1960

# Optical pulse indicator for determination of systolic blood pressures in newborns, infants, and small children

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# AN OPTICAL PULSE INDICATOR
# FOR DETERMINATION OF SYSTOLIC BLOOD PRESSURES
# IN NEWBORNS, INFANTS AND SMALL CHILDREN

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Submitted in Partial Fulfillment for the Degree of
Doctor of Medicine

College of Medicine, University of

Nebraska April 1, 1960

Omaha, Nebraska

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**Figure 1 - Optical Pulse Indicator**

**grey scale scan**

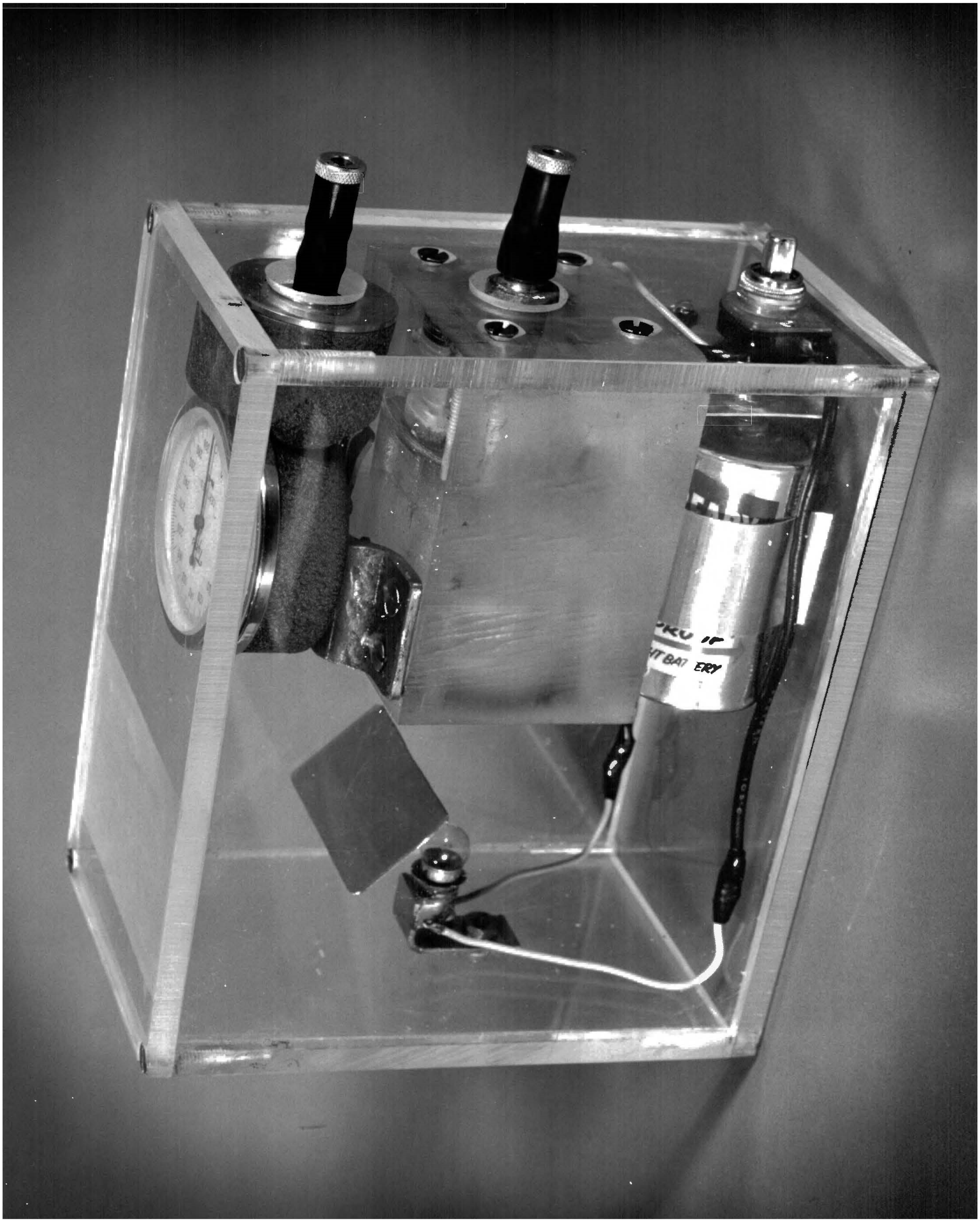
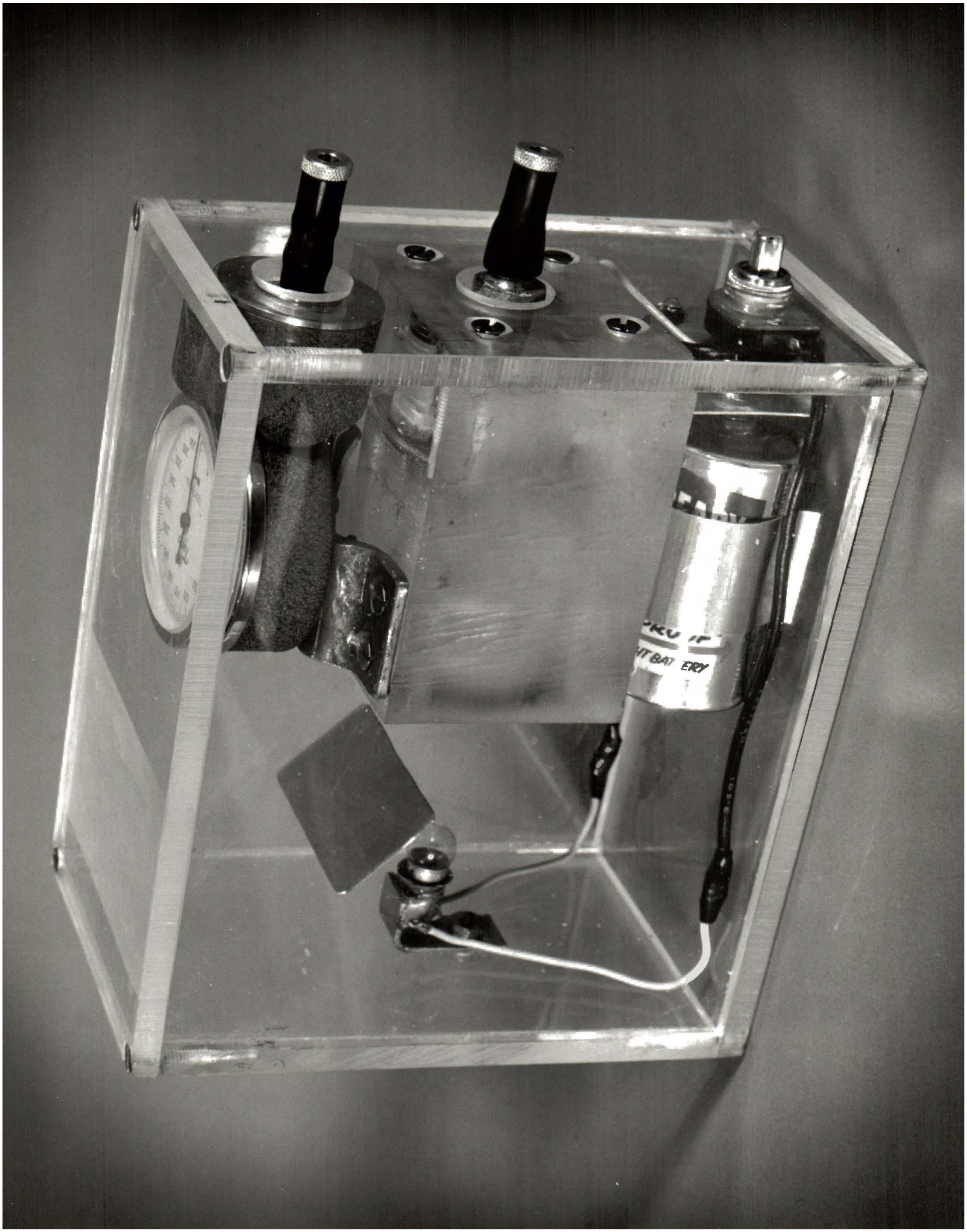


Figure 1 -- Optical Pulse Indicator

color scan



INTRODUCTION

There are three general ways of determining systolic blood pressure indirectly. One, the palpitory technique of Riva-Rocci (1896).[21] Two, the oscilliometric method of Erlanger (1904),[9] and three, the ausculatory method of Koratkow (1905)[15] which is the most accurate indirect method in general use.[13] However, none of these three methods is adequate in the determination of blood pressure in the infant or small child routinely because of difficulty in palpation of pulse, difficulty in auscultation of the pulse, or expense of equipment. There is a necessity for the accurate determination of blood pressures in infants suspected of having coarctation of the aorta, congenital anomalies of the kidney, nephrotic syndrome, asphyxia, and metabolic disturbances, such as potassium deficiency and hypoglycemia, and in babies born of toxemic and diabetic mothers.[1,3,4,5,12,22,23] For this reason the flush technique has been popularized lately by Goldring and Wohltmann[11] in 1952 although it was first described in 1899 by Gaertner[10] for determining digital blood pressure. They, Goldring and Wohltmann, have shown that the flush method gives systolic blood pressures which are approximately that found with the ausculatory method. Reinhold and Pym[19] in a later series state that the pressure found by the flush method is about 10 mm Hg. lower than the ausculatory systolic pressure. Because of this variable of the relationship of the flush method to the ausculatory method there have been some elaborate mechanisms developed.[1,2,7,9,16,24,26] Most of these, however, are large, expensive or impractical. Rice and Posener[20] have developed an optical pulse indicator which is used along with an ordinary sphygmomanometer to determine the systolic blood pressures in infants. This apparatus is relatively inexpensive and is quite simple to use. In their series they showed that with this apparatus they would consistently get a systolic blood pressure which was slightly higher than that determined by the ausculatory method.

GENERAL OUTLINE OF THE APPARATUS

I have constructed a similar optical pulse indicator but have added several modifications which, I believe, make the instrument less complex, more compact, and less expensive. The total cost is in the neighborhood of $6.00, excluding the price of the sphygmomanometer.

In this apparatus a standard sphygmomanometer is used. Aneroid or mercury could be used. Distal to this on the extremity is located a pick-up cuff which is slightly inflated. The pick-up cuff is attached to the optical pulse indicator. The pulse is transmitted via the pick-up cuff to the indicator where it is transmitted to a tambour. A mirror on the tambour then transmits reflected light to a screen. Each pulse which passes the occluding cuff is then indicated on the screen as a movement of the spot of light.

## DETAILS OF THE APPARATUS

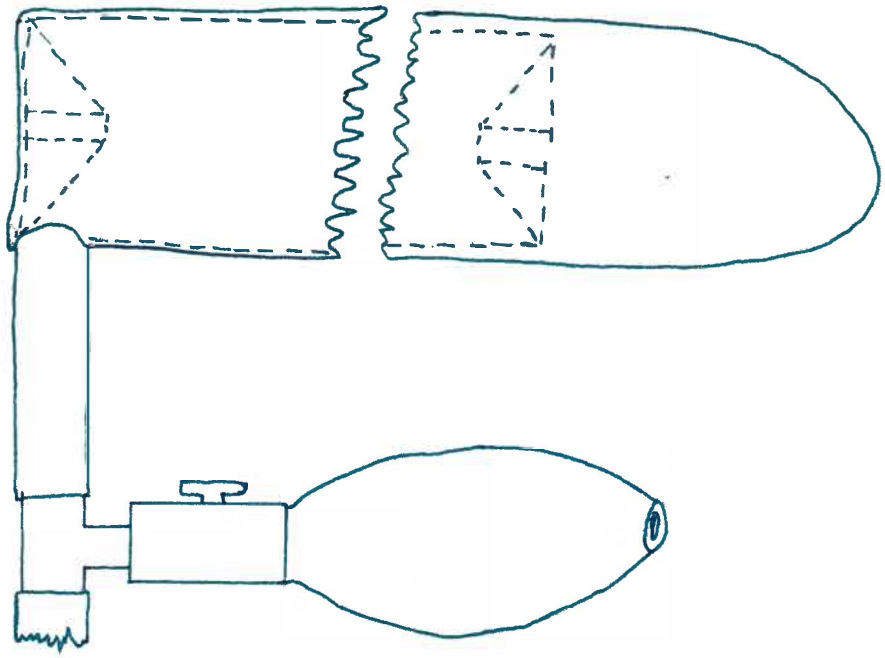
### Occlusion Cuff and Manometer

The occlusion cuff is any standard sphygmomanometer cuff. This cuff should be 9 cm. in width if the patient is less than eight years old,[8,25] if the child is less than four years old the cuff should be 6 cm.[25] and for the newborn the cuff should be 2.5 cm. in width.[2,8,11,22,23,25,27] For use on adults the cuff should be 13 cm. in width if the arm is used or 15 cm. if the leg is used.[18,25] The aneroid type of meter was used. Because of its smaller size, it could more easily be mounted in close proximity to the screen of the pulse indicator.

### Pick-up Cuff

This cuff is applied distal to the occlusion cuff. It consists of a rubber bag which is made of a large penrose drain three cm. in width and 20 cm. long. This is cemented to a piece of rubber tubing which has a 5 mm. lumen diameter. The tubing should be of a type which will resist expansion in luminal size which would make transmission less effective. The lumen size is important in that if it is too small, there will be greater resistance to the displacement of pressure through the tube from the cuff to the indicator, on the other hand if the lumen diameter is too great, then the pressure due to the displace volume of air will be damped out. This bag is then placed in a cuff in which the outer cover is of some non-resistant material such as a light canvas. This is important so that the pressure from the pulse is transmitted through the tubing to the diaphragm and not absorbed by the elasticity of the cuff itself. The inner surface of the cuff covering the bag should be of a very light material so as to get better transmission of the pulse to the recorder bag. The pump can be placed on a "T" connection in the tubing from the cuff to the indicator. It is better placed here than on another tube leading from the cuff since this will cut some of the surface area which will absorb pulse impulse. Another point is that the tubing leading to the indicator should be as short as possible and in as straight a line as possible in order to minimize loss of transmission of the pulse wave. When in use this cuff is inflated to anywhere from 20 to 90 mm Hg. of pressure in order to increase the compression of the air and thus make a better conducting medium which will transmit minute variations in pressure within the pick-up cuff.

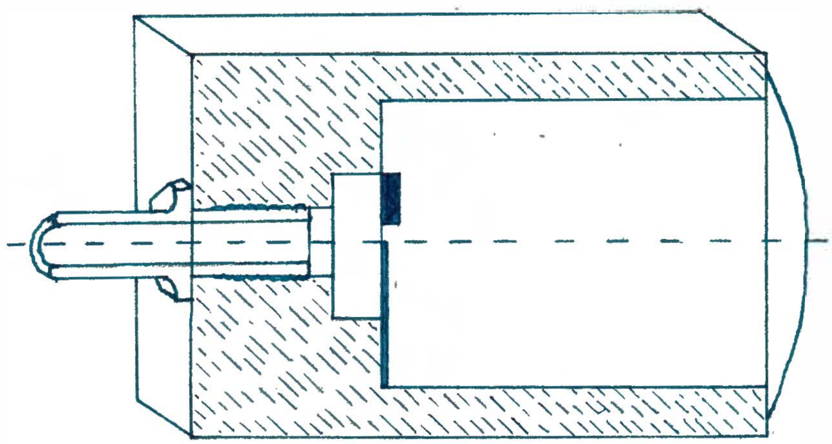
Figure 2 -- The Pick-up Cuff



The Pulse Indicator

The indicator itself is made of a two-inch square block of Plexiglass which is three inches long. A one and one-half inch hole was drilled to a depth of two inches. A 3/4 inch hole was then drilled at the base of the 1 1/2 inch hole to a depth of 1/4 inch. The hole was then continued through the block as a 3/8 inch hole. The 3/8 inch hole is then tapped to fit a brass adaptor which connects the tubing from the indicator cuff to the indicator itself. This is then divided into two chambers, a front and a back, by the recording diaphragm. The recording diaphragm is cemented at the base of the 1 1/2 inch hole. The volume of the front chamber should be four to five times as much as that of the back chamber (about 20-30 ml.) since a smaller ratio between these two chambers would have a damping effect on movement of the diaphragm because the walls of the front chamber are rigid except for the diaphragm. The recording diaphragm is patterned after the principle used by Burch.[6] It consists of a rubber diaphragm which is made from a very thin dental dam with a mirror cemented on it. This mirror should be mounted near the periphery of the movable portion of the diaphragm since this will give a greater tangential change than one mounted near the center of the diaphragm.[14] A thin sheet of stiff plastic material is then cemented over the other half of the diaphragm. The diaphragm is slit in the middle, parallel and adjacent to the straight edge of the plastic. This then acts as a valve to equalize pressure between the two chambers as the recording cuff is under pressure and the diaphragm must remain flat between pulsations. The one half of the diaphragm is covered in order to force all of the displaced air to act on that portion of the diaphragm on which the mirror is mounted. The size of the diaphragm is important since if it is too large the amount of excursion will be small and if it is too small, the inherent resistance of the rubber of the diaphragm becomes too great for the exchange to move it effectively. The anterior wall of the front chamber is formed by a plano-convex lens of a plus 13 diopters. The light source is from an ordinary flash light bulb which is powered by two 1 1/2 volt batteries.

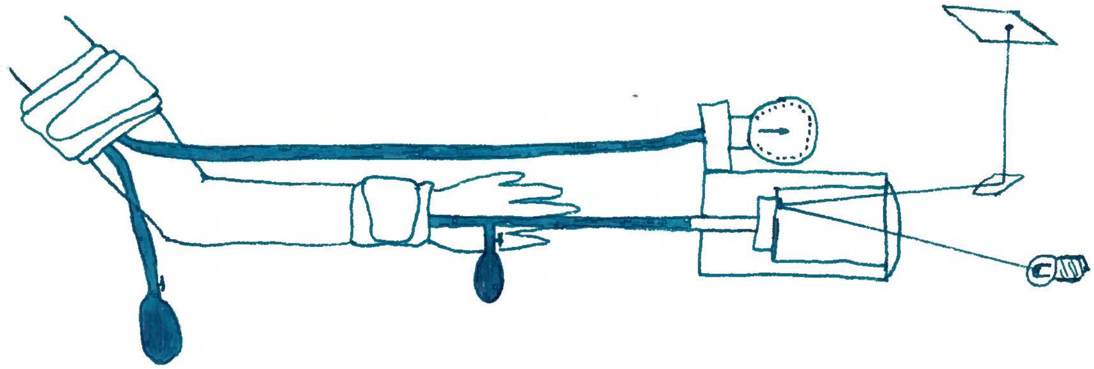
Figure 3 -- The Pulse Indicator



RATIONALE OF MECHANISM

The light is transmitted through the lens and onto the small flat mirror cemented on the diaphragm. This light is then reflected out through the lens and is focused onto a ground glass screen. When the first pulsation passes the indicator cuff, as the occluding cuff pressure is decreased, it displaces proportional volume of air through the tubing into the posterior chamber and causes a bulging of the diaphragm just prior to the pressure being equalized by the valve in the diaphragm. This is represented as movement of the spot of light on the indicators screen which is reflected from the moving mirror.

Figure 4
Diagram of Optical Pulse Indicator
set up to determine a systolic blood pressure



PROCEDURE

The recording cuff is placed distal to the occluding cuff and is inflated while watching for the maximum deflection on the recording screen. Following this the occluding cuff is inflated to about 30 mm Hg. above the suspected systolic blood pressure. This pressure is then dropped until the first deflection is noted on the recording screen. This is taken as the systolic blood pressure. Any muscular activity in the area of the recording cuff will cause a deflection to appear on the recording screen, however, this can easily be differentiated from that representing arterial pulsation. The infant should not be crying during the determination since this raises the blood pressure an average of 27 mm Hg. and can raise it as much as 60 mm Hg.[22] Feeding the infant during the determination or use of a pacifier will usually control this. Several determinations should be done in order to be more accurate.

RESULTS

This optical pulse indicator was then compared with the flush method on ten newborns and five infants, and with the flush, ausculatory, and palpitory methods on six older children and four adults. In all instances a preliminary systolic pressure was approximated with the optical pulse indicator and then the occluding cuff was inflated to approximately 30 mm Hg. above the systolic blood pressure. The pressure was then dropped at a rate of approximately 2-3 mm Hg. per second. The results appear in Tables A, B, and C.

TABLE A -- Newborns

| Pt. | Age | Pressure by Flush Method | | Difference | Pressure by OPI | | |
|---|---|---|---|---|---|---|---|
| #1 | 2 days | 78 | | | 88 | | (crying) |
| | | 60 | 59 | 3 | 64 | 62 | |
| | | 58 | | | 60 | | |
| #2 | 2 days | 96 | | | 102 | | (crying) |
| | | 94 | 91 | 7 | 102 | 98 | (crying) |
| | | 84 | | | 90 | | (crying) |
| | | 78 | 78 | 4 | 82 | 82 | |
| #3 | 2 days | 94 | | | 98 | | |
| | | 96 | 93 | 0 | 92 | 93 | |
| | | 90 | | | 90 | | |
| #4 | 3 days | 64 | | | 68 | | |
| | | 64 | 63 | 2 | 64 | 65 | |
| | | 60 | | | 62 | | |
| #5 | 3 days | 72 | | | 80 | | |
| | | 70 | 73 | 6 | 80 | 79 | |
| | | 76 | | | 78 | | |

(TABLE A -- Continued)

| | | | | | | |
|---|---|---|---|---|---|---|
| #6 | 4 days | 82 | | | 88 | |
| | | 76 | 79 | 8 | 88 | 87 |
| | | 80 | | | 84 | |
| #7 | 4 days | 88 | | | 96 | |
| | | 90 | 90 | 4 | 94 | 95 |
| | | 92 | | | 94 | |
| #8 | 4 days | 68 | | | 80 | |
| | | 70 | 70 | 9 | 80 | 79 |
| | | 72 | | | 78 | |
| #9 | 4 days | 104 | | | 110 | |
| | | 106 | 103 | 8 | 114 | 111 |
| | | 100 | | | 108 | |
| #10 | 5 days | 88 | | | 94 | |
| | | 82 | 83 | 8 | 90 | 91 |
| | | 80 | | | 90 | |

The systolic blood pressures found with the optical pulse indicator in Table A averaged 5.2 mm Hg. higher than those found with the flush method.

TABLE B -- Infants

| Pt. | Age | Pressure by Flush Method | | Difference | Pressure by OPI | |
|---|---|---|---|---|---|---|
| #1 | 7 mo. | 84 | | | 102 | |
| | | 82 | 83 | 16 | 100 | 99 |
| | | 82 | | | 96 | |
| #2 | 8 mo. | 92 | | | 96 | |
| | | 82 | 85 | 10 | 94 | 95 |
| | | 80 | | | 94 | |
| #3 | 9 mo. | 76 | | | 88 | |
| | | 76 | 74 | 11 | 84 | 85 |
| | | 70 | | | 84 | |
| #4 | 11 mo. | 78 | | | 86 | |
| | | 78 | 79 | 6 | 84 | 85 |
| | | 80 | | | 84 | |
| #5 | 12 mo. | 68 | | | 78 | |
| | | 70 | 69 | 8 | 78 | 77 |
| | | 70 | | | 76 | |

In this series the OPI systolic pressures averaged 10.0 mm Hg. higher than those found with the flush method.

TABLE C -- Children and Adults

| Pt. | Age | Palpatory Method | | Ausculatory Method | | Flush Method | | O.P.I. Method | |
|---|---|---|---|---|---|---|---|---|---|
| #1 | 4½ yr. | 108 | | 108 | | 100 | | 108 | |
| | | 104 | 104 | 106 | 107 | 98 | 100 | 106 | 107 |
| | | 100 | | 106 | | 102 | | 106 | |
| #2 | 7 yr. | 108 | | 110 | | 96 | | 112 | |
| | | 108 | 109 | 108 | 109 | 104 | 105 | 114 | 113 |
| | | 110 | | 110 | | 104 | | 112 | |
| #3 | 8 yr. | 120 | | 120 | | 110 | | 120 | |
| | | 114 | 118 | 118 | 120 | 112 | 112 | 118 | 120 |
| | | 120 | | 122 | | 104 | | 122 | |
| #4 | 9 yr. | 92 | | 94 | | 88 | | 98 | |
| | | 96 | 95 | 98 | 97 | 88 | 87 | 96 | 97 |
| | | 98 | | 98 | | 86 | | 98 | |
| #5 | 12 yr. | 110 | | 116 | | 100 | | 110 | |
| | | 112 | 110 | 118 | 117 | 104 | 102 | 112 | 110 |
| | | 108 | | 118 | | 102 | | 108 | |
| #6 | 12 yr. | 120 | | 128 | | 120 | | 128 | |
| | | 126 | 123 | 126 | 127 | 118 | 119 | 130 | 129 |
| | | 124 | | 126 | | 120 | | 128 | |
| #7 | 24 yr. | 114 | | 114 | | | | 114 | |
| | | 114 | 114 | 114 | 114 | | | 114 | 114 |
| | | 114 | | 114 | | | | 114 | |
| #8 | 25 yr. | 110 | | 110 | | 100 | | 112 | |
| | | 110 | 110 | 110 | 110 | 102 | 100 | 110 | 111 |
| | | 110 | | 110 | | 98 | | 110 | |
| #9 | 25 yr. | 108 | | 110 | | 100 | | 110 | |
| | | 112 | 110 | 114 | 113 | 100 | 101 | 114 | 113 |
| | | 110 | | 114 | | 104 | | 114 | |
| #10 | 28 yr. | 128 | | 128 | | | | 128 | |
| | | 130 | 129 | 132 | 131 | | | 132 | 131 |
| | | 130 | | 132 | | | | 134 | |

In this series the palpatory method was an average of 2.3 mm Hg. lower than the OPI method while the ausculatory method averaged out the same and the flush method averaged 9.2 mm. Hg. lower.

DISCUSSION

Since the flush method of blood pressure determination has been shown to have a variable relationship to actual blood pressure, this method could not be used as a reliable comparison in testing the optical pulse indicator method. Because of this, the optical pulse indicator method was compared to the ausculatory, palpitory, and flush methods on older children and adults where all of the methods could be consistently determined. As has previously been stated, the ausculatory method is one of the most accurate indirect methods known, and this was therefore used as the main standard of accuracy. Also the ausculatory and optical pulse indicator methods could be done at the same time. In all but one case the first indication of a pulse seen was before or at the same time as one was noted by the ausculatory method. The one exception was patient number 5 of Table C where the ausculatory systolic blood pressure was consistently higher by an average of 7 mm Hg. than the pressure determined by the optical pulse indicator method. On this basis then the optical pulse indicator method of systolic blood pressure determination was assumed to be as accurate as the ausculatory method.

A comparison between the flush method and the optical pulse indicator method then was done (Table A) on newborns, (Table B) on infants, and (Table C) on adults. And as is seen from these tables, there was quite a variable difference found among these methods ranging from 0 mm. Hg. in patient #3 of Table A, to 16 mm. Hg. in patient #1 of Table B.

The optical pulse indicator method of systolic blood pressure determination is essentially using the palpatory method except that considerable error can be introduced by the different thresholds for palpation by human feeling.[17] The comparison between these two methods is shown in Table C, and it shows that the optical pulse indicator method consistently was more sensitive; and, because there is no human factor in the palpation, it was more constant.

CONCLUSION

It has been reasonably shown that the optical pulse indicator method of systolic blood pressure measurement is as accurate as the ausculatory method and much more accurate than the flush technique. From this, then, it would seem that this would be a much more desirable method of systolic blood pressure measurement than the flush technique in newborns, infants and small children. Also, the construction of this pulse indicator is simple and inexpensive.

This would also seem to be a practical method of determining systolic blood pressures in laboratory animals such as dogs and monkeys when one would want to note the effect on blood pressure of some drug or procedure over a period of weeks or months, since by this method one could avoid the effects of anesthetic and or trauma seen when the blood pressure is measured directly.

SUMMARY

A simplified, economical, optical pulse indicator has been designed and constructed for the purpose of determining the systolic blood pressures in newborns, infants and small children when other methods are not practical. This method of systolic blood pressure determination was then compared with the ausculatory method which is one of the most accurate common methods, and it was shown to give as high, if not higher, systolic blood pressures. The optical pulse indicator method was then compared to the flush method of systolic blood pressure determinations and was found to give higher and more consistent pressures than the flush method which is the most widely accepted method used today in this age group of patients.

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