periods. The antepartum risk score assessed the number and severity of any maternal conditions that may adversely affect the pregnancy outcome for either mother or newborn. The risk items included pre-pregnancy maternal disease(s), history of obstetrical complications, and maternal complications associated with the current pregnancy. A pregnancy was considered low risk if the antepartum risk score was ≤2, moderate risk if 3–5, high risk if 6–10, and extreme risk if ≥10. The most common maternal complications were defined by the following criteria:

Antepartum haemorrhage: bleeding from the genital tract after 28 weeks of gestation.

Table 1 Continued

<table>
<thead>
<tr>
<th>Item</th>
<th>Morbidity attribute</th>
<th>Discriminatory index†</th>
<th>χ²‡</th>
<th>Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>45</td>
<td>Intra-ventricular haemorrhage</td>
<td>0.86</td>
<td>0.6</td>
<td>152</td>
</tr>
<tr>
<td>46</td>
<td>Grade 1 or 2 from birth to discharge</td>
<td>1.84</td>
<td>0.8</td>
<td>186</td>
</tr>
<tr>
<td>47</td>
<td>Any time before discharge</td>
<td>2.06</td>
<td>2.6</td>
<td>162</td>
</tr>
</tbody>
</table>

MAIN score, sum of the scale values of all checked items. †Discriminatory index, this is an indicator of discriminative capability of an item to capture various grades of morbidity on the morbidity continuum. χ², this statistic reflects fitness of observed on predicted test score distributions. Scale, relative scale values derived from item response analyses that provide weighting to the item(s) reflecting its contribution to the overall morbidity score. NA, not available because of small number of subjects for χ² analyses. All statistical parameters are derived fitting two parameter item analysis model using BILOG-W software. Please see text for further details.
Intrauterine growth restriction: ultrasound predicted BW <3rd centile using Canadian standards for gestational age.

Hypertension: chronic or pregnancy related hypertension: systolic blood pressure (BP) >140 mm Hg or diastolic BP >90 mm Hg on ≥2 occasions, recorded at least six hours apart.

Pre-eclamptic toxaemia: pregnancy related hypertension when the total urinary protein is greater than 300 mg during the recommended maternal blood glucose concentration criteria after a two hour 100 g oral glucose tolerance test.

Diabetes mellitus: insulin dependent diabetes mellitus from 15 records and on presentation at delivery from eight.

Gestational diabetes mellitus: two or more values exceeding the recommended maternal blood glucose concentration criteria after a two hour 100 g oral glucose tolerance test.

Group B streptococcus: a positive culture growth of Streptococcus agalactiae upon routine screening at 35–36 weeks’ gestation by lower vaginal/perianal swab.

Malpresentation: any obstetrical presentation other than cephalic.

Smoking was recorded as no smoking, <10 cigarettes/day, or >10 cigarettes/day.

The assessment form also showed the use of alcohol and marijuana (termed recreational drug use) or street drug use (including misuse of cocaine, narcotics, amphetamines, inhalation of fumes, etc) There was no distinction as to the quantity or frequency of drug ingestion in drug misusers.

The intrapartum risk score assessment included any of the above complications that onset during labour or present as labour related complications. This score also included assessment of gestational age, prolonged rupture of fetal membranes (>24 hours), maternal fever, fetal heart rate abnormalities, etc. An intrapartum score of 0 was considered no risk and a score of ≥5 extreme risk.

Missing data

Data on the hospital of delivery and the type of delivery were missing from six maternal records; maternal smoking status was absent from 26 records; data regarding drug misuse, diabetes mellitus, and pre-eclamptic toxaemia were missing from 15 records and on presentation at delivery from eight.
ity score and the proportion of morbidity were significantly
newborn and maternal populations. Both the mean morbid-
distribution of MAIN scores within specific subgroups of
categories, 84.6% had none/minimal, 11.3% mild, 3.1%
classifying 2892 newborns into clinically relevant qualitative
MAIN score profile. The average MAIN score in our
congenital anomaly were used to compute and analyse the
delivered at or beyond 28 weeks’ gestation, with no
Data from 2892 newborns (1480 males and 1412 females)
RESULTS

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>N (%)</th>
<th>Mean MAIN score (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall total*</td>
<td>2892 (100)</td>
<td>70.3 (64.2, 76.4)</td>
</tr>
<tr>
<td>APH</td>
<td>163 (5.7)</td>
<td>135.8 (113.5, 158.0)</td>
</tr>
<tr>
<td>IUGR</td>
<td>79 (2.7)</td>
<td>235.1 (168.6, 301.7)</td>
</tr>
<tr>
<td>Group B streptococcus</td>
<td>485 (16.5)</td>
<td>61.5 (47.8, 75.1)</td>
</tr>
<tr>
<td>Hypertension</td>
<td>223 (7.8)</td>
<td>127.2 (98.1, 156.3)</td>
</tr>
<tr>
<td>PET</td>
<td>118 (4.1)</td>
<td>157.2 (103.8, 210.7)</td>
</tr>
<tr>
<td>GDM</td>
<td>112 (3.9)</td>
<td>79.8 (51.5, 108.1)</td>
</tr>
<tr>
<td>Diabetes mellitus</td>
<td>30 (1.0)</td>
<td>135.6 (47.6, 223.6)</td>
</tr>
</tbody>
</table>

*Reference category: APH, antepartum haemorrhage; IUGR, intrauterine growth restriction; PET, pre-eclamptic toxemia; GDM, gestational diabetes mellitus.

Table 3  Mean MAIN score (95% CI) in selected high risk maternal populations

records. The number of newborns thus available for various
different analyses is shown in the respective tables. The
hospital charts of all infants were available. As noted earlier,
we have assumed that all abnormal examinations and tests
were recorded on the chart. In the absence of checked items
on the MAIN score inventory, we have considered that infant
completely healthy with a MAIN score of zero. Thus, there
were no missing data for calculation of the MAIN score.

Statistical analyses

Analyses were performed using the SPSS 10.0 version (IL,
Chicago). To facilitate analysis and to improve the clinical
application of MAIN score tool, it was elected to divide the
MAIN scores into four subgroups according to their relative
severity of morbidity. After consultation with the obstetrical
and paediatric consultant groups from the three hospitals,
morbidity scores were subgrouped empirically into: (1) none/
minimal, score 0–150; (2) mild, 151–500; (3) moderate, 501–
800; or (4) severe, >800.

Bivariate analytical techniques were used to test differ-
ences in the MAIN score among various specific newborn and
maternal populations shown in tables 2 and 3. Linear trend
analysis was performed to show the influence of increasing
degree of adverse prenatal exposure and obstetrical complica-
tions on newborn morbidity.

RESULTS

Data from 2892 newborns (1480 males and 1412 females)
delivered at or beyond 28 weeks’ gestation, with no
congenital anomaly were used to compute and analyse the
MAIN score profile. The average MAIN score in our
population was 70.3 with 95% CI 64.2 to 76.4 (table 2). On
classifying 2892 newborns into clinically relevant qualitative
categories, 84.6% had none/minimal, 11.3% mild, 3.1%
moderate, and 1% severe morbidity. Table 2 also shows the
distribution of MAIN scores within specific subgroups of
newborn and maternal populations. Both the mean morbid-
ity score and the proportion of morbidity were significantly
higher in all of the following: males compared with females;
twin/triplets compared with singletons; infants delivered by
caesarean section compared with vaginal delivery; malpre-
sentation compared with cephalic presentation; tertiary
compared with community hospital delivery, infant of
smoker compared with non-smoker; or infant of multiple
drug misusers compared with recreational/no drug misusers.
As shown in table 2, with each increment in GA (except
>40 weeks) and BW (except >4500 g), there was significant
reduction in newborn morbidity. Among twins and triplets,
about half (49%) had no/minimal morbidity at birth but the
remaining had significantly higher morbidity over the entire
spectrum of morbidity compared with singletons.

Table 3 provides the MAIN scores for selected high risk
maternal populations. Except for group B streptococcus and
gestational diabetes, the MAIN scores for infants from
mothers with other maternal conditions were statistically
significantly higher than the overall population. With each

![Figure 1](http://jech.bmj.com/)

**Figure 1** Relation between the MAIN scores and antepartum risk score category (A) and intrapartum risk score (B). There was a significant correlation between the MAIN scores and both of these obstetrical risk indicators. The numbers above the histograms show the number of infants in that group.

**Key points**

- The MAIN score fulfils the need for a simple, universal,
yet sensitive and robust tool to provide a numerical
index of the influence of prenatal care and adverse
prenatal exposures on early newborn morbidity. Data
presented show that the MAIN score provides fine
discrimination across the spectrum of newborn mor-
bidity in the general newborn population.
- In the public health domain, this tool could assist in
community health programming by early identification
of infants who may require increased use of community
healthcare resources.
Intrapartum risk scores (Pearson’s correlation coefficient, \( r \)) had significant linear positive correlation with both antepartum mean MAIN scores of their infants. The MAIN scores had a complete range of morbidity, from minimal to severe. Our data show that the score is sensitive enough to capture subtle differences in morbidity according to GA, BW, sex, and maternal influences. We are not aware of any other measures of newborn morbidity that have illustrated such fine discrimination in evaluating severity of morbidity. This study also confirms that the MAIN score agrees well with the current medical awareness about the impact of adverse prenatal exposures on newborn morbidity.

In contrast with the parameters developed for very low BW (<1500 g) babies to predict developmental outcome, mortality, or severe morbidity,\(^7,9\) the MAIN score was designed to function as a simple and universal measure of early neonatal morbidity over the entire spectrum of morbidity. Optimal performance of the MAIN score can be attributed to two major factors in the construction of this tool: (1) a comprehensive inventory of standard assessment items that reflect pathophysiology in early newborn period; and (2) the use of IRT to produce robust yet sensitive scaling units for each individual morbidity item.

We had excluded babies born with major structural anomaly or life threatening birth defect diagnosed at birth; however, we recognise that a small proportion of babies whose defect was not detected at birth (for example, metabolic anomaly or heart defect) may have been included in our dataset. Also, the four morbidity subgroups used to describe the severity of morbidity, from very mild to severe, are merely empirical, which should be substantiated in future studies by involving a larger number of perinatal consultants and with the help of large datasets.

We propose several potential uses for the validated MAIN score tool for policy makers and health administrators:

- The score has utility in comparing the health of newborn populations across regions/countries or within regions after a change in the healthcare delivery system. (Who could initiate this change? Public health decision makers and advocacy groups)
- The MAIN score could also be used as an outcome measure in research projects investigating the effects of novel interventions in the maternal-child healthcare delivery system. (Who could initiate this change? Public health, community health, and clinical researchers, and epidemiologists)
- The score could be used to support hypotheses regarding the effects of adverse prenatal exposures on neonatal outcome. An example of this could be the data presented in this manuscript regarding the effects of maternal smoking or drug misuse on newborn’s health. (Who could initiate this change? Public health, community health, and clinical researchers, and epidemiologists)

The MAIN score fulfills the need for a simple, universal, yet sensitive and robust tool to provide numerical index of the influence of prenatal care and adverse prenatal exposures on early newborn morbidity. In summary, data presented herein show that the MAIN score provides fine discrimination across the spectrum of newborn morbidity in the general newborn population. In the public health domain, this tool could assist in community health programming by early identification of infants who may require increased use of community healthcare resources. Currently analyses of studies are underway to determine predictive value of MAIN score in health services use by one year of infant’s age.

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Conflicts of interest: none declared.

REFERENCES


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Anila Verma, Angela Weir, Jane Drummond and Bryan F Mitchell

*J Epidemiol Community Health* 2005 59: 420-426
doi: 10.1136/jech.2003.019109

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