Abstract:
Background & Objectives There is a decline in infant mortality in developing countries but no significant reduction in neonatal mortality. Growth monitoring is the best objective method to know wellbeing of the baby. Existing growth monitoring charts are on the basis of weekly or monthly growth monitoring, hence cannot be used for any day growth monitoring. To bridge this gap ‘Individualised Colour Coded Any Day (ICCAD) Neonatal Growth Monitoring Charts’ were prepared. Methods Growth of 430 normal neonates was studied by weighing apparently healthy babies daily from birth to 30 days of their life. The babies were weighed on a standard electronic weighing machine taking all the precautions to avoid errors in weighments. Expected growth curve lines were drawn for four birth weight groups namely 1000gm to 1499gm, 1500 to 1999gm, 2000 to 2499gm and equal to or more than 2500gm by taking central value of the groups. A growth curve was drawn using actual daily mean values of duration and amount of weight loss, duration required to regain birth weight and weight gain thereafter. Results Four patterns of growth charts were prepared corresponding to the four birth weight groups. The growth curve has expected growth curve line and unsatisfactory growth curve line. The unsatisfactory growth curve line represents excessive weight loss or failure of weight gain for 2½ to 3½ days. The starting point of expected growth curve line on the y axis is kept blank where birth weight of the baby to be monitored is to be written after choosing appropriate birth weight group. Colour coding is used to indicate good growth (Green Colour), inadequate growth (Yellow Colour) and severely inadequate growth (Pink Colour) corresponding to recommended type of care – namely home care, supervised care at home and referral care, respectively. These newly prepared charts are translational research tools which can be used for any baby with known birth weight by a primary health care worker.

Key Words: Individualised Neonatal Charts, Colour Coding, Any Day Growth Charts, Neonatal Growth Monitoring, Translational research.

Introduction:
Infant mortality is decreasing throughout the developing world but there is no significant reduction in neonatal mortality. About 45% of neonatal deaths occur by 48 hours of birth, the causes being birth asphyxia, trauma, and problems related to extreme prematurity, LBW, congenital malformations and infections.

There is an increase in number of institutional deliveries due to different initiatives. In India, we have Janani Suraksha Yojana (JSY), Janani Shishu Suraksha Karyakram (JSSK) and Navajat Shishu Suraksha Karyakram (NSSK) supported by UNICEF which are being implemented for improving care during & immediately after birth, thereby reducing mortality within 48 hours of birth among institutional deliveries. Under RCH II and IMNCI programmes the health workers are expected to undertake home visits to provide Maternal and Child health care after discharge of mother and the baby from the institution. Growth monitoring is one of the best objective parameters to know the baby’s well being. The paediatricians can compute the expected weight on a given day by knowledge of birth weight and using mathematical formulae or percentile charts. Such a computation of expected weights is difficult for the primary healthcare workers. At present there are no Individualised any day growth monitoring charts for neonates which indicate expected weight of the given baby on a given day. Existing growth monitoring charts are based on weekly or monthly growth monitoring pattern and hence cannot be used for any day growth monitoring during neonatal period by primary health care workers like ANM, AWW or ASHAs. To bridge this gap the ‘Individualised Colour Coded Any Day (ICCAD) Neonatal Growth Monitoring Charts’ were prepared for the first time for health workers. With the knowledge of expected value of the weight and expected cut off value, the primary health care workers would be in a better position to take action during neonatal period for identification of problems related to breast feeding/infection during the home visits prescribed under RCH II and IMNCI. This Translational Research approach of ICCAD Neonatal Growth Monitoring charts as a
tool for the primary healthcare workers is presented in this paper.

**Material and Methods:**

The present study is based on the data collected for Post Graduate Dissertations on “Study of Growth Velocity during Neonatal Period” and “Development of Growth Curves for Estimation of Birth Weight in Infants Below 2000gms”. These were the prospective cohort studies to find out daily change in the weight from the birth to 30 days. The studies were carried out partly in the hospital and partly in the community. All eligible babies using inclusion and exclusion criteria born at Sassoon General Hospital (SGH) attached to B. J. Medical College Pune were weighed every day in the hospital till the baby was in the hospital (3 days for normal birth weight baby and till 7 days for a LBW baby) and as long as per required for very low birth weight babies who were not able to suck and swallow at birth) and at home in the community after discharge from the hospital. In the first study, the data was collected from 1st July 1992 to 28th February 1993 and in the second study from 1st August 1993 to 31st July 1994. The first study was carried out on full term babies between 37 to 42 weeks of gestation and second study was carried out on babies born before 37 weeks of gestation and below 2000gm birth weight.

Taking proportion of normal birth weight (P) value of 80% for first study and proportion of babies with birth weight below 2000gm (P) 12% for the second study, an allowable error of 5%, α at 95% confidence level and using the formula of \[ n = \frac{4pq}{\alpha^2} \] the minimum sample size was 256 for the first study and 169 for the second study. Considering the difficulties in taking daily weights, all consecutive eligible 283 babies in the first study and 210 in the second study were enrolled with expected attrition rate of 10% and 24% respectively. The inclusion and exclusion criteria were otherwise same for both the studies except gestational period and birth weight of the babies.

**Criteria of inclusion -**

1. All apparently healthy singleton babies born in SGH to apparently healthy mothers.
2. Babies born to mothers residing in the two kilometre radius of SGH for the ease of taking daily weights after discharge from the hospital.

**Criteria of Exclusion –**

1. Any baby with congenital malformation, genetic abnormality, any obvious evidence of Intra Uterine Infection
2. Babies born with obvious illness.
3. Multiple pregnancies.
4. Infants of mothers with underlying chronic diseases like tuberculosis hypertension, diabetes etc.
5. Babies born after abnormal pregnancy or delivery or any obvious placental abnormality.
6. Babies receiving feeds other than breast milk.

The clearance from Institutional Ethics Committee was obtained and informed consent was taken from the mothers before initiation of these studies. Weights were taken on newly purchased portable Alfa digital baby weighing machine with digital read out and a least count of 2gm. The weighing machine was checked for correct weights by using standard weights every day before starting the field work. The babies were weighed within 24 hours to measure the birth weight.

The researchers studied the growth of 430 (260 + 170) neonates since birth to 30 days. All the precautions for obtaining accurate daily weights were followed. The baby was weighed at the same time of the day before feeding and with no clothing. 23 babies from first study and 40 babies from the second study could not be weighed daily for 30 days due to death of the baby, illness or inability to contact the mother and the baby.

Since daily weight change is largely dependant on birth weight of the baby, the four birth weight groups namely 1000gm to 1499gm, 1500 to 1999gm, 2000 to 2499gm and ≥ 2500gm were identified. The values of four growth parameters were taken into consideration for each of the birth weight groups namely – average weight loss, average duration of weight loss, average duration required to regain the birth weight after physiological weight loss was over; and average daily weight gain thereafter (Table 1). In each of the birth weight groups, every day mean values of weight change were determined.

The central birth weight value, ‘the hypothetical birth weight’, for each birth weight group e.g. 1250gm for 1000gm to 1499gm group, was taken for compilation of expected growth curve line of that group using values of four growth parameters. Similarly the central birth weight values of 1750gm, 2250gm and 2750gm were used for constructing expected growth curve lines for remaining birth weight groups respectively. This process generated 29 weight values for each birth weight group. To construct these charts; duration in days, from birth to 30 days, was taken along X-axis and mean weight values were taken along Y-axis. The day wise weights were plotted on Microsoft Excel Sheet and were connected to develop a central growth curve line for each birth weight group. The smoothening of the curve was done taking care that the line did not go below mean-1SD and above mean+1SD value while balancing the daily mean values generated mathematically for the hypothesised central value for each of the birth weight groups. These smoothened growth curve lines for each of the birth weight groups were designated as ‘Expected Growth Curve Line’.
parallel line to this expected growth curve line was drawn to demarcate unsatisfactory growth by lesser than 50 gm, 75 gm, 100 gm and 125 gm for the increasing order of birth weight groups. These unsatisfactory growth curve lines in all the four patterns of birth weight groups roughly indicated extra weight loss or failure of growth of babies for 2½ to 3 days. These lines were made to meet at y-axis at birth weight value since there was no question of unsatisfactory growth value for the birth weight.

The colour coding used was green; on and above expected growth curve line indicating satisfactory growth, yellow; between expected growth curve line and unsatisfactory growth curve line indicating less than satisfactory growth and pink colour; below unsatisfactory growth curve line indicating grossly unsatisfactory growth. (Figure I to IV)

Results

Four patterns of ICCAD Neonatal Growth Monitoring Charts were prepared (Figure I to IV) using the growth parameters described in Table 1. These charts could be used by first choosing the birth weight group depending on the birth weight of the baby and then choosing pattern of growth chart. The birth weight would be written at an appropriate place indicated by an arrow on the growth monitoring chart and the individualised chart would be prepared for that baby by writing +25 gm above the birth weight row on y axis and – 25 gm below the birth weight row on y axis as described in the foot note of the four patterns of the growth curves. (Fig. 1 to 4)

Table 1: Growth Parameters of 430 Newborn Babies in Four Birth Weight Groups

<table>
<thead>
<tr>
<th>Birth Weight Group (Gm)</th>
<th>n</th>
<th>Mean Duration of Weight Loss in Days</th>
<th>Mean Quantity Total Weight Loss in Gm</th>
<th>Average Time Taken in Days to Regain Birth Weight since birth</th>
<th>Average Daily Increase in Weight after Regaining Birth Weight in Gm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Observed mean ±SD (days)</td>
<td>Observed mean ±SD (gm)</td>
<td>Observed (mean ±SD) (days)</td>
<td>Observed (mean ±SD)</td>
</tr>
<tr>
<td>1000-1499</td>
<td>67</td>
<td>6.67 ±0.47</td>
<td>7</td>
<td>60.40 ±11.11</td>
<td>13.53 ±0.34</td>
</tr>
<tr>
<td>1500-1999</td>
<td>103</td>
<td>6.55 ±0.50</td>
<td>7</td>
<td>72.43 ±10.58</td>
<td>12.38 ±0.79</td>
</tr>
<tr>
<td>2000-2499</td>
<td>59</td>
<td>3.85 ±0.36</td>
<td>4</td>
<td>108.54 ±21.06</td>
<td>9.44 ±2.54</td>
</tr>
<tr>
<td>2500-3700</td>
<td>201</td>
<td>3.61 ±1.35</td>
<td>4</td>
<td>112.45 ±26.28</td>
<td>8.13 ±1.05</td>
</tr>
</tbody>
</table>

*: Values rounded off to nearest whole number

**: Values rounded off to nearest multiple of five

Validation of these ICCAD Neonatal Growth Monitoring Charts was done during 2011 on 208 babies attending OPD or admitted at Krishna Hospital, Karad during neonatal period. 84.13% of these babies were in the appropriate zone of respective growth charts in accordance with the health status. All babies with illness were in yellow or pink zone indicating failure of growth as per expected growth curve line. The 15.87% babies not showing concordance were apparently healthy babies in the yellow zone of the graph i.e. between expected and unsatisfactory growth curve lines.

Discussion:

Most of the growth charts for children are from birth to 6 years and based on monthly weighing of the children. They are used for identification of malnourished children in different grades of malnutrition. The charts presented in this paper are action oriented for neonatal period only and have an objective of prevention of morbidity and mortality in neonatal period by using objective criteria for babies who are not growing as others in similar condition.

Bertino et al have taken a review in 2009 of 43 neonatal growth charts published in the last decade. A majority (80%) of them have been reference charts and none of them is for day to day growth monitoring at community level. The new WHO 2006 charts have been developed separately for two sexes as well as for preterm and full term babies. These charts are excellent and can be used easily by experts in the field but are
Pattern (I)

Individualized Birth Weight Specific Colour Coded Neonatal Growth Monitoring Chart for **BW 1000 gm to 1499 gm**

- **Put the birth weight** (corresponding to day 0) of the baby at top (Green) line (A) at the place designated by an arrow, which is demarcation line between yellow and green colours.

- **Add 25 gm** for each horizontal dark blue line above birth weight and subtract 25 gm for each horizontal dark blue line below birth weight. Green curved line indicates expected growth curve of a baby with specific birth weight between 1000 to 1499 gm. Orange curved line indicates unsatisfactory growth curve of 50 gm less than expected weight on the growth curves.

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**Fig. 1**

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Pattern (II)

Individualized Birth Weight Specific Colour Coded Neonatal Growth Monitoring Chart for BW 1500 gm to 1999 gm

- Put the birth weight (corresponding to day 0) of the baby at top (Green) line (A) at the place designated by an arrow, which is demarcation line between yellow and green colours.
- Add 25 gm for each horizontal dark blue line above birth weight and subtract 25 gm for each horizontal dark blue line below birth weight. Green curved line indicates expected growth curve of a baby with specific birth weight between 1500 to 1999 gm. Orange curved line indicates unsatisfactory growth curve of 75 gm less than expected weight on the growth curves.

Fig. 2
Pattern (III)

Individualized Birth Weight Specific Colour Coded Neonatal Growth Monitoring Chart for **BW 2000 gm to 2499 gm**

- Put the birth weight (corresponding to day 0) of the baby at top (Green) line (A) at the place designated by an arrow, which is demarcation line between yellow and green colours.
- Add 25 gm for each horizontal dark blue line above birth weight and subtract 25 gm for each horizontal dark blue line below birth weight. Green curved line indicates expected growth curve of a baby with specific birth weight between 2000 to 2499 gm. Orange curved line indicates unsatisfactory growth curve of 100 gm less than expected weight on the growth curves.

### Fig. 3

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• Put the birth weight (corresponding to day 0) of the baby at top (Green) line (A) at the place designated by an arrow, which is demarcation line between yellow and green colours.

• Add 25 gm for each horizontal dark blue line above birth weight and subtract 25 gm for each horizontal dark blue line below birth weight. Green curved line indicates expected growth curve of a baby with specific birth weight greater than or equal to 2500 gm. Orange curved line indicates unsatisfactory growth curve of 125 gm less than expected weight on the growth curves.
difficult to be used by the primary health care workers with limited education. These are weekly growth monitoring charts for first three months of life on which growth of neonate cannot be monitored on ‘any specific day’. There are no action oriented cut off levels during neonatal period.

The premature growth grid constructed by Dancis et al15 in 1948 & growth graph prepared by Babson & Benda16 in 1976 have been updated by K K Brosius et al17 (1984), Wright K. et al18 (1993) & Fenton T R19 (2003). These charts are for NICU Care of very low birth weight infants. Charts developed by us are meant to be routinely used by primary health care workers in the field for babies >1500gm and able to suck and swallow; and cared at home.

A longitudinal growth has been studied on 1660 hospitalised very low birth weight infants free of major congenital anomalies between 501gm to 1500gm surviving beyond 7 days by Ehrenkranz R A et al20 in 1999. After regaining of birth weight, gain in weight of 14.4 to 16.1 gm per kg has been observed to be similar to the growth in the intra uterine period. Gestational age & gender have no effect on growth within 100gm birth weight strata.

Initial weight loss has been studied by various workers21-26. A systematic review of Physiological weight loss in the breast fed neonates has been done by Noel-Weiss J et al27 in 2008. Weight loss has been observed in 11 studies to range from 5.7% to 6.6% of birth weights. The days of maximum weight loss has been on second and third days. The majority of infants have been found to regain their birth weight within first two weeks. The weight loss values are 4 to 6% in our study for all birth weight categories. The maximum weight loss in our study has been for first three days after birth. The regaining of birth weight in our study is seen by 14th day of life in majority of cases.

Stanley Shaffer et al27 have observed that the duration of post natal weight loss has been similar among all birth weight groups below 2500gm and the weight gain expressed as gm/kg has also been similar in all birth weight groups after studying 385 surviving infants with birth weight <2500gm from birth to 45 days.

Weight loss during neonatal period has not been different in Appropriate for Gestational Age (AGA) & Small for Gestational Age (SGA), or gender in a study carried out in new born nursery by Elizabeth Simpson et al26.

These studies indicate that weight loss and weight gain during neonatal period is mainly dependant on birth weight and not dependant on gender or gestational age of the newborn.

This is for the first time that an innovative approach of birth weights stratified grouped values of daily weight change during neonatal period are used for construction of individualised growth chart based on mean amount and duration of initial weight loss, mean duration required to regain birth weight and the mean daily weight gain thereafter.

This new approach for constructing ICCAD Neonatal Growth Monitoring Charts can be a valuable tool for the primary health care workers being individualized, colour coded and action oriented.

It is not expected that babies who are not able to suck and swallow, usually below 1500gm to be cared at home but they should receive NICU care. However even after referral the parents often do not avail the referral services due to domestic difficulties like nobody to cook at home or no body to look after older children etc. For monitoring of growth of such babies that the charts for this group namely between 1000 to 1500gm (Pattern I) are prepared. Pattern II, III & IV would be routinely used during field visits. Severity of failure to gain weight is indicated by the duration in days taken by the baby to cross the unsatisfactory growth curve line and enter the pink zone of the growth chart. Shorter the duration, more severe is the problem.

Failure to gain weight could be related to many factors out of which problems and difficulties in initiation and continuation of breast feeding, possibility of infection and problems related to LBW are very common and are important causes of neonatal mortality after 48 hours of birth. They can be identified and managed by primary health workers with specific training.

The charts are simple. There is no need of calculations. Due to colour coding the health worker knows what he/she is supposed to do. Green coloured area on the chart indicates satisfactory growth. The yellow colour indicates home care after identification of problems related to breast feeding, infection, hypothermia etc. The babies in yellow colour of monitoring chart should be observed for a period of one week or so. If there is deterioration and baby goes in pink colour, it indicates need for referral to a specialist. Although the scheduled home visits, one fixed as per RCH II and IMNCI programme are day 1, 2, 3, 7, 14, 21 and 28 for Low Birth Weight babies and days 1, 7, 28 for Normal Birth Weight babies, there is a possibility of some change in actual day of visit and proposed day of visit. As the Individualized neonatal growth monitoring charts indicate the expected weight on each day, the health workers can refer to appropriate individualised chart on the day of visit and find out position of the baby on the chart, and compare the actual weight to its expected weight on that day.
This translational research may help health workers in identifying babies not growing as per expected growth pattern and they can then plan appropriate intervention in the form of local care or referral. The programmatic implication of use of this appropriate technological tool can be enormous.

The growth charts described in this paper are based on data collected twenty years back and the unsatisfactory growth curve line is arbitrarily drown based on clinical experience. There is a need to collect data on neonates of daily weight change and redline expected and unsatisfactory growth curve lines which would reflect currently existing neonatal growth pattern in the community and statistically determined cut off values. A limitation of use of these charts is that they can be used only if the birth weight of the baby is known and if the portable weighing machines with 25gm least count or less is available to the field level health workers.

It is the concept of such a screening tool which is very important and not the actual growth curves. The criteria for grouping the babies in different birth weight groups, and the level of unsatisfactory growth curve line could vary as per need. There could be variation in growth pattern according to ethnicity, regions, practices related to neonatal care etc. Similar Growth Curves may have to be prepared to suit the local situations.

References
3. Available from: http://cghealth.nic.in/ehealth/jssk.htm


