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A FOETAL PLETHYSMOGRAPH

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Observation of changes of foetal volume provides a method for studying a number of problems in foetal physiology. Among these are fluctuations in the partition of the foetal blood between foetus and placenta, the rate of blood flow in the umbilical cord, and rapid fluid exchanges between foetus and mother.

The desirable features of a foetal plethysmograph are as follows:

(1) The seal between the umbilical cord and the plethysmograph must be made without pressing on, and preferably without touching, the cord, on account of the extreme irritability of the vessels within it.

(2) It should be easy and quick to apply.

(3) The sealing of the plethysmograph should be immediate and positive.

(4) The foetus and the umbilical cord should be totally immersed in physiological saline at body temperature, to simulate conditions in utero.

(5) The foetus should be clearly visible within the plethysmograph, so that any movements may be noted.

Plethysmographs have been designed and made which fulfil all these criteria with the exception that a short length of the umbilical cord passes out of the saline bath and lies on a rounded Perspex strip.

Four plethysmographs have been used. The largest has been successfully employed with sheep foetuses of 1700–4200 g. weight (Fig. 1). It is basically an open-topped tank of 14-gauge tinned brass, 38 cm. long, 20 cm. wide and 14 cm. deep. One of the lower long edges is bevelled, so that on this side the vertical wall is only 6 cm. deep. In use, this bevel fits against the lower abdomen of the mother and allows the plethysmograph to be brought more closely to her uterus exposed through a laparotomy opening and brought out on to the abdominal wall.

The rim of the plethysmograph is provided with a 3 cm. wide out-turned flange, and care is taken that the upper surface is smooth and flat. Where the walls meet the flange the edge is rounded off with a radius of about 0·5 cm. The umbilical cord passes over the brim at a distance of 13 cm. from one end. Soft rubber draught excluder is arranged round the top surface of the flange except at the place where the cord is to enter. Here, the ends of the rubber are carried vertically downwards for 5 cm. at a distance of 4 cm. apart on the inside of the wall.

To provide a smooth support for the cord a Perspex strip, 2·5 cm. wide within the plethysmograph and 6 cm. wide outside it, is bent over and attached to the flange as shown in Fig. 2. Small electric bulbs are arranged below this strip to transilluminate the cord, and holes are drilled in the flange to allow light to pass.

Recesses for the fore and hindlimbs, 6 cm. deep and 5 cm. square, are made in the side of the plethysmograph, one on each side of the entry point for the umbilical cord. The tops of the recesses are 1 cm. below the brim, so that the flange is left clear to take the clamps for fixing the lid. The foot recesses allow the umbilicus to be brought close to the entry point of the cord.

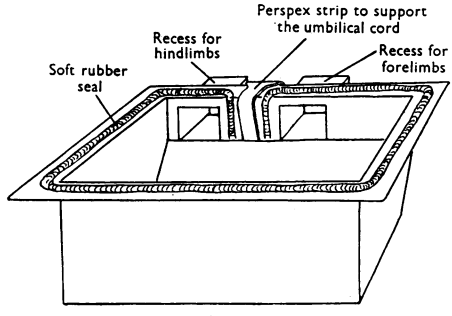

Fig. 1. Perspective drawing of the plethysmograph tank.

The lid of the plethysmograph (Fig. 3) is made of $\frac{1}{4}$ in. Perspex sheet. A notch, 2·8 cm. wide and 4 cm. deep, as measured from the wall of the plethysmograph, is cut in one side to allow the cord to enter. A curtain of Perspex 3 cm. deep hangs from the edges of the notch and the ends of the curtain are turned outwards to make shoulders which press against the vertical parts of the rubber

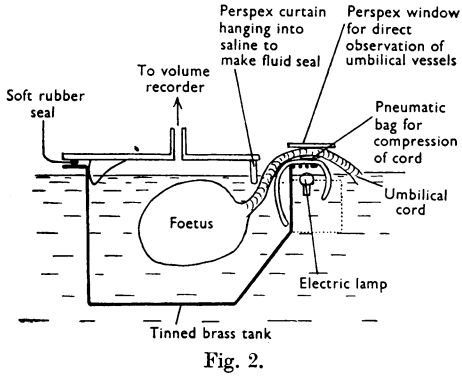

Fig. 2.

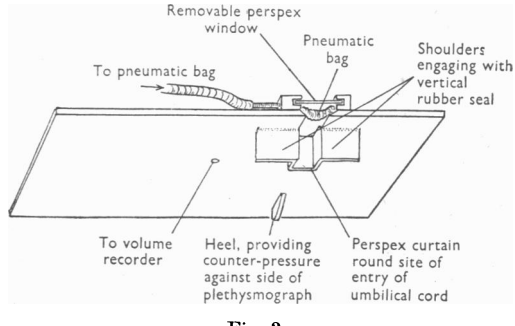

Fig. 3.

Fig. 2. Section through the plethysmograph at the point of entry of the umbilical cord. The umbilical cord is seen in position, lying on a gently curved Perspex strip.

Fig. 3. Perspective drawing of the lid of the plethysmograph, as seen if held in the normal horizontal position, and viewed from below.

seal. A heel of Perspex on the under-side of the lid provides counter-pressure against the opposite side of the plethysmograph, and holds the vertical joint tight. Where the shoulders meet the lid the angle is filled in with Perspex, shaped to a smooth curve of 1 cm. radius. The lid is held in position by eight clamps which effect a tight seal. The lid is provided with a tube connecting with the volume recorder, and a 1 cm. hole for use in calibrating, which is normally closed by a vaselined Perspex plate.

Provision for compression of the cord is made at the point where the cord passes over the brim. A rubber finger stall, which can be inflated as desired from a reservoir, is arranged to lie transversely across the path of the cord, and a removable Perspex window is arranged over it so that

there is a gap of 1·5 cm. when the finger stall is deflated. The finger stall is of sufficient size to fill the gap completely when it is distended at minimal pressures. Both finger stall and window are attached to the lid. Provision is made to hold the plethysmograph rigidly in position when in use, as any movement during an observation is inadmissible.

The following sizes of plethysmograph have been found suitable at different foetal ages. In each case the last figure is the depth. The cord enters at a point one-third along a long side. All have limb recesses:

Age (days)	Weight (g.)	Plethysmograph dimensions (cm.)
60	50– 100	12 × 6 × 4
70–100	100– 750	20 × 10 × 7
100–120	750–1600	28 × 13 × 10
120–143	1700–4200	38 × 20 × 14

Principles in use. The effective working of the plethysmograph depends on the fluid seal provided when it is filled to a depth sufficient to immerse the lower edge of the Perspex curtain round the point of entry of the cord. In practice it is filled to within 1 cm. of the brim, and it is immersed as a whole in a bath to the same level.

It will operate only in conjunction with a volume recorder which is so balanced that it exerts no back pressure in any static position, and a minimum of back pressure due to dynamic factors. In these conditions the level of the fluid in the plethysmograph remains always the same as that in the trap through which the cord enters. A change in volume of the foetus therefore alters the level in the two compartments equally, and the volume displaced in each compartment is proportional to the fluid area exposed in it. For this reason, the compartment through which the cord passes is made as small as possible, compatible with complete freedom of the cord, and the fluid surface area within it is very small indeed when the cord is in place. The smaller this area is made, the greater is the tolerance of dynamic imperfection in the volume recorder.

It follows from this that the volume of air displaced from under the lid of the plethysmograph is a definite and very large fraction of any volume changes in the foetus. The precise size of the fraction need not be known, as the plethysmograph and volume recorder are calibrated as a whole with the foetus and cord in position, or a suitable rubber tube may be used to represent the cord.

SUMMARY

A foetal plethysmograph is described which avoids the use of a contact seal at the point of entry of the umbilical cord.

I wish to thank Dr C. J. Hodson for a remark which led me to the design of the seal for the umbilical cord.