

Learning curve in measurement of fetal frontomaxillary facial angle at 11–13 weeks of gestation

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KEYWORDS: first-trimester screening; FMF angle; learning curve; measurement

ABSTRACT

Objective To determine the number of ultrasound examinations required to train sonographers to accurately measure the fetal frontomaxillary facial (FMF) angle at 11–13 weeks of gestation.

Methods Eight sonographers accredited for nuchal translucency thickness (NT) measurement (and with different levels of experience) were trained to measure the fetal FMF angle using specially acquired three-dimensional (3D) volumes. Training was provided in cycles, and each cycle consisted of a training period on 20 randomly selected cases followed by an examination using 10 randomly selected cases. During training, the sonographer was informed of the true FMF angle value after each FMF angle measurement on a case-by-case basis. During examination, the difference between the measured and the true values of the FMF angle (i.e. the delta angle) was calculated. A measurement was considered accurate if the delta angle was less than 5°. The sonographer was considered to be competent and the training finished if all 10 examination cases satisfied this criterion. Otherwise, the sonographer would undergo further cycles of training–examination, until he/she became competent.

Results The number of training cases required for a sonographer to become competent was 40 for two sonographers, 60 for one, 80 for one, 100 for two, 120 for one and 140 for one, with a median of 90. The median number of failed cases reduced from 2.5 (out of 10) at the first cycle to 0 by the 7th cycle. As training cycles increased, the mean angle deviation and measurement time required both reduced significantly.

The average delta angle of the passing examination cycle was $2.06 \pm 1.40^\circ$. The number of training cases required to become competent in FMF angle measurement was 40 for the two most experienced trainees and 80, 120 and 140 for the three least experienced ones.

Conclusions We have demonstrated that competence in FMF angle measurement was achieved after a median number of 90 cases, with a range of up to 140. The number required was substantially lower, at 40 cases, among those with extensive experience of NT measurement. Copyright © 2010 ISUOG. Published by John Wiley & Sons, Ltd.

INTRODUCTION

Recent studies have shown that the fetal frontomaxillary facial (FMF) angle in trisomy 21 fetuses is wider than that in euploid fetuses, in both the first and the second trimesters of pregnancy^{1–4}. In the first trimester of pregnancy a high proportion of fetuses with trisomy 21 showed a wide FMF angle, with measurements above the 95th centile of the normal range⁵. The FMF angle has been reported not to be significantly associated with other first-trimester markers including nuchal translucency (NT) thickness, maternal serum free beta human chorionic gonadotropin (free β -hCG) and pregnancy associated plasma protein A (PAPP-A)⁴, making the FMF angle a potentially useful additional marker for fetal Down syndrome screening. In a sequential screening strategy⁵, addition of the assessment of the FMF angle to the combination of maternal age, NT thickness and maternal serum free β -hCG and PAPP-A could improve the

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Accepted: 18 September 2009

detection rate for Down syndrome to more than 90% for a 3% false-positive rate⁵.

However, the mean delta FMF angle (i.e. the difference between each FMF angle and the gestational-age specific median value) among Down syndrome fetuses was found to be only $7.172 \pm 4.029^\circ$ ⁵. The FMF angle will therefore only be useful in differentiating chromosomally normal and abnormal fetuses if its measurement is as precise and reproducible as NT measurement. Training will obviously play a major role in ensuring the quality of measurement. However, at present there is no published study regarding the time required for training in the measurement of the FMF angle.

The aim of this study was to determine how long it takes for an operator to become competent in FMF angle measurement in the first trimester of pregnancy.

METHODS

Overall design

A bank of three-dimensional (3D) ultrasound volumes was captured specifically for training and examination purposes. Volumes in the bank were divided randomly into training and examination sets. Eight sonographers, who were accredited for first-trimester measurement of NT by The Fetal Medicine Foundation of the United Kingdom and who had different levels of experience, were recruited for training. Each sonographer was taught to measure the FMF angle using data volumes from the training set. After every 20 cases of training, an examination was performed on 10 volumes from the examination set. This cycle of training–examination continued until the sonographer was judged to have passed the examination. All training and examination cycles were performed offline using four-dimensional (4D)-View software (version 5.0, GE Medical Systems, Zipf, Austria).

Ultrasound volumes

One hundred and eight volume blocks were taken from 108 pregnant women attending the first-trimester Down syndrome screening clinic in a university obstetric unit. All subjects were ethnic Chinese, and all carried a singleton pregnancy with normal outcome. All volumes were acquired transabdominally using a Voluson 730 Pro system (GE Medical Systems) with a 4–8-MHz curved array 3D transducer. The study was approved by the institutional review board of the local institution, and informed consent was obtained from all participants. All volumes were acquired using the sample box including the fetal head and upper chest only, with the fetus as close to the mid-sagittal section as possible (as defined in a previous study⁴). All volume blocks were reviewed and the FMF angle measured by one of the authors (M.B.) with extensive experience in FMF angle assessment^{1–4}, and all measurements taken by M.B. were regarded as the ‘true FMF angles’ for these cases.

The 108 available blocks of 3D volumes were divided into two sets using a random number generator – 60 blocks for a training set and 48 blocks for an examination set.

Training

Before any training commenced, each sonographer was taught individually how to manipulate the 3D volume to get the true mid-sagittal section, how to measure the FMF angle using the 4D-View software, and how to measure the FMF angle according to published standards^{1–4}. Afterwards, a volume was selected randomly from the training set for the trainee to measure the FMF angle. When the measurement was finished, the trainee was informed of the true FMF angle for that case. This process was repeated until a total of 20 volumes had been measured.

During the training, a trainer was present and restricted to assisting the trainee if they had any difficulty in using the 4D-View program, and informing the trainee of the true FMF angle when the trainee had finished measuring a 3D volume. The trainer was not allowed to assist the trainee in the measurement process.

Examination

For each examination, 10 3D volumes were randomly selected from the examination set. The trainee was asked to measure the FMF angle on each of the volumes. Unlike during training, the value of the true FMF angle was not given to the trainee after they had measured it. Instead, the delta angle, defined as the difference between the measured FMF angle and the true FMF angle, was calculated. A measurement was considered ‘successful’ if the delta angle was less than 5° , and ‘failed’ if the delta angle was 5° or more. A trainee would be considered to have passed the examination, the ‘passing cycle’, if all 10 measurements were successful (i.e. the delta angle was less than 5° in all 10 cases). During the examination, the trainer functioned only as a facilitator and did not provide any assistance, comment or opinion on FMF angle measurement.

Statistical analysis was performed with SPSS for Windows 15.0 software package (Chicago, IL, USA). $P < 0.05$ was considered to be statistically significant.

Figure 1 summarizes the training and examination process. The time required to perform an individual measurement was recorded throughout the training and examination process.

RESULTS

All eight sonographers completed the training–examination cycle. Two sonographers required only two cycles (40 cases) to pass the examination, one required three cycles, one required four cycles, two required five cycles, one required six cycles, and one required seven cycles. The median number of cases required for a sonographer to become competent in measuring the fetal FMF angle was 90 (range, 40–140).

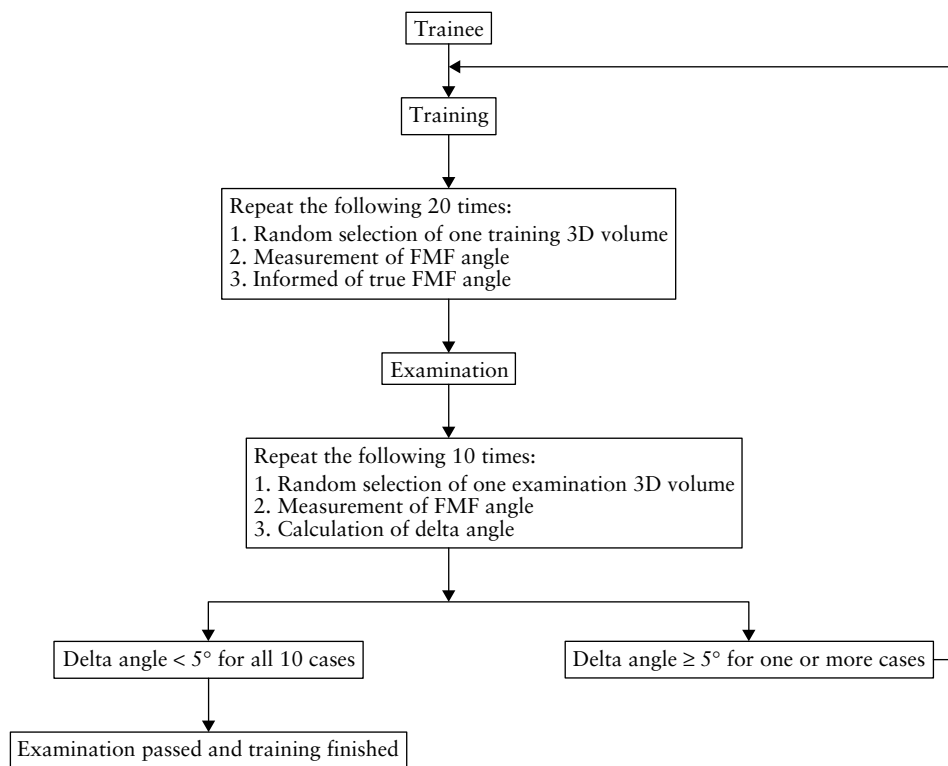


Figure 1 Training strategy for measurement of the fetal frontomaxillary facial (FMF) angle. Delta angle is the difference between measured and true values of the FMF angle. 3D, three-dimensional.

Table 1 Examination performance of eight sonographers in measuring frontomaxillary facial (FMF) angle after different stages of training

Cycle	Cumulative number of cases	Number of trainees	Number of trainees passing examination	Examination result	
				Median	Range
1 st	20	8	0	2.5	2–5
2 nd	40	8	2	2.5	0–4
3 rd	60	6	1	2.0	0–6
4 th	80	5	1	2.0	0–4
5 th	100	4	2	0.5	0–1
6 th	120	2	1	0.5	0–1
7 th	140	1	1	0	0

Table 1 and Figure 2 show the number of examination cases that were failed at the end of each training cycle. The median number of failed cases was inversely correlated to training cycles received. The median number of failed cases (out of a total of 10 cases) progressively reduced with increasing number of training cycles, from 2.5 at the first cycle to 0 at the 7th cycle.

Looking at only cases from the last examination cycles of these eight sonographers, i.e. the cycle when they became competent, the averaged delta angle was $2.06 \pm 1.40^\circ$, which was significantly lower than that in the first examination cycle ($3.93 \pm 3.32^\circ$; $P < 0.0001$).

During the training cycles the mean (\pm SD) duration for offline measurement of the FMF angle decreased

significantly from 3.07 ± 2.32 min per case (first cycle) to 1.77 ± 1.07 min per case (final cycle) ($P < 0.0001$). During the examination cycles, the mean duration decreased significantly from 2.05 ± 1.38 min (first cycle) to 1.46 ± 0.83 (last cycle) ($P = 0.002$).

Table 2 shows the relationship between trainees' experience on NT measurement and the outcome of the FMF angle training. Although all eight sonographers were accredited for NT measurement, their experience of it varied widely. The number of training cases required to achieve competency in FMF angle measurement was 40 for the two most experienced trainees and 80, 120 and 140 for the three least experienced trainees, the others having intermediate results.

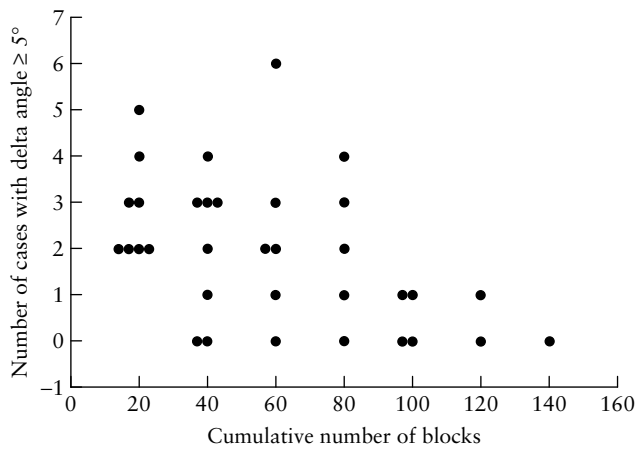


Figure 2 Number of cases, out of a total of 10, in which the difference between measured and true values of frontomaxillary facial angle (delta angle) was $\geq 5^\circ$. Each dot represents a trainee. All eight sonographers participated in the first examination (after training with 20 cases). Since those who passed the examination were not required to carry on with the study, the number of candidates in subsequent examinations reduced progressively.

Table 2 Relationship between experience in nuchal translucency (NT) scanning and outcome of training in frontomaxillary facial (FMF) angle measurement

Sonographer	Number of NT scans*	Number of training cases required to be competent in FMF angle measurement
A	5585	40
B	5461	40
C	2081	60
D	755	100
E	400	100
F	< 100	120
G	< 100	140
H	< 100	80

*Number of NT scans that the sonographer had performed before the start of training in FMF angle measurement.

DISCUSSION

The FMF angle is a new sonographic marker for fetal trisomy 21 that is independent of other biochemical and ultrasound markers, and improves the detection rate for Down syndrome in combination with NT thickness and maternal serum free β -hCG and PAPP-A measurement^{4,5}. In experienced hands, measurement of the FMF angle has been shown to be highly reproducible, and in about 95% of cases the difference between two measurements by the same observer or measurements by different observers was within 3°⁶. Similar to other sonographic examinations and measurements, such as NT, this highly reproducible result could only be achieved with proper training. We found that the median number of examinations required for a sonographer to become competent in measuring the FMF angle was 90 and is similar to that reported for examination of the fetal nasal bone, an apparently

simple procedure that nevertheless took an average of 80 examinations before an experienced sonographer became competent⁷.

In this study we assessed the learning curve of the FMF angle measurement amongst NT-accredited sonographers using acquired 3D volumes. We have demonstrated the important potential role of 3D technology in training and quality assurance. Without the 3D technology, all training would have had to be based on real-time two-dimensional imaging in the presence of an experienced trainer. This is usually a time-consuming and slow process, inconvenient for patients, and is usually interrupted or affected by the clinical condition of the subject. With the availability of 3D sonographic volumes, it has become possible to run training sessions in a much more structured manner, and the process can be repeated as many times as is required. The obvious advantage is that a gold standard or a ‘true value’ for a particular 3D volume is known and therefore could be given immediately afterwards for comparison and reinforcement, which would potentially enhance the efficacy of the training process. The same model could be used for a certification or recertification process, to ensure that a particular sonographic marker is measured correctly. However, whether the use of stored 3D volumes improves the efficacy of training in FMF measurement, compared with other forms of training approaches, requires further evaluation.

The results of this study showed that the measurement of FMF angle is not easy. Even after training with 20 cases, trainees still failed the FMF angle measurement in 20–40% of cases in their examination, an alarmingly high result. Furthermore the learning curve varied widely. While two trainees became competent (passing all examination cases) after training with only 40 cases, the median number required was 90 cases. This finding was surprisingly similar to the results of three previous studies that reported on competence in the measurement of NT thickness, assessment of the nasal bone and Doppler assessment of ductus venosus flow in the first-trimester scan. NT-accredited trainees in these studies achieved competency after a minimum of 80 scans^{7–9}. It is highly likely that, for less experienced sonographers, the training curve would be even longer. This is supported by the results of our study, which demonstrate that the more experienced the trainee was in performing NT scans the fewer the number of training cycles he/she required before becoming competent in measuring the FMF angle. Trainees with extensive experience of NT assessment only required 40–60 training cases to be competent in FMF angle measurement. If the training were based purely on real-time scanning in real patients instead of using the 3D volume model, the learning curve might be different.

Our study also showed that the time required for measuring the FMF angle reduced significantly with training and experience. At the last training cycle, trainees could measure the correct FMF angle in around 1.5 min, a time that is expected to decrease further

with additional experience. Therefore, incorporation of FMF angle assessment in routine clinical practice is feasible.

The major difficulty in the design of this study was the definition of 'successful' measurement of the FMF angle. We defined a successful measurement if the delta angle was less than 5°. If a more liberal definition, e.g. less than 10°, had been adopted, the learning curve would definitely have been shorter but at the expense of reducing precision in the measurements. If a stricter criterion had been used, e.g. less than 1°, the measurements of those who passed would be highly precise, but the chance of passing would be very low because all measurements carry a degree of error. After much deliberation, we believe that the definition we have used was the best compromise. In fact, the mean delta angle in the last examination cycle of our eight sonographers was $2.06 \pm 1.40^\circ$, a result highly comparable to that achieved by operators who were experienced in FMF angle measurement⁶. Our findings therefore support our original decision on the choice of definition for a successful measurement.

In conclusion, we have demonstrated that competence in the measurement of FMF angle would require a median number of 90 cases with a range of up to 140. The number required was substantially lower, at 40 cases, among those with extensive experience in NT measurement. We have also demonstrated the potential application of 3D ultrasound technology in training and quality assurance.

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