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EDITORIAL

Who was the first to monitor blood pressure during anaesthesia?

The measurement of blood pressure is the single most common clinical examination; its importance in the treatment and prevention of hypertensive cardiovascular disease, and as a predictor of mortality and morbidity cannot be disputed. In acute medicine, such as intensive care and anaesthesia, mandatory blood pressure monitoring has played an important role in improving the outcome. It is fair to say that the progressive advancement in the quality of anaesthesia from its birth 150 years ago to modern times owes a great deal to the vigilant monitoring which includes repeated measurements of blood pressure.

The years 1996 and 1997 have a special importance to anaesthetists: these two consecutive years mark the anniversaries of the introduction of ether and chloroform, and therefore, the birth of the specialty. The inauguration of ether was duly celebrated in 1996 at the 11th World Congress of Anesthesiologists in Sydney, Australia, while 1997 has been marked by the chloroform sesquicentenary [1]. In this atmosphere of celebrations, it seems appropriate to record that 1997 is also the centenary year of the first report on monitoring blood pressure during anaesthesia.

Ether and chloroform became widely used all over the world shortly after their introduction, and remained the only major anaesthetic agents for over 100 years. The mortality associated with chloroform was a matter of great concern, even during the first decade of its introduction. Later, growing concern led to the appointment of a committee by the Royal Medical and Chirurgical Society, who published their report in 1864. This voluminous report mentioned that a haemadynamometer had been used to asses the effect of chloroform on animal hearts during the experiments carried out for the report [2]. This confirms the recognition that close monitoring of the heart during chloroform anaesthesia was a useful observation.

The earliest device capable of recording the pulse was invented during the same decade in which anaesthesia was discovered. A Frenchman had introduced Marey's Sphygmograph in 1860, and this instrument was improved by many modifications, which soon found a place in clinical practice [3,4]. These novel devices, forerunners of present-day non-invasive blood pressure measuring apparatuses were successfully used by physicians in their clinical practice. Some of the investigations using these devices which were published were well-executed studies in which the actions of various chemicals and therapeutic agents on the heart were investigated and a number of workers obtained the earliest tracings of the pulse. In 1866, the sphygmograph was used by comparing the difference in the sphygmographic tracings of radial arteries from both sides to monitor and confirm the diagnosis of an aneurysm of the right axillary artery [5]. In 1867, the sphygmograph was again used as a prognostic tool during acute pulmonary consolidation [6]. In another study, the pulse tracings were made during the administration of alcohol, a popular therapeutic agent [7].

Towards the last quarter of the nineteenth century, still better and more reliable devices were introduced so that the pulse recordings could be made both in physiological laboratories and at the bedside. One such apparatus, a real *object de art* of Victorian engineering, was the Dudgeon Sphygmograph and its improved modification by Richardson, which was capable of marking the time intervals while the pulse trace was recorded on smoked paper [8,9]. Other devices which were classed as sphygmometers are worth mentioning: von Boch's sphygmometer and Potain's sphygmometer, both of which were introduced towards the latter half of the nineteenth century [10,11]. These instruments were used not only in France, but also in the UK and America. The sphygmometers were portable, easy to use and reasonably accurate instruments which were widely available and popular among physicians who could conveniently use them

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904 THE BRITISH MEDICAL JOURNAL] A NEW SPHYGMOMETER. [OCT. 2, 1897.

A SIMPLE AND ACCURATE FORM OF SPHYGMOMETER OR ARTERIAL PRESSURE GAUGE CONTRIVED FOR CLINICAL USE.

BY

LEONARD HILL, M.B., Lecturer on Physiology, London Hospital, and HAROLD BARNARD, M.S., F.R.C.S., Surgical Registrar, London Hospital.

THIS instrument consists of: (1) A broad armlet, which is strapped round the upper arm. The armlet is formed of a flexible steel band, on the inside of which there is fastened a bag of thin indiarubber. The rubber bag is connected by a Y-tube with (2) a small compressing air pump fitted with a valve and (3) a pressure gauge.

The pressure gauge is of special construction. Roughly, it consists of a metal tambour, the expansion of which is exhibited in a highly magnified form by means of an index or pointer which travels round a dial. This dial is graduated in millimetres of mercury. The armlet, pump, and pressure gauge when not in use fit conveniently into a leather case. The instrument is used thus: (1) The armlet is strapped round the upper arm so that it fits closely to the skin. (2) By means of the pump the pressure is raised within the rubber bag until the pulsation indicated by the index of the pressure gauge becomes of maximal excursion. (3) At this point the pressure indicated by the gauge is read, and this pressure is the mean arterial pressure.

The armlet can be applied to the arm of any individual with the greatest ease, for the flexible steel band adapts itself to any shape or size. In children the armlet can be fitted equally well to the thigh, and the pressure is then taken in the femoral artery. The armlet is bound closely round the arm so that the rubber bag may be but slightly distended when the pressure is raised within up to the arterial tension. If the bag were greatly distended the elasticity of the bag would come into play, and from this an error in the readings would arise. To avoid this error the rubber bag is made thin and flaccid. By raising the pressure within the bag the venous outlets are blocked. This, if continued for long, produces great congestion of the arm and discomfort. For this reason the readings must be taken rapidly. The pressure is never to be maintained on the arm for more than a minute or so. The following is a convenient plan of work:

(1) Force up the pressure rapidly till pulsation appears. (2) Continue to force up the pressure till pulsation disappears or obviously becomes lessened. (3) Slightly open the valve and allow slow leakage. As the pressure falls, note where the pulsation becomes maximal. (4) Let the air out entirely, and empty the arm of venous blood either by elevation of the limb or friction. (5) Repeat the operation and take another reading.

By following this plan no pain or discomfort will arise.

In studying the effect of exercise, posture, drugs, etc., successive readings must be taken in the above manner, first during the normal, and then during the experimental condition.

Owing to the effect of position on the circulation, the readings must be taken uniformly, with the arm placed by the side and on the same level as the heart. The muscles of the arm must be relaxed during the observations. The arterial tension is constantly varying slightly, owing to changes in the force of the heart beat and the respiratory oscillations of pressure. Thus the maximal pulsation may be found now at one place and now at another, a few millimetres higher or lower. The mean of the different readings must be taken just as is done when the mercurial manometer is used in physiological experiments on animals. In conditions of quiet respiration these variations are often not great, and the pressure may be read at each observation within 2 or 3 millimetres. Variations of pressure by 5 to 10 mms. Hg. are of frequent occurrence, are physiological, and of no importance.

When the rubber bag presses upon the outside of the arterial wall, with a pressure equal to that mean pressure exerted from within, the wall is able to oscillate with the greatest freedom. In systole the artery is fully expanded, while in diastole it is collapsed by the pressure of the bag.

The accuracy of this index has been proved by repeated experiment. Thus the armlet was strapped round the neck of a dog (excluding the trachea). A cannula was inserted into the femoral artery, and connected with a mercurial manometer. Simultaneous readings were then taken of the pressure in the femoral artery, as indicated by the mercurial manometer, and the pressure in the carotid arteries as indicated by the sphygmometer. The maximal pulsation of the index of the sphygmometer was thus found to occur always at a pressure which exactly corresponded with the mean pressure in the femoral artery.

It is well known that the carotid and femoral mean pressures are practically the same in the dog when the animal is lying in the horizontal position. To show in yet another way the accuracy of this instrument the following experiment was performed. Whilst one arm was passively elevated above the head and the other remained dependent by the side, simultaneous readings were taken from either brachial artery by means of two sphygmometers. From the dependent arm the higher reading was obtained. The difference was equivalent in mercury to the height of the vertical column of blood which separated the two points of observation.

The facility with which the instrument can be used for clinical purposes is illustrated by a series of observations which we have made upon patients placed under the influence of anæsthetics. Before and during administration a series of readings were taken at intervals of time, and from the figures thus obtained curves were plotted out. In 8 cases of anæsthesia with gas and oxygen (sitting posture) the arterial pressure either rose a few millimetres of mercury or remained constant. In 4 cases of anæsthesia with ether the arterial pressure remained constant or fell a very few millimetres of mercury. In 6 cases of anæsthesia with chloroform the sphygmometer indicated an extensive and rapid fall of arterial pressure. This fall equalled 20 to 40 mm. of mercury. The normal arterial pressure in most healthy young men appears to be 110 to 130 mm. Hg. in the sitting posture.

We shall shortly be in a position to publish a series of preliminary observations on arterial pressure in different pathological states. By means of this instrument, which is made for us by Mr. J. Hicks, of 8, Hatton Garden, E.C., we believe that the arterial pressure can be taken in man as rapidly, simply, and accurately as the temperature can be taken with the clinical thermometer.

MEMORANDA:

MEDICAL, SURGICAL, OBSTETRICAL, THERAPEUTICAL, PATHOLOGICAL, ETC.

THYROID GLAND SUBSTANCE IN OBESITY.

I HAVE been trying this treatment on stout Anglo-Indians (who were desirous of taking off a stone or two, and improving their figures) for some time back, but have only done so systematically and regularly since the beginning of this year. I first used tabloids of the whole gland substance

Fig. 1. Paper published in the *British Medical Journal* in 1897.

at the bedside. No doubt, these instruments were also suitable for use during ether or chloroform anaesthesia, but somehow, they did not find their place in monitoring the pulse. Surprisingly, there are no reports in which any such instruments were employed to study and monitor the patient during surgical anaesthesia. Perhaps maintenance of the airway and level of anaesthesia with primitive inhalers fully occupied the thoughts of the single-handed anaesthetist.

The practice of anaesthesia during first 50 years remained totally dependent on the observation of breathing as the sole method of monitoring. A quote from professor James Syme's (1799–1870) lecture illustrates the fact that even the palpation of the pulse during anaesthesia was not recognized as a good practice: 'you never see any one here with his fingers on the pulse while chloroform is given' [12]. In contrast with this, the picture in the anaesthesia history books of Dr J. T. Clover feeling the pulse while administering ether to a patient is a unique example. No wonder he was credited with exceptional success in his profession!

In 1896, Scipione Riva-Rocci (1863–1936), while he was professor at Turin, described his vertical mercury manometer with a rubber arm cuff to occlude the brachial artery. His extensively researched 30-page paper was published in December 1896 [13]. This classic historical publication has never been translated into English, but there is no mention that Riva-Rocci's revolutionary apparatus was considered for the measurement of blood pressure during anaesthesia in the summary translations which are available. This apparatus was introduced in America by Harvey Cushing in 1901, who was also responsible for introducing the practice of blood pressure recording on the anaesthetic charts [14].

The first report of blood pressure monitoring during anaesthesia was recorded in a joint publication to the *British Medical Journal* on 2 October 1897 (Fig. 1). It was a short, one-page article by Leonard Hill and Harold Barnard, describing a new blood pressure measuring device. At the start of the paper, the instrument was described briefly. It consisted of a narrow armlet to occlude the brachial artery, a small bicycle-type metal pump and a metal manometer graduated in mmHg. The construction of the pressure gauge was described as consisting of a metal tambour connected to a needle or a pointer. The pressure changes caused the pointer to move over a round, graduated scale to 200 mmHg. The authors also described a portable, pocket sphygmometer, although the date of its introduction cannot be ascertained accurately. Both of these instruments are in the exhibition at the Wellcome Museum in London.

The following quote from the Hill and Bernard paper offers ample evidence that the authors had carefully monitored the blood pressure of anaesthetized patients:

'The facility with which the instrument can be used for clinical purposes is illustrated by a series of observations which we have made upon patients placed under the influence of anaesthetics. Before and during administration a series of readings were taken at intervals of time, and from the figures thus obtained curves were plotted out. In 8 cases of anaesthesia with gas and oxygen (sitting posture) the arterial pressure either rose a few millimeters of mercury or remained constant. In 4 cases of anaesthesia with ether the arterial pressure remained or fell a few millimeters of mercury. In 6 cases of anaesthesia with chloroform the sphygmometer indicated an extensive and rapid fall of arterial pressure. This fall equalled 20 to 40 mm. of mercury. The normal arterial pressure in most healthy young men appears to be 110 to 130 mmHg in sitting position.' [15]

Fig. 2. Harold Leslie Barnard MS FRCS (1868–1908).

The above quotation offers the first evidence of measurement of blood pressure during surgical anaesthesia. Unfortunately, my efforts to trace details and data on relevant material mentioned in the quote have not been fruitful.

Harold Leslie Barnard (1868–1908) was born in London (Fig. 2). He was the grandnephew of Michael Faraday. Barnard qualified with many distinctions

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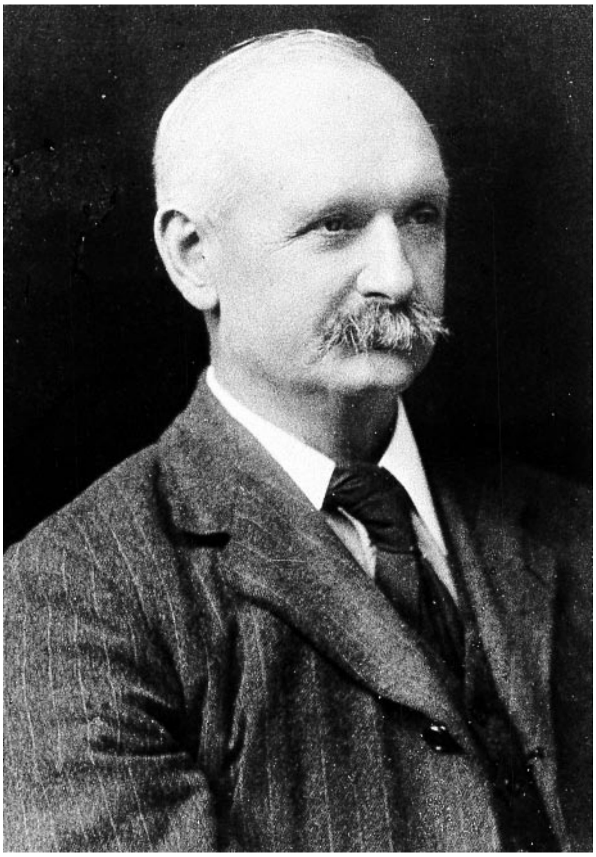

Fig. 3. Leonard E. Hill MB FRCS (1886–1952).

from the London Hospital, now the Royal Hospital, in 1892, and served there as a demonstrator in physiology, obtaining his surgical fellowship in 1895. He died when he was only 40 years old [16].

Leonard Erskine Hill (1886–1952) was also born in London and had an equally flawless pedigree (Fig. 3). Hill was the son of a headmaster and the grandnephew of Sir Rowland Hill, who had pioneered penny postage in 1840. He himself became Sir Leonard Hill in 1930 and two of his brothers were also knighted. His third son was Sir Austin Bradford Hill, the well-known medical statistician. Among many other interests, Hill was an accomplished painter and author of children's storybooks [17]. In a later publication, Leonard Hill modestly claimed to be the independent inventor of the arm cuff along with Riva-Rocci [18].

Leonard Hill's interest in anaesthesia may also be affirmed by his severe criticism of the unreliable methods which were employed by the Hyderabad Chloroform Commission and his published laboratory study on the effect of chloroform on the heart [19].

After 100 years, it is only justice that the pioneering contributions made by the two doctors who were the first to monitor blood pressure during surgical anaesthesia should be recognized.

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N. H. Naqvi
Department of Anaesthesia,
Royal Bolton Hospital,
Bolton, UK

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