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Development of a training model for ultrasound-guided invasive procedures in fetal medicine

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ABSTRACT

Training in ultrasound-guided procedures in fetal medicine is currently available in a few major fetal medicine units. Unlike elective surgical procedures, cordocentesis is usually performed without sedation as an outpatient procedure and active supervision of the trainee intensifies the anxiety already felt by the patient. In addition, the complication rate is higher in the initial few procedures or when the procedure is not regularly practiced. We have developed a comprehensive method of training for transabdominal invasive procedures using a medical model that simulates the in vivo *situation.*

INTRODUCTION

Fetal blood sampling (cordocentesis) and other invasive procedures in fetal medicine are now carried out under ultrasound guidance and are finding widespread applications, not only for prenatal diagnosis of inherited disorders but also for antenatal evaluation of the fetus in high-risk pregnancies and in fetal surgery[1,2]. As ultrasound technology and training improve, the demand increases for more fetal medicine specialists who are able to perform these procedures competently. However, active supervision of the trainee during the procedure is stressful for the patient and can be detrimental to the fetus. To aid initial steps of this training, a medical model allowing simulation of fetal blood sampling under ultrasound guidance would be of benefit.

DESCRIPTION OF THE MODEL

The model consists of a soft pre-vulcanized rubber dome 15 cm high by 21 cm in diameter and 4 mm thick, which rests in a rigid plastic holder 30 cm in diameter and 10 cm in height. In describing the model, anatomical names of the different simulations are used by way of definition.

The dome simulates the dimensions of a mid-trimester pregnant abdomen and gives the optical field of a hemisphere. It is palpable when filled, preferably with distilled water, although tap water is adequate. Water is introduced and taken out through a small tap on the underside of the dome. The tension of the 'abdomen' is governed by the amount of water within the rubber dome. When filled to hold its form, the dimensions and softness simulate this state of pregnancy.

The internal structure of the dome is shown in Figure 1. The rubber wall of the 'abdomen' is designed to give the correct ultrasonic reading and tactile resistance. It does not have the anatomical structure which is found in life. The wall has been developed to withstand multi-puncturing. Two placentas, each 15 × 15 × 3 cm, made from the same rubber and filled with a type of foam mesh are bonded to the top and bottom of the internal profile of the dome. In each case, cords (each

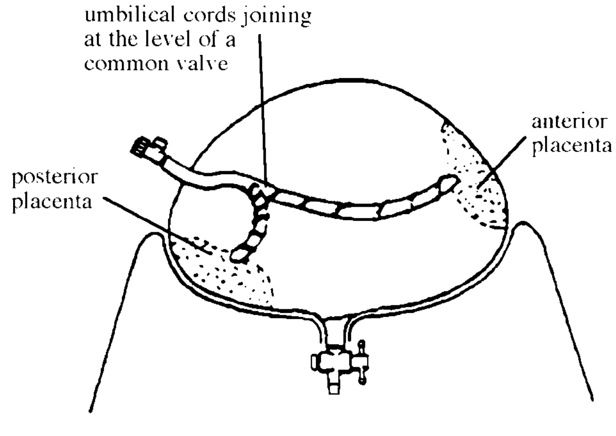

Figure 1 Simple line drawing of the model. There are anterior and posterior placentas; their two cords join at the level of the valve. The container can be filled separately

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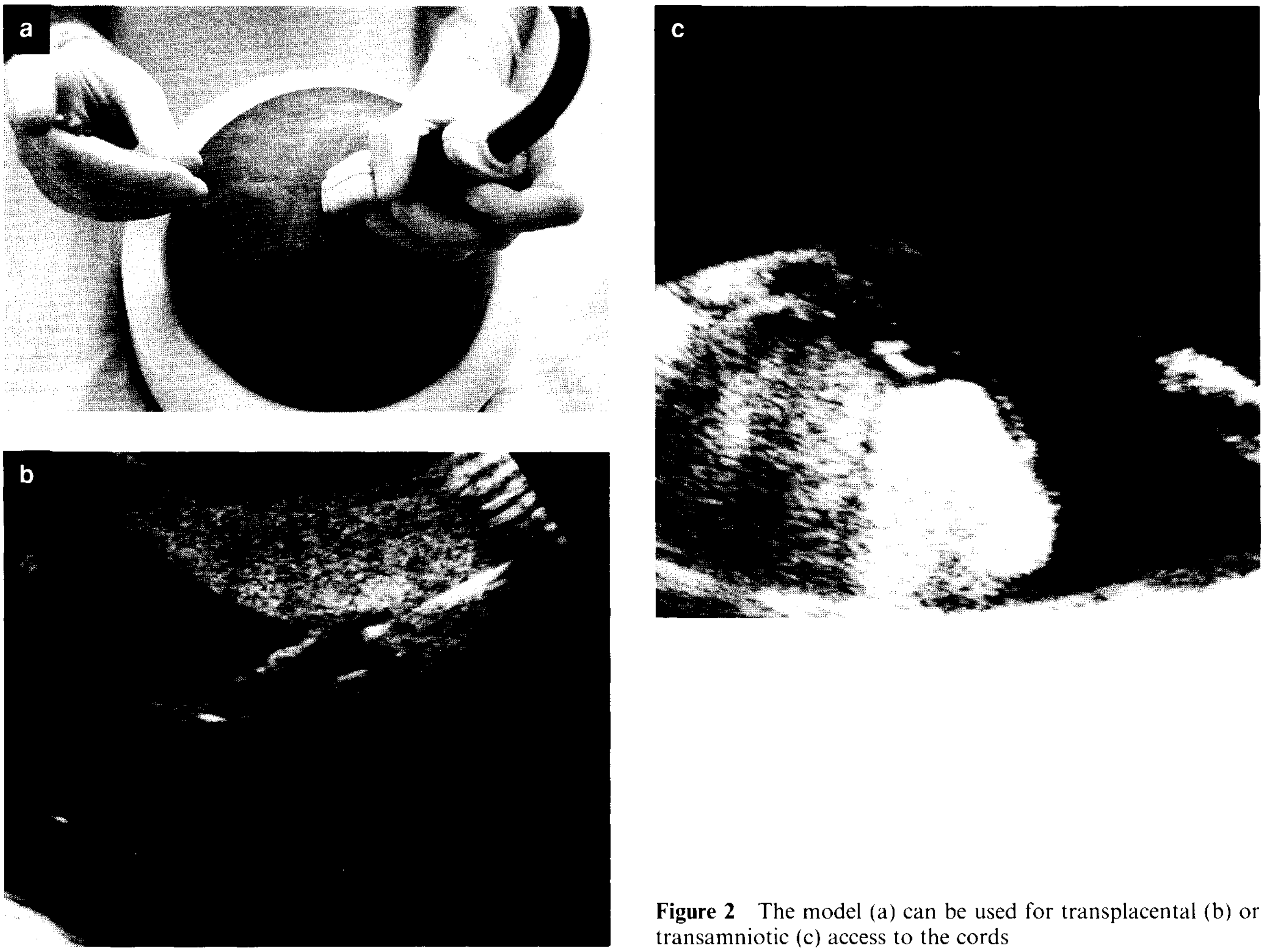

Figure 2 The model (a) can be used for transplacental (b) or transamniotic (c) access to the cords

20 x 9 cm) extend from the placentas which join at the level of the common valve. The cords are composed of three vessels; for simplicity, just the veins are filled with red liquid which simulates blood in color and viscosity. The technique employed in making the veins has been developed and used for years by the company behind the construction of this model. The cord can be punctured and aspirated repeatedly. The extension of the common valve is connected to a one-way valve mounted on the outside of the wall. Replacement blood can be introduced through the valves. Care should be taken that the extraction and replacement of amounts of liquid are similar; this ensures a constant tension and 'normal' sensation when the vein is punctured and does not cause overloading. The dimensions of the model are compatible with those of a 24-weeks fetoplacental unit, including an umbilical cord of 10 mm in diameter[3], and the configuration of the model, with two separate placentas, allows training in transplacental or transamniotic access to the cord. The model has been used with needles ranging from 22 to 18 gauge and more than 300 punctures of the dome and the cord did not cause any damage. Furthermore, the dome wall is made with the same material as the veins, so preventing any fluid leakage. The echogenicity of the model using conventional ultrasound is close to that of a mid-trimester placental unit (Figure 2), and a needle can be followed from the entrance in the model towards its target. The resistance of the dome wall and that of the placenta prevent movements which could not be performed *in vivo* to correct the position of a misdirected needle and provide a similar feeling to that in the *in vivo* situation. The placental insertion is fixed but the cord is able to move freely within the water, leading to the same difficulties encountered when puncturing a free loop in the *in vivo* situation. Puncturing the cord provides the same tactile perception. Correct insertion can readily be checked by aspirating artificial blood if the procedure is successful. The dome, with its smooth hemispheric shape, allows different approaches toward the target, so affording experience with the different positions of the transducer and the needle within an area resembling the maternal abdomen to be punctured at 20–24 weeks' gestation. The model should be stored away from the light to prevent progressive alteration of its softness. When the abdominal wall and the veins are finally exhausted after much use, the dome and each of its contents can be replaced.

DISCUSSION

Although programs for training junior doctors in obstetric ultrasound are now well established, the opportunity to acquire the skills necessary to perform cordocentesis is currently available in only a few major fetal medicine centers throughout the world and training is carried out through active supervision of the trainee. Unlike training in elective surgical procedures, cordocentesis is usually performed without sedation as an outpatient procedure. The supervision of the trainee intensifies the anxiety already felt by the patient as a result of the uncertainty over the outcome of the pregnancy.

The overall fetal loss rate due to cordocentesis is estimated to be 1%[4]. However, there is a great variation in the series published, with the rate ranging from 0 to 12%[4]. There is a negative correlation between fetal loss rate and the size of the series published. Furthermore, several authors have pointed out a learning curve in cordocentesis with the importance of the first 100 procedures being critical where fetal loss rate is maximal[1,5–7], or when the procedure is not regularly practiced. Training on fetuses before termination of pregnancy for fetal abnormality can only be considered as a poor alternative and might not be always ethically justified. Furthermore, fetal abnormalities often make the procedure more difficult. Models will never replace people, but, on the other hand, they allow practice and an understanding of technique which cannot be achieved as quickly and safely by learning the procedure on patients. Models are designed to fulfil different functions; in this case, as well as being anatomically correct in the areas crucial to the technique, the materials need to reproduce the tactile response and ultrasonographic picture in keeping with those found in life. In some instances, anatomical detail has to be sacrificed in order to achieve a true tactile response and realistic image. The model proposed simulates an abdominal wall and uterus, the placenta and umbilical cord, including simulated blood flow in the umbilical vein.

The particular aim of the training is to direct a needle transabdominally towards a target in the fetoplacental unit under complete operator control and visualization of both the target and the needle. In our experience, invasive procedures can be performed by one operator with a free-hand technique[2]. We use a 5-cm curvilinear transducer, visualizing clearly the abdominal wall, and the target must be placed in the center of the screen. The transducer is ideally held in the left hand of a right-handed operator at right angles to the table and is held in the same position during the procedure. The needle must be inserted 3 cm away from the transducer at an angle of 45° with the horizontal probe (Figure 3). These are the prerequisites for directing the needle accurately towards the target with a clear visualization of the whole length of the needle throughout the procedure. Some of the most difficult aspects of the procedure are:

(1) Visualizing the cord longitudinally at either the placental or umbilical insertion;

(2) Maintaining the transducer in this position throughout the procedure;

(3) Introducing the needle through the skin at the correct angle and distance from the transducer;

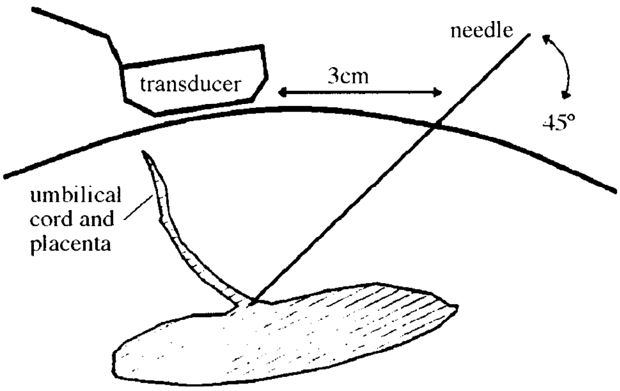

Figure 3 Comprehensive approach of invasive procedures in fetal medicine. The target is in the middle of the screen; the transducer is held at right angles to the table and the needle is inserted 3 cm away from the transducer at a 45° angle to the horizontal probe

(4) Advancing the needle under full vision towards and into the cord;

(5) Introducing the needle into the umbilical vein through Wharton's jelly surrounding the cord;

(6) Finding the target again and repositioning the needle in the same alignment when the target has moved or changed.

The model allows training in all of the above aspects, without the need to perform one's first procedures on a patient. The rubber and foam mesh chosen reproduce appropriate images of normal anatomy when scanned with normal ultrasound equipment (Figure 2) as well as the respective resistance to the needle to simulate the conditions under which fetal blood is taken by cordocentesis. The resistance of the rubber wall limits the speed of penetration of the needle as closely to the *in vivo* procedure as possible.

Other training models for fetal invasive procedures have been proposed using fresh delivered placentas with their own cord[8,9]. Although these models were realistic, inexpensive and simple to assemble, their widespread use may have been prevented by the poor quality of conservation and the technical difficulties encountered in scanning and performing procedures on 'large' and rudimentary models. This does not help the trainee in becoming familiar with the respective positioning of the transducer and needle in a restricted area while sitting comfortably, and being able to move gently and precisely towards the target, as should happen in the *in vivo* situation. The model presented offers an effective method for training doctors in invasive procedures with no patient risk as well as providing an elegant way of testing new instruments or ultrasound transducers.

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