A new simple method to estimate the gestational age from chest x-ray measurements in newborns and preterm infants

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Aims and objectives

1. Introduction: Why is it important to know the gestational age in a newborn?

The importance of differentiating between pre-term and term newborns [1]

Preterm birth complications are estimated to be responsible for 35% of the world's annual neonatal deaths. Furthermore, these complications are the second most common cause of death after pneumonia in children under 5 years old.

Preterm birth increases the risk of death due to neonatal infections and in almost all countries, preterm birth is the leading cause of child deaths as well as there is an increased risk of cerebral palsy, impaired learning, visual disorders, and of chronic disease in adulthood.

The economic and social cost of preterm birth is high in terms of neonatal intensive care and ongoing health-care and educational needs.

Pediatric radiologists and lack of clinical information[1]

The accurate dating of pregnancy is critically important for pregnancy management. Ultrasound gave clinicians a method to measure the fetus to estimate gestational age (GA). But knowing the gestational age is not only important before pregnancy but also after it, specially during the first days of life.

Pediatric radiologists usually report initial plain chest films of newborns admitted to the neonatal intensive care unit (NICU) without having this critical information. Digital image reading may be misleading as displayed image size does not closely follow gestational age.

The precise gestational age assessment helps radiologists to suspect several pathologies (surfactant deficiency disorder, haemorrhage, meconium aspiration syndrome, or intrauterine growth restriction) dependent on premature, term, or post-term gestational age.
Current known measurements on fetus: Estimation of gestational age based on US Findings [2][3][4][5]

It is well known that dating a pregnancy using ultrasound measurements is clinically superior to using menstrual dating. This demonstrates the reliability of imaging techniques for estimating the gestational age during pregnancy. Ultrasound biometric measurements determine gestational age based on the assumption that the size of the embryo or fetus is consistent with its age.

First trimester: During the first-trimester, the crown-rump length is the best parameter for determining gestational age. Direct measurement of the CRL provides the most accurate estimate of gestational age once the embryo is clearly seen. Between the 12th and 14th weeks, crown-rump length and biparietal diameter are similar in accuracy.

Second and Third Trimester: A combination of multiple biometric parameters (biparietal diameter, head circumference, abdominal circumference, and femur length) is used to determine gestational age, rather than a single parameter.

2. Objective of this scientific exhibit

The purpose of this scientific exhibit is to describe a reliable and quick method to estimate the gestational age by measurements taken in A-P chest x-ray exams of newborn infants, full-term, critically ill and premature, admitted to a neonatal intensive care unit (NICU). The method may provide this critical information frequently unavailable while reporting initial studies.
Methods and materials

-Patient characteristics

This study includes 274 newborns full-term, critically ill and premature, admitted to a neonatal intensive care unit (NICU) between September 2014 and September 2015, both included.

This scientific exhibit divides newborns into 3 main groups: pre-term (70.75%), term (28.89%) and post-term (0.36%). The pre-term group was subdivided in extremely preterm (16.97%), very preterm (19.85%) and moderate/late preterm (33.93%).

This classification is based on the WHO guidelines which define preterm birth as any birth before 37 completed weeks of gestation, or fewer than 259 days since the first day of the women's last menstrual period (LMP) and this can be further subdivided on the basis of gestational age: extremely preterm (<28 weeks), very preterm (28–<32 weeks), and moderate or late preterm (32–<37 completed weeks of gestation). These subdivisions are important since decreasing gestational age is associated with increasing mortality, and disability.

-Chest x-ray assessment

One chest x-ray was performed to 206 (75.2%) newborns; two chest x-rays were performed to 48 (17.5%) newborns during the first two consecutive days of life and three chest x-rays were performed to 16 (5.8%) newborns during the first three consecutive days. Only 4 (1.5%) newborns had 4 chest x-rays performed during the first four consecutive days of life.

This is a cross-sectional study of 366 plain chest films of 274 newborns.

Three simple measures were obtained from chest A-P exams (Fig.1):

1. Dorsal spine length (DSL): A straight line from the superior rim of D1 to the lower rim of D12.

2. Right pulmonary length (RPL): From the right pulmonary apex to the right diaphragmatic dome.
3. **Transversal chest width (TCW):** From the external surface of the right 8 or 9th rib to the contralateral external surface.

- **Other relevant variables**

Other variables were recorded in our scientific exhibit. The gestational age, weight, twin pregnancy, persistent ductus arteriosus, congenital malformations, metabolopathies, premature newborn complications (hyaline membrane disease, necrotizing enterocolitis, respiratory distress syndrome or haemolytic disease of the newborn requiring phototherapy), previous pregnancies and maternal complications (pre-eclampsia and eclampsia, chorioamnionitis or threat of premature birth).

- **Statistical analysis (Fig.2)**

ROC analysis was performed to assess cut points for each measure to find optimal sensitivity and specificity for predicting gestational age.

ROC analysis was performed to assess best cut points for each measure to find optimal sensitivity and specificity for predicting gestational age. ROC curves were drawn for each measure.

R squared correlation was calculated for each measure with the same measure in subsequent chest x-rays to assess if they differed substantially.
Images for this section:

Fig. 1: Three simple measures were obtained from chest A-P exams. Dorsal spine length (DSL): A straight line from the superior rim of D1 to the lower rim of D12. Right pulmonary length (RPL): From the right pulmonary apex to the right diaphragmatic dome. Transversal chest width (TCW): From the external surface of the right 8 or 9th rib to the contralateral external surface.

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Fig. 2: R squared correlation was calculated for each measure with the same measure in subsequent chest x-rays to assess if they differed substantially.

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Results

Multiple threshold measures were obtained in order to establish an optimal value (high sensitivity and specificity) to classify newborns into pre-term (extremely preterm, very preterm and moderate/late preterm), term and post-term.

Threshold values obtained by measurements taken in A-P chest x-ray exams:

1. One key measure to differentiate preterm from term and postterm newborns (Fig.3):

   - Dorsal Spine length: 90mm
     
     S: 90.82% (IC 86- 94.5%) PPV: 92.2%
     E: 81.48% (IC 71.3-89.2%) NPV: 78.6%

2. Three key measures to differentiate between extremely and very preterm from late preterm and term newborns:

   - Dorsal Spine length: 80mm
     
     S: 92.16% (IC 85.1-96.6%)  
     E: 81.71% (IC 75.2-87.1%)

   - Right pulmonary length: 47mm
     
     S: 78.4% (IC 69.2-86%)  
     E: 89% (83.6-94%)

   - Transversal chest width: 93mm
     
     S: 79.4% (IC 70.3-86.8%)  
     E: 91.4% (IC 86.3-95.1%)
3. The triple combination of the 3 measures mentioned above, helps to improve the PPV for differentiating between extremely/very preterm from late/term newborns (Fig.4):

-1 or more values: PPV: 68.3% / NPV: 96.3%

-2 or more values: PPV: 85.5% / NPV: 93.5%

-3 values: PPV: 93.1% / NPV: 82.1%

4. Other variables

Other variables were recorded without observing significant differences.

Other studied variables were the gestational age, weight, twin pregnancy, persistent ductus arteriosus, congenital malformations, metabolopathies, premature newborn complications (hyaline membrane disease, necrotizing enterocolitis, respiratory distress syndrome or haemolytic disease of the newborn requiring phototherapy), previous pregnancies and maternal complications (pre-eclampsia and eclampsia, chorioamnionitis or threat of premature birth).
Fig. 3: ROC curve for a Dorsal Spine Length of 90 mm to differentiate preterm newborns from term/postterm newborns.

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Fig. 4: ROC curve for a triple combination of the 3 measurements (dorsal spine length, right pulmonary length and transversal chest width) to differentiate extremely/very preterm newborns from late preterm/term and postterm newborns.

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Conclusion

Dorsal Spine Length (DSL) and Right Pulmonary Length (RPL), and their combinations, are quick and reliable estimates of the gestational age of full-term and preterm newborns.

These measures and their combinations allow radiologists to classify newborns into pre-term (extremely preterm, very preterm and moderate/late preterm), term and post-term just by measurements taken on A-P chest plain films.
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References


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